Budget Officer
Director, RSBS
2.1.8.26 JAB:sw
19 June 1989

c.c. Business & Technical Manager
RSBS

Expenditure Table for Council

As you are aware, the 1988 Annual Report of the Research School of Biological Sciences will be presented to Council on 11 August 1989.

The attached table is to accompany the report and I should be grateful if you would let me know by 28 July if the 1988 details are acceptable.

J.A. Brayshaw

THE AUSTRALIAN NATIONAL UNIVERSITY

SUMMARY OF ACTUAL EXPENDITURE BY MAJOR COST CATEGORIES IN THE YEARS 1984 TO 1988

SCHOOL/SECTION: RESEARCH SCHOOL OF BIOLOGICAL SCIENCES

Year	Total Expenditure		Salaries		Salary Related		Equipment		Expendable Materials		Movement Expenses		Field and Survey		Scholarship Stipends		Scholarship Expenses		Other Expenses	
	$000	%	$000	%	$000	%	$000	%	$000	%	$000	%	$000	%	$000	%	$000	%	$000	%
1984	8,693	100.00	5,339	61.42	1,200	13.80	530	6.10	547	6.29	127	1.46	37	0.43	201	2.31	22	0.25	690	7.94
1985	9,264	100.00	5,315	57.37	1,155	12.47	927	10.00	703	7.59	207	2.23	33	0.36	225	2.43	45	0.49	654	7.06
1986	10,137	100.00	5,748	56.70	1,274	12.57	1,047	10.33	816	8.05	210	2.08	33	0.32	289	2.85	55	0.54	665	6.56
1987	10,112	100.00	5,691	56.28	1,106	10.94	1,139	11.26	825	8.16	248	2.45	27	0.27	280	2.77	34	0.34	762	7.53
1988	10,357	100.00	5,836	56.35	1,159	11.19	1,108	10.70	707	6.83	314	3.03	36	0.35	256	2.47	39	0.37	902	8.71

SCHOOL/SECTION: MOUNT STROMLO AND SIDING SPRING OBSERVATORIES

Year	Total Expenditure		Salaries		Salary Related		Equipment		Expendable Materials		Movement Expenses		Field and Survey		Scholarship Stipends		Scholarship Expenses		Other	
	$000	%	$000	%	$000	%	$000	%	$000	%	$000	%	$000	%	$000	%	$000	%	$000	%
1984	3,497	100.00	1,436	41.06	415	11.87	966	27.62	122	3.49	131	3.75	-	-	-	-	-	-	427	12.21
1985	3,194	100.00	1,655	51.82	399	12.49	522	16.34	102	3.19	176	5.51	-	-	-	-	-	-	340	10.65
1986	4,332	100.00	2,458	56.74	563	13.00	523	12.07	103	2.38	175	4.04	10	0.23	64	1.47	84	1.94	352	8.13
1987	4,530	100.00	2,484	54.84	530	11.70	667	14.72	60	1.32	158	3.49	2	0.04	56	1.24	72	1.59	501	11.06
1988	4,650	100.00	2,665	57.32	551	11.85	414	8.90	68	1.46	185	3.98	2	0.04	69	1.48	86	1.85	610	13.12

Note

Expenditure on equipment includes that which is financed from general funds as well as from the specific equipment grant.

Budget Officer
Director, RSBS
2.1.8.26 JAB:sw
19 June 1989

✓c.c. Business & Technical Manager
RSBS

Expenditure Table for Council

As you are aware, the 1988 Annual Report of the Research School of Biological Sciences will be presented to Council on 11 August 1989.

The attached table is to accompany the report and I should be grateful if you would let me know by 28 July if the 1988 details are acceptable.

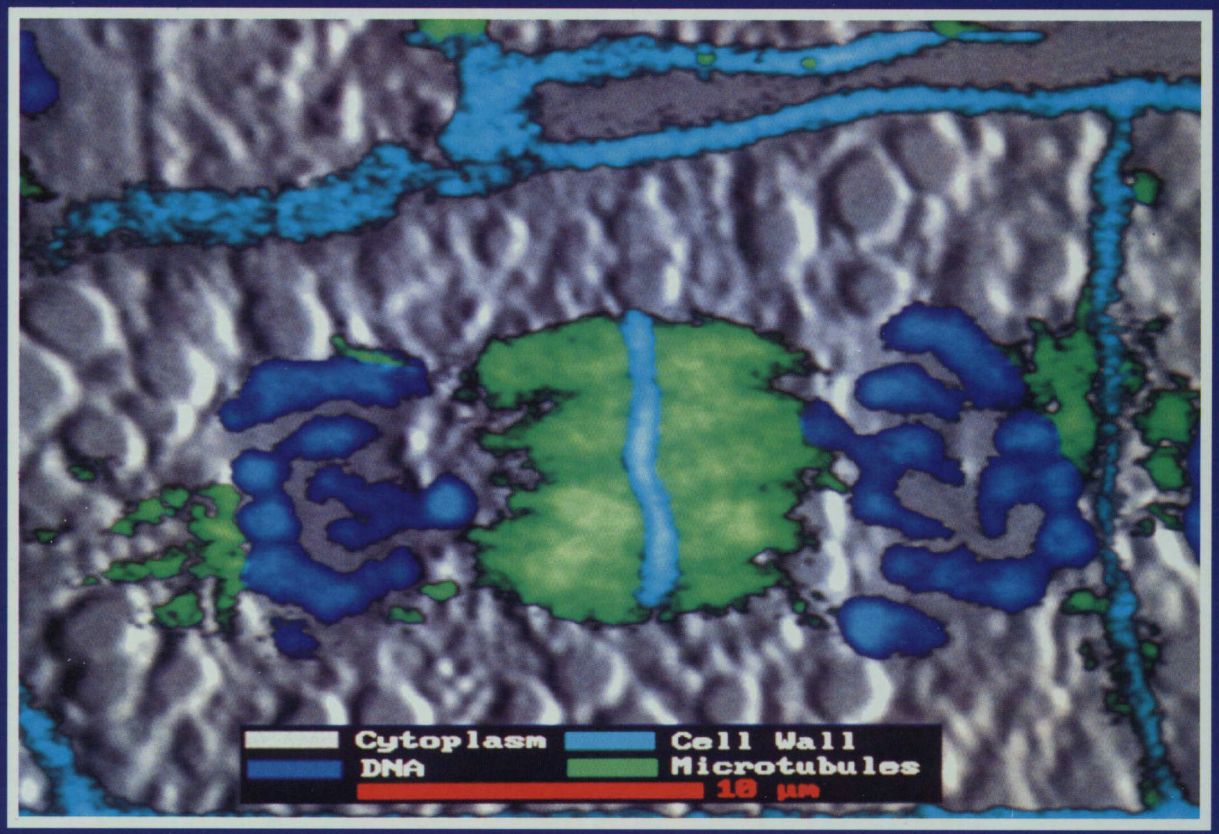
J.A. Brayshaw

John,
Figures have been checked and are acceptible

24/7/89

Alex Pls check + respond

RESEARCH SCHOOL OF BIOLOGICAL SCIENCES



ANNUAL REPORT 1988

THE AUSTRALIAN NATIONAL UNIVERSITY

Cover photograph

CELL DIVISION IN PLANTS

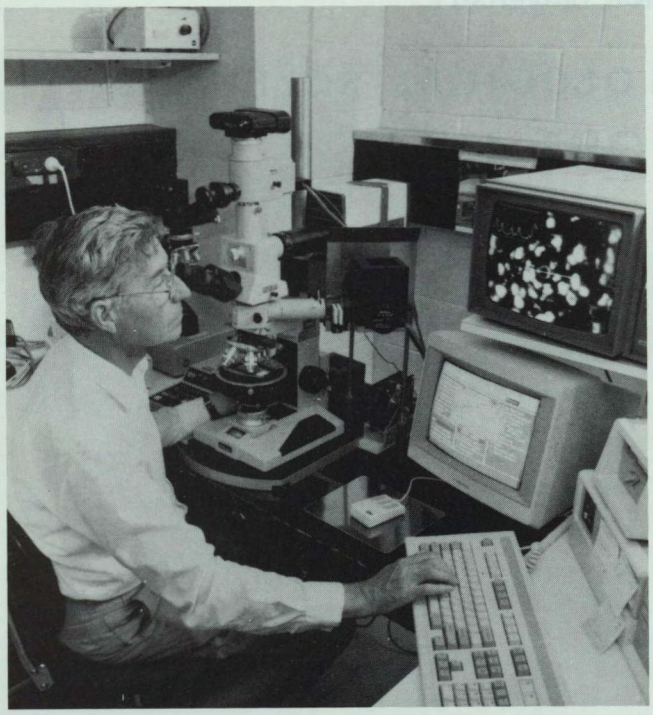
Much of the research of the Plant Cell Biology Group concerns the intracellular machinery of cell division, and its hormonal and molecular regulation. The picture shows a dividing cell at a stage when the nucleus has divided into two groups of chromosomes (blue), with an apparatus of microtubules (green) supporting a new cell wall (centre, blue-green) which is growing outwards toward the old walls to divide the parent cell into two.

Onion root tip tissue, sectioned and stained by a new technique developed by Dr F. Gubler; video microscopy and image processing by Professor B. Gunning, using new equipment illustrated on the following page.

THE AUSTRALIAN NATIONAL UNIVERSITY

RESEARCH SCHOOL OF BIOLOGICAL SCIENCES

ANNUAL REPORT 1988



Professor B. Gunning using a video microscope to enhance images of plant cells stained with fluorescent antibodies (see front cover).

SYMBOLS

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

Postal Address
Research School of Biological Sciences,
GPO Box 475,
Canberra City, ACT 2601
Fax: 61-62-489995

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

Design by ANU Graphic Design
Typeset and Printed by Union Offset Co. Pty Ltd, Canberra

CONTENTS

DIRECTOR'S INTRODUCTION

R.O. Slatyer
Director

1988 was an important year in the development and evolution of the School. The new structure, based on Research Groups rather than Departments, is now well established. The flexibility of the new structure has been reflected in the movement of a number of tenured academic staff, and their non-tenured associates and support staff, from one Group to another. In addition, a new Group, headed by Dr George Miklos has been established in Molecular Neurobiology—a rapidly expanding field in international neuroscience.

With the establishment of the Molecular Neurobiology Group, we now recognize nine areas of research activity. They are

- Developmental Neurobiology
- Molecular Neurobiology
- Visual Sciences
- Molecular Genetics
- Population Genetics
- Plant Cell Biology
- Plant Molecular Biology
- Plant Environmental Biology
- Ecosystem Dynamics.

In addition to these structural arrangements, several other important developments have occurred or are taking place.

- The rapid dispersion of the concepts and techniques of molecular biology through most areas of the School's research is continuing. In the process, the School, jointly with the John Curtin School of Medical Research, the Research School of Chemistry and the Faculty of Science, has prepared a Strategic Plan for Molecular Biology at ANU which should ensure that the University remains in the forefront of this important field of research, nationally and internationally. The core of the plan involves the establishment of a Centre for Gene Delivery and Expression and a Centre for Molecular Structure and Design, together with arrangements that will strengthen undergraduate and postgraduate teaching.
- In the neurosciences, the establishment of the Molecular Neurobiology Group means that the School will be able to introduce recombinant DNA techniques into new areas of neuroscience, so as to enhance the School's research in developmental and sensory neurophysiology.
- Areas of research that concentrate on plant-microbe interactions have been strengthened during the year. In addition to the challenging questions related to recognition phenomena between host and parasite, this research has the potential to generate important practical applications in agriculture. They range from biological nitrogen fixation to disease control, and will contribute to reductions in the use of agricultural chemicals and to increased rural productivity and competitiveness. We expect to extend this research to plant-insect

interactions, drawing on the School's expertise in insect neurobiology, molecular biology and plant science.

- The School's ecological research received a major boost this year from the University's strategic funding programme. A powerful research team, under Dr I.R. Noble's leadership, has now been formed to develop an underlying body of basic ecological knowledge on which the conservation and management of areas of natural or semi-natural vegetation—such as forests, rangelands and conservation areas—can be based. It is hoped to link this research with other ecological groups in the University, notably in CRES, the Research School of Pacific Studies and The Faculties and with the new Centre for Information Sciences.

The research associated with these and other activities is outlined in the body of the report.

The School's physical resources were enhanced during the year by the completion of a substantial extension to the RSBS building. It will enable the staff of the Developmental Neurobiology Group, who have been housed in a separate building, to be united with the rest of the School, and for the Centre for Visual Sciences to accommodate researchers from the John Curtin School of Medical Research and the Research School of Physical Sciences. Substantial internal modifications have also been made to enable expansion of the Groups concerned with plant molecular biology and ecosystem dynamics.

In 1988, the School's academic staff totalled 57 of whom 45% were tenured. Another 16 non-tenured staff were supported by outside funds. The total value of external funds was in the region of $1.0 million.

The School has maintained its strong commitment to postgraduate training, with 57 students enrolled in 1988 and 19 gaining their PhD's. However, like the rest of the Institute, the School relies largely on interstate and foreign students to maintain its student numbers. Great benefit flows from these students because of the diversity of ideas and training which they bring with them. Regrettably, with the introduction of the Federal Government's visa charges, the influx of foreign students has almost ceased. The flow from interstate Universities has also declined. It is hoped that urgent action will be taken to rectify this situation.

Members of the School competed strongly for National Research Fellowships during 1988. Of the nine Fellowships obtained by the University four, plus one Queen Elizabeth II Fellowship, were awarded to RSBS.

Among honours received by the School, Dr Graham Farquhar was elected a Fellow of the Australian Academy of Science, and Dr Adrienne

Hardham was awarded the Gottschalk Medal of the Australian Academy of Science as well as the Goldacre Prize of the Australian Society of Plant Physiologists.

Two new Chairs were established in 1988 in areas in which the School intends to maintain a high level of research concentration: plant molecular biology, with special reference to plant-microbe interactions, and in plant physiology with special reference to plant-environment interactions. Dr Barry Rolfe and Dr Graham Farquhar were appointed to these posts.

The title of the Robertson Symposium for 1988 was 'Molecular Interactions of Viruses, etc'. It was organized by Dr Adrian Gibbs and Dr Wayne Gerlach of CSIRO. The Symposium was opened by Professor Sir Rutherford Robertson on 30th November. It attracted over 80 participants from Australia and overseas.

During 1988, Professor John Pateman retired after spending ten years with RSBS, as Head of the Department of Genetics. Professor Pateman played a key role in introducing molecular biology into the School and in establishing the Centre for Recombinant DNA Research.

Dr Adrienne Hardham (top left) was awarded the Gottschalk Medal of the Australian Academy of Science (in recognition of distinguished work in the biological sciences) and the Goldacre Award of the Australian Society of Plant Physiologists. Dr Graham Farquhar (top right) was elected a Fellow of the Australian Academy of Science and appointed to the new Chair in plant physiology. Dr Barry Rolfe (bottom left) was appointed to the new Chair in plant molecular biology and Professor John Pateman (bottom right) retired after 10 years at RSBS.

RESEARCH SUBJECT AREAS

In the following pages research projects are generally included under the group in which the researchers are located. These Groups are:

DEVELOPMENTAL NEUROBIOLOGY
MOLECULAR NEUROBIOLOGY
VISUAL SCIENCES
MOLECULAR GENETICS
POPULATION GENETICS
PLANT CELL BIOLOGY
PLANT MOLECULAR BIOLOGY
MOLECULAR ANALYSIS OF PLANT PERFORMANCE (an inter-Group research program)
PLANT ENVIRONMENTAL BIOLOGY and
ECOSYSTEM DYNAMICS

DEVELOPMENTAL NEUROBIOLOGY

Introduction

In Developmental Neurobiology, we examine the processes that lead to the formation of complex nervous systems with their intricate patterns of neuronal connectivity, their relationships with the effectors that execute their commands, and to the various specialised sensors that supply them with information from the outside world.

Projects within the Group include experimental studies on the development of the brain in the pouch young of wallabies, with particular reference to the visual system; the auditory biophysics of pigeons, and the early development of the avian auditory system; the cell biology of arthropod photoreceptors, in the inter-relating contexts of transductive membrane turnover, cytoskeletal organisation, and transductive biochemistry.

Cell Biology of Photoreceptors: Cytoskeletal Organisation, and the Distribution and Characterisation of Transduction Enzymes.

Investigators: Stephen Trowell, Sally Stowe, Margrit Carter and A. David Blest.

Our long-term program concerns the diverse strategies of phototransductive membrane turnover in arthropods, and how intracellular structures and mechanisms collaborate to ensure the very precisely regulated cell surface architectures typical of the photoreceptors of insects and crustaceans.

We have previously shown arthropod rhabdomeral microvilli to contain a cytoskeleton; Dr H.G. de Couet demonstrated by biochemical assays that rhabdomeres have high complements of F-actin, but how it is distributed in these photoreceptors has remained an open question. Filamentous systems morphologically compatible with the ultrastructural manifestations of F-actin are extremely labile in these cells, and can only be conserved for electron microscopy by techniques that we have been developing since 1982. The dimensions of cytoskeletal filaments alone are not unequivocal proof of their biochemical identities. In 1988 we used light and electron microscopical immunolabelling techniques to show that (a) regions of blowfly and crab photoreceptors that are densely occupied by labile slender filaments also exhibit intense immunofluorescent and immunogold actin labelling; (b) immunogold labelling of actin is found in the rhabdomeral microvilli.

The interpretation of these findings is complicated because the nature of a single axial filament within each rhabdomeral microvillus is enigmatic. Hitherto, we have assumed it to account for the rhabdomeral F-actin complement. *ninaC* mutant alleles of *Drosophila* appear by conventional electron microscopy to lack axial filaments. C. Montell and G. Rubin have conducted a molecular genetic analysis of *ninaC* alleles (Cell 52, 757–772): the *ninaC* locus encodes unusual proteins that could be supposed to represent a novel cytoskeletal element of which axial filaments are primarily composed. We have treated retinae of one *ninaC* allele (*P221*) with pre-fixation

routines that inhibit cysteine proteases. Despite the absence of one of the *ninaC* proteins in *P221*, our preliminary results indicate that axial microvillar filaments are fragmentarily present. *ninaC* proteins may be implicated in assembling or maintaining axial filaments, but on our present evidence seem unlikely to constitute them. *P235*, which lacks both *ninaC* proteins, should finally resolve the problem.

Dr S.C. Trowell has continued his work on a phosphoprotein phosphatase in photoreceptors of crab and *Drosophila*. Quantitatively, it is a major retinal protein, and is topologically associated with phototransductive membrane in representative insects, crustaceans, cephalopods and *Limulus*. In *Drosophila* and a crab, it now proves to be the most heavily light-dependently phosphorylated protein in the retinae. At a molecular weight of ca. 48–49 kDa it is of comparable molecular mass to the vertebrate retinal protein, arrestin, which has recently been shown to exhibit phosphatase activity. Thus, the invertebrate 48–49 kDa phosphatase is a prime candidate enzyme for roles in the termination of photoreceptor excitation consequent upon photon capture and/or sensitivity modulation.

Dr Trowell has also continued his work on the inositol polyphosphatases that he discovered in crab retina. InsP3 (which they degrade) is the intracellular second messenger that triggers the release of calcium from smooth endoplasmic reticulum, calcium fluxes determining some processes of light adaptation. The very high titres of inositol tris- and bis-phosphatases demonstrated in crab photoreceptors are implicitly required for arthropod photoreceptors to achieve their observed time-resolutions.

Conceptually, photoreceptors can be regarded as cells responsive to stimuli (photons) which are functionally comparable to the numerous molecules (hormones, transmitters, etc.) that assault other receptive cells. We suppose photoreceptors to be almost unique in terms of the temporal resolution required of their responses. To achieve such resolution, we assume that their biochemical machinery amplifies certain pathways with no necessary introduction of novelty. Thus, high titres of inositol polyphosphatases in arthropod photoreceptors (as compared to low titres in receptors whose responses need only be sluggish) can be predicted from first principles.

Evolution of the Unique Physiological Optics of Jumping Spider Eyes: the Origin of Rhabdomeral Light-Guides.

Investigators: A. David Blest, Peter McIntyre[#], David C. O'Carroll[§], Mandyam V. Srinivasan, Margrit Carter.

The principal eyes of jumping spiders achieve visual resolutions of as little as 2.4 minutes of arc, a remarkable acuity. Over the last eight years, we have demonstrated that these eyes are designed as miniature Galilean telescopes, or telephoto lenses, and that only Layer I of the complex tiered retina is of good enough mosaic quality to sustain the fine visual discriminations that the spiders are observed to make.

Layer I receptors at the foveal retinae of 'advanced' species each contain a single rhabdomere designed as a long light-guide. Similar light-guides composed each of a single rhabdomere have been intensively studied in the compound eyes of higher Diptera, but evolutionary pathways that might have led to them have not been proposed.

During 1988, we have examined the mosaic properties of Layer I receptive segments at the fovea, drawing upon material obtained in Central America during field work in 1987, and ancillary species from Sri Lanka and Central and North Africa provided by Dr R.R. Jackson (University of Canterbury, New Zealand). We have secured forms spanning a range between unequivocally 'primitive' and advanced jumping spiders.

The phylogeny of high-resolution Layer I retinal mosaics that we infer is remarkable: firstly, an embryological study of the morphogenesis of a principal retina showed that a tiered retina results from the lateral compression of an initial hemispherical cup. The most primitive jumping spiders we have studied, in the

Central African genus *Goleba* exhibit fully established tiering, but the Layer I mosaic is an optically inefficient rhabdomeral network with short receptive segments. An intermediate state has foveal segments each with two rhabdomeres sufficiently long to act as light guides: rhabdomeres of adjacent receptive segments are horizontally closely contiguous, whereas a pair within a receptive segment are well-separated. Thus, in this intermediate state, a Layer I mosaic offers photoreceptive pixels with complex topographical patterns of optical coupling. The final elimination of a 'redundant' rhabdomere within a receptive segment also proceeds in a complex manner. We are examining the inferred evolution of these high-resolution retinal mosaics in terms of the modulation transfer functions that can be supposed to follow from their sampling geometries.

One of us (David O'Carroll) has discovered tiered principal retinae in some lycosid, oxyptilid and thomisid cursorial spiders. They suggest starting points for the evolution of the sophisticated principal retinae of jumping spiders.

Development of the Visual System of the Tammar Wallaby.

Investigators: Richard Mark, Shin-Ho Chung, Lauren Marotte, Xiao-Ming Sheng, Geoff Henry†, Lidia Mayner*, Margaret Porter, Amanda Devlin.

We study the mechanisms involved in the formation of specific connections in the nervous system. Australian marsupials offer a unique opportunity to study the mammalian nervous system throughout virtually its whole period of development. They are born at an extremely early stage and complete their development in pouches. We use a combined anatomical and electrophysiological approach. The latter technique is impossible *in vivo* in placental mammals.

An anatomical study of the development of topographical connections in the primary visual centers has continued and a study of retinal development has been completed. Despite ganglion cells in the retina developing from an initially homogeneously distributed population to an adult pattern where there is a streak of high ganglion cell density across the nasotemporal axis, the inhomogeneity of central representations of this adult pattern is present from early stages of development. With the arrival of Dr. Shin-Ho Chung we have started an electrophysiological study of the development of these topographical connections.

An electrophysiological study of the adult LGN has been carried out in collaboration with Geoff Henry (JCSMR) correlating the response properties of LGN neurons with the pattern of lamination and overlying terminal bands in the LGN.

A study of the visual projections to the dorsal lateral geniculate nucleus (LGN) has shown that the LGN develops in the absence of interactions between afferents from the two eyes. Competition for territory plays a limited role in the formation of connections.

We are also studying the formation of second-order visual connections between the thalamus, the mid-brain and the cortex. We have shown that some fundamental connectivities are established several weeks before eyes open. Precedents suggest that rules for the establishment of connections within mammalian visual systems may rely upon early visual experience. Wallaby pouch young provide a system that allows such paradigms to be tested.

A Visiting Fellow, Dr Lidia Mayner, formerly a member of the Department of Behavioural Biology, continues to prepare a stereotaxic atlas of the wallaby brain.

Motoneuron Cell Death in the Wallaby.

Investigators: P.E. Comans*, I.S. McLennan*, R.F. Mark, I. Hendry†.

Cell death is an integral part of the development of the vertebrate nervous system. We have completed an investigation of the development of the lumbar lateral motor column of the wallaby, a model of mammalian motoneuron cell death that is accessible to experimental manipulation. The period of cell death is biphasic and occurs entirely postnatally. The initial phase is similar in extent to the motoneuron death reported for postnatal birds and placental mammals. The second phase has not

been previously described. Our experimental results support the hypothesis that mammalian motoneurons must contact their appropriate muscles in order to survive throughout the period of natural neuronal cell death.

The Effect of Eye Movement on Visual Evoked Potentials in Man.

Investigators: Richard Mark, G. Danta[+].

This year has seen the beginning of a collaborative project with the Royal Canberra Hospital. The visual evoked potential is being measured during voluntary eye movement to see whether it is reduced compared to potentials recorded with the eye stationary. As well as being of significance to basic research in the psychophysiology of visual perception, this measure could give an objective, non-verbal index of high-order perceptual processing more sensitive to disease or damage to the cerebral cortex than the visual evoked potentials which are currently used as a routine diagnostic procedure.

The Development of Chick Embryonic Muscles.

Investigators: Ian S. McLennan[*], Margaret Porter, Hiroto Naora, Kyoto Kyoshi.

Dr I.S. McLennan left RSBS in May 1988, to occupy a post in the Medical School of the University of Otago, New Zealand. The research he concluded before he left concerned the influence of prostaglandins on the differentiation of embryonic muscle, using *in ovo* chicken embryos as an experimental material.

The research starts to define how the number of cells within a muscle is regulated during development: it is important in the contexts of optimising agricultural meat production, and of notional strategies for induction of the regeneration of diseased human muscle.

Modulation of Inhibitory Transmission.

Investigators: S.H. Chung, P.W. Gage[†], R.F. Mark.

A main inhibitory system in the mammalian central nervous system depends on the opening of chloride channels in cell membranes by the neurotransmitter γ-aminobutyric acid (GABA). Drugs such as barbiturates and benzodiazepines increase the efficacy of GABA in the central nervous system by changing the behaviour of these channels and it is generally accepted that their antiepileptic and behaviour modifying effects are mediated in this way. We are exploring new ways of potentiating the inhibitory effect of GABA by manipulating the extracellular concentrations of transition-metal ions and pyridoxal-5′-phosphate. There is evidence that these naturally-occurring substances, in small excesses, impair the efficacy of the inhibitory system and render the brain hyperexcitable. Thus, a reduction of these substances by pharmacologically 'tailored' drugs should in principle potentiate GABA-ergic transmission and depress epileptic discharges. We are planning to synthesize a number of such compounds and test their effects on ion channels activated by GABA in cultured neurons, on cells in brain slices and on animal models of epilepsy.

Sensory Coding in the Avian Cochlea.

Investigators: Ken Hill, Tony Gummer, Jianwu Mo, Gert Stange, Bridget Hilton.

Auditory perception, both of sounds in three dimensional space and of the quality of speech sounds, requires that the fine structure of acoustic signals be encoded. As part of our investigation of temporally-synchronized, afferent spike responses in the avian auditory system, we find that spike trains may be entrained to extrinsic acoustic stimuli, to an intrinsic periodicity, or to a combination of the two. Intrinsic periodicity in spontaneous firing in avian auditory fibres has been tentatively attributed to electrical tuning in hair cells. We have found intrinsic periodicity in evoked spike trains that appears independent of spontaneous periodicity. Suppression of spike trains by acoustic tones is associated with the periodicity that may occur in spontaneous spike trains. It appears that previously unrecognized aspects of temporal coherence in the sensory response may subserve perceptions of transient, impulsive sounds.

We have developed a mathematical description of the processes of excitation and suppression. An excitation function is proportional to the intracellular DC receptor potential and the suppression function is proportional to the extra-cellular DC

receptor current at the spike generator. This current is modelled as the weighted sum of the contributions from a longitudinal array of hair cells. The weighting function is a symmetric, two-sided exponential, describing longitudinal current spread in a uniform, resistive medium. By assuming a constant receptor cell membrane conductance, the suppression function becomes directly proportional to the excitation function convolved with the weighting function; that is, the suppression function is a linear, spatially filtered version of the excitation function. When followed by a spike generator, this model accurately predicts the apparently enigmatic single-unit responses. One of the important features to emerge is that the longitudinal space constant for single-tone suppression is about 0.7 mm, which corresponds to about 100 tall hair cells.

Determinants of High Frequency Sensitivity in the Avian Auditory System.

Investigator: A.W. Gummer.

Auditory function depends on the mechanisms that determine the limit of high-frequency sensitivity. Until now the high-frequency exposure has been attributed predominantly to the middle ear. However, we have found evidence in the pigeon that its origins are intra-cochlear and that it is determined by the mechanics of basilar membrane motion at the extreme basal end. The basilar membrane maps frequency to distance along the cochlea. Part of the incident energy is reflected at the basal end back to the columella footplate, where it causes destructive interference with the incident vibration. The columella footplate initiates fluid motion in the cochlea. The reflection becomes significant for stimulus frequencies close to the maximum frequency represented on the basilar membrane (6 kHz), at which the incident and reflected vibration modes at the columella footplate approach cancellation, so that the net input to the cochlea vanishes. Although evidence for this phenomenon can be found in the published data from mammals, it was never considered by former researchers because the upper frequency limit (30–50 kHz) precluded unequivocally accurate measurements at such high frequencies. Intra-cochlear reflection appears to be responsible for the high-frequency response in both avian and mammalian auditory systems. This basic physical principle has important consequences for our study of auditory development, since functional maturity begins at low frequencies and proceeds to higher ones.

MOLECULAR NEUROBIOLOGY

Introduction

Recombinant DNA technologies have allowed new approaches to examining the architecture and functioning of nervous systems. Some organisms have proven more tractable than others, and this is particularly so with the fruit fly and the locust. The former provides novel interfaces between neurogenetics, molecular biology, neuroanatomy and gene transfer techniques. The locust yields access to large neurons and to well defined circuits that are individually recognizable in every preparation. Furthermore, when important molecules such as fasciclins are targeted in the locust, the genes for these molecules can be used to isolate homologous genes in the fruit fly, thus giving access to the genetic systems available in that organism.

Since nearly 40% of monoclonal antibodies to the fruit fly brain cross react in specific ways to the human brain, the fruit fly is a very useful test organism for many basic principles of mammalian nervous system function. The fly has the current advantage that not only can neurobiologically significant genes be rapidly searched for and cloned, but the molecular pathways in which these genes participate can be unravelled using the extensive genetic data base of the fly. Mutant phenotypes

are readily rescued using sophisticated genomic re-entry vectors. *In vivo* mutagenesis can be routinely performed using specially tailored transposons such as Jump Starter, or modified vectors containing a 'reporter' gene. *In vitro* mutagenesis permits alterations to neurobiological genes, followed by their stable re-introduction into the genome and subsequent biological evaluation. Such uniquely manipulable genetic extraction and re-entry techniques have yet to be developed for mammals. In the Molecular Neurobiology Group, therefore, we are utilizing the fruit fly and the locust and focussing our approaches on the control of neuronal fate in the CNS, neuronal connectivity, and cell adhesion and cell recognition phenomena during neuronal development.

Neurogenetics and Developmental Gene Circuits: *Drosophila melanogaster*

Investigators: George L. Gabor Miklos, David Hayward, Stephen Delaney, Ute Schuppler

A major problem in neurobiology is to understand the mechanisms by which nerve cells form specific connections. In order to build nervous systems, genomes must encode and utilize certain protein molecules to sequentially coordinate 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 utilize the 100,000 neuron nervous system of the fly *Drosophila melanogaster* because of the pragmatic technical advantages *Drosophila* offers over nearly all other organisms. We have focussed all three approaches onto a selected subset of genes which we believe have a major involvement in events relating to (a) neuronal connectivity; (b) the construction of various subsystems of the brain; and (c) neuromuscular networks. We have developed an international and local network which melds our genetic and molecular biological expertise with the neuroanatomical, neurophysiological and embryological expertise of overseas laboratories.

We have targeted a small section of the X-chromosome which contains a large number of genes of particular interest to us. When mutated, they give rise to particularly interesting neurobiological phenotypes such as *shaking, uncoordinated, small optic lobes, sluggish, introvert, sozzled* and *stoned*. This year we have concentrated on the area containing the *small optic lobes* and *sluggish* genes. By using the extensive genetics that we have developed for this region, we have delineated *small optic lobes* to an area of 15kb and *sluggish* to an area of 23kb. Having localized the genes to such relatively small genomic locations, we are currently analysing the expression of the entire landscape by Northern blotting, in order to characterise these genes and any others which may be present. In addition, genomic fragments have been used to screen cDNA libraries, in order to isolate sequences encoded by the *small optic lobes* and *sluggish* genes. cDNAs derived from at least three transcription units have already been isolated and these are currently undergoing sequence analysis. Genomic fragments, which genetic and molecular data suggest contain the *sol* and *slg* genes, are also being cloned into genomic delivery vectors. This will allow us to directly assay their ability to rescue the mutant phenotypes, and so to positively identify the genes in question. This ability to introduce cloned DNA into the *Drosophila* genome will yield information on the regulation and functions of these genes.

Our major achievements this year have concerned—(i) the isolation and characterization of large numbers of cDNA clones for the *flightless* as well as the *small optic lobes* and *sluggish* areas (Fiona Hall, James Cotsell, Steve Delaney, Dave Hayward and George Miklos); (ii) the strict genomic delimitations of the *small optic lobes, sluggish* and *collagen-like* genomic landscapes using molecular breakpoint analyses (Ute Schuppler, Dave Hayward and Steve Delaney); (iii) the localization within our micro

cloned libraries of the repetitive DNA sequences that are sequestered within and between the neurobiological gene landscapes (Jane Olsen, James Cotsell, Kevin O'Hare, Andy Mitchelson).

The Organisation of Identified Neurones in the CNS of the Locust.

Investigators: George Boyan, Les Williams#, Eldon Ball

We are interested in how the pattern of connections between nerve cells in an adult central nervous system becomes established. Insects, like vertebrates, have a segmented (or metameric) central nervous system consisting of a chain of linked ganglia. The cercal receptor/giant interneurone system of the locust is involved in flight behaviour, and although the afferents enter the CNS in the terminal ganglion, the network of neurones involved stretches over the whole CNS. We are now studying the locust embryo to identify those neurones in the cercal system that are segmentally homologous. We have already discovered neurones in different segments of the adult CNS which may be homologous and which, despite sharing some physiological and anatomical properties, have developed into different types of cells. Even within the one segment, we have identified members of a group of cells which originate from the one mother cell (neuroblast) in the embryo, but where only one cell develops into a 'giant' cell in the adult, and where the member cells develop different adult physiological properties. An understanding of the mechanisms responsible for these patterns of differentiation will provide an insight into the developmental processes that shape the structure, and therefore function, of nervous systems.

The Neural Basis of Behaviour: Flight and Song in the Orthopteroid Insects.

Investigators: George Boyan, Matthias Hennig, Les Williams#, Alan Watson#, Eldon Ball.

The insect nervous system contains many large, individually identifiable nerve cells and this allows us to analyze the causal basis for behaviour at a level not yet possible in most vertebrates. During the past year George Boyan has continued his physiological analysis of the cercal receptor/giant interneurone system, which connects directly to the flight system of the locust. This has involved analyzing the way in which many parallel pathways carry different information, at different speeds and with different delays, from cercal hairs to the interneurones controlling flight. Les Williams, Alan Watson, and Eldon Ball have carried out neuronanatomical studies on the same system, to provide an anatomical basis for interpretation of the physiological results.

In insects it is now possible to investigate such questions as how a single small population of motor neurones and muscles is coordinated to produce quite different behaviours. Matthias Hennig has been doing such a study on the neurones and muscles that control the wing movement during cricket song and flight. He has achieved a technical tour de force by being able to elicit these two behaviours at will and showing that instead of single interneurones being involved in both behaviours, there is probably a hierarchy of interneurones subserving one function or the other.

Neuromuscular Development in the Locust Embryo

Investigators: Camilla Myers, Paul Whitington#, Joan Quinn and Eldon Ball.

There is currently considerable interest in the cues used by outgrowing motor neurones to locate their target muscles and in the accuracy with which they do so. During the past year our work has established that the four neurones which innervate the large jump muscle of the hindleg of the locust all form inappropriate axon branches during their growth out to the muscle. These branches generally form in pre-existing pathways and in some cases may grow some distance away from the target muscle. In all cases the inappropriate branches are later withdrawn to leave only the appropriate branch to the muscle. Little is known about the mechanisms by which neurones establish their mature pattern of connections with a muscle, and this preparation appears to be particularly well suited to analyzing these processes at the cellular level.

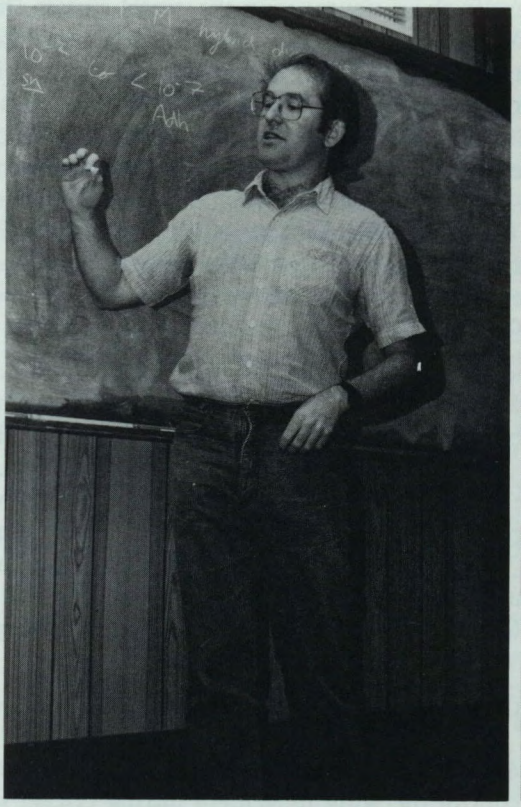
Eldon Ball and Joan Quinn have continued their studies on the detailed interactions between the growing tip of an identified developing motor axon (growth cone) and its

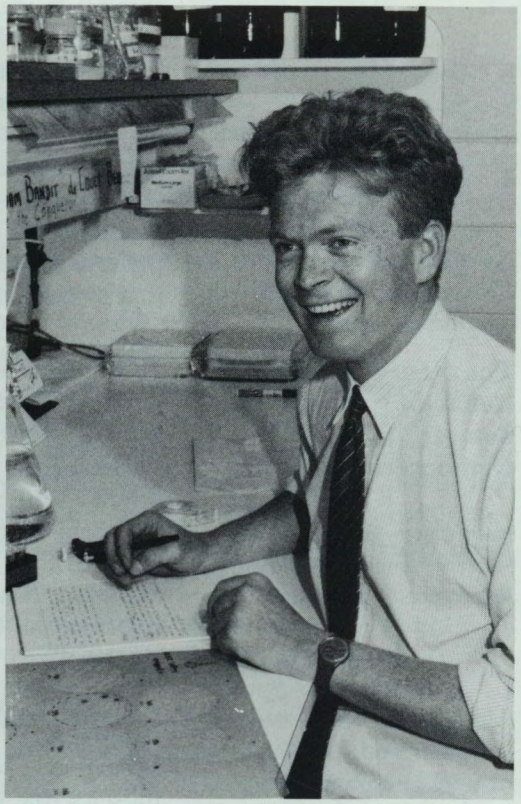
target muscle. Two major findings of the past year have been first, that the growth cone interacts extensively with the undifferentiated mesoderm cells which surround the muscle precursor cell, and second that the growth cone is inactive for a long period after it has located its appropriate target tissue. These findings are unexpected and again underscore the advantages of studying invertebrate nervous systems where it is possible to work with identified cells. Similar 'waiting periods' during development are now starting to be discovered in vertebrates.

THE IMPERIAL COLLEGE CONNECTION

A number of molecular biologists from the Imperial College of Science and Technology, University of London have extensive collaboration with Dr George Miklos' Plant Molecular Biology Group.

In 1988, Dr Kevin O'Hare and Dr Andrew Mitchelson visited RSBS on joint research projects funded by the Royal Society of London Bicentennial Grants Scheme. Dr O'Hare gave a lecture on the genetic engineering and properties of mobile DNA sequences in the fruit fly. These DNA elements are used as genetic delivery vectors for moving DNA sequences around a genome and represent 'state of the art' jumping gene technologies.





VISUAL SCIENCES

Introduction

The former Department of Neurobiology was largely concerned with peripheral aspects of photoreception by insects: optics of compound eyes, phototransduction, photoreceptor ultrastructure, visually-determined behaviour, and the electrophysiology of peripheral visual pathways. Now, the Vision Group is extending these interests to examine the deeper processing levels of the insect visual system. In one way or another, most of the projects conducted by the Group relate to the concept of 'motion parallax' which evolved from earlier studies.

Our research in 1988 has confirmed that the higher-order visual neurons of insects are not interested in stationary images on the retina: the most (and possibly only) significant visual stimulus is motion. Although many groups of insects have colour vision, the visual pathways that measure movement prove to be colour blind.

Thus, we are particularly concerned with how insects interpret the visual world around them despite an apparently minimal analysis of the shapes of static objects. Also, most (but not all) insect vision is based on a literal interpretation of sensory input, with little matching to engrams stored as memory. We are dealing, step-by-step, with the higher-order processing of visual stimuli, using a combination of mathematical, ethological, electrophysiological and genetic techniques.

However insects perceive their worlds, they are suberbly skilled at interpreting them. The limited range of percepts that they need are echoed by the specialised requirements of the human blind. We have received a major grant of $330,000 from the Department of Industry, Technology and Commerce to develop an aid for the blind based on the principles of insect vision. The associated development of hardware and software applications is supported by a grant from the ANU Centre for Information Science Research.

Many fundamental principles of retinal connectivity are probably similar in both vertebrates and invertebrates, despite their very different anatomies. Dr I.G. Morgan works on the distribution of synaptic transmitters in the retinae of vertebrates, and how they relate to retinal hard-wiring. His research bridges the gap between studies in insect visual processing, and the similar research on vertebrate retinae being conducted in JCSMR. In 1989, members of the new ANU Vision Research Centre from JCSMR and RSPhysS will be united in an extension to the RSBS building that has just been completed. We anticipate an intensive, joint effort to evaluate the factors common to arthropod and mammalian vision.

Visual Discrimination by Honeybees.

Investigators: M.V. Srinivasan, M. Lehrer#, S.W. Zhang# and G.A. Horridge.

We have completed a series of experiments in which freely-flying honeybees were trained to distinguish between objects (artificial flowers) at various distances, independent of their size. Distance discrimination based on motion cues appears to be mediated primarily through input from green-sensitive receptors. It is therefore colour-blind, although honeybees possess excellent trichromatic colour vision, in other contexts.

We have shown that bees can be trained to detect a textured figure when it is raised over a similarly-textured background. It seems that the figure is detected primarily from the discontinuity in apparent motion (motion parallax) that exists at its boundaries. Further experiments, that investigate the nature of the relevant parallax cues, indicate that covering and shearing parallax are equally important in detecting an edge.

Ability to track moving targets is being assessed by training bees to find a reward on a stationary target, and then video-filming the bees' approach flights to the target when it is in motion. Analysis of the flight trajectories shows that both the angular

CENTRE FOR VISUAL SCIENCES

Standing in front of the early construction work on the RSBS extension which will house the Centre for Visual Sciences are the principals involved in the Centre's establishment (from left to right—Professor Alan Snyder, RSPhysS; Professor Bob Porter, Director, JCSMR; Professor Adrian Horridge, RSBS; Professor Ralph Slatyer, Director, RSBS; Professor John Carver, Director, RSPhysS and Professor Bill Levick, JCSMR).

position and the angular velocity of the target are important control variables for tracking by a bee. Further experiments that investigate the spectral properties of tracking are in progress.

Neural and Visual Correlates of Adaptive Animal Coloration.

Investigators: M.V. Srinivasan, D. Osorio and R. Guy*.

The dronefly is a Batesian mimic of the honeybee, living on nectar from flowers and sharing the same ecological niche. Spectral properties of directionally-selective movement-detecting neurons in the lobula plate of the dronefly are being measured using stimuli consisting of flashes or moving gratings. The flash response exhibits a twin-peaked spectral sensitivity, with peaks in the UV and the blue-green, akin to that of the R1-6 photoreceptors. In the response to movement, however, the UV sensitivity is greatly suppressed or absent. 'Standard' flies such as *Lucilia* or *Calliphora* do not show this suppression when tested with the same stimulus. We postulate that the reduction in UV sensitivity is caused by inhibition from R7 UV photoreceptors acting on R1-6 signals at some stage in the movement-detecting pathway. This renders the spectral properties of motion detection in *Eristalis* more akin to those of the honeybee than to those of other flies; we suggest, therefore, that the dronefly not only looks like a bee, but also 'sees' like one.

Much animal coloration, ostensibly used for camouflage, does not simply make a bearer match its surroundings as closely as possible. Instead, many patterns should make an animal more conspicuous to an adversary that possesses a 'matched filter'. But natural visual systems are clearly fooled by camouflage patterns. Possibly, matched filters do not exist. We are using camouflage patterns as a natural source of optical illusions to speculate about edge-detection in natural visual systems, and how they are fooled by the complex edge patterns seen in many cryptic species.

Processing of Colour, Motion, Edges and Intensity.

Investigators: G.A. Horridge, M.V. Srinivasan, D. Osorio, R.B. Pinter[§], R. Findlay[*], Q.J. Sun, J. Shi, D. Reye[*] and X. Wang[#].

Insect optic lobes contain families of nerve cells, many of which respond to stimuli of patterns of light and shade moving across a retina. Some of these neurons respond to extended patterns that occupy the whole of a large field, and appear to be concerned with the stabilization of flight. Others are inhibited by motion of extended patterns, but excited by movement of small objects, as if they perceptually isolate local detail from background. We are establishing which of these neurons are colour blind and which are colour-coded. Locust neurons respond as if they receive inputs from dark edges and light edges separately, which is contrary to current theories of motion perception. This novel paradigm of edge-detection should have behavioural correlates.

In a re-evaluation of fixation behaviour we find that walking flies head towards the centre of a wide stripe in dim conditions but to its edges in bright conditions. This edge fixation was previously thought to involve a separate and more complex neural computation than simple negative phototaxis. However, analysis of the paths walked by the flies and selective occlusion of different eye regions strongly indicates that they simply tend to head for the darkest perceived region. In dim light this is at the centre of a dark area, but in bright light lateral inhibition creates 'Mach-band' effects which attract the flies to a region between 5° and 10° to the dark side of a black-white edge.

Signal Coding in Insect Optic Neuropils.

Investigators: D. Osorio, A.C. James and R.R. Poznanski.

Both the anatomy and physiology of large monopolar cells (LMCs) in fly lamina ganglion are already known in great detail. It is an excellent site for the study of 'neural network' processing by a natural system, because the dynamic properties and connections between elements can be accurately described.

Spatio-temporal white-noise analysis proves to be a powerful tool for testing the properties required by some simple models of LMC function: for example, cells may be adapted to transmit as much information as possible, for later analysis by the brain. Spatio-temporal receptive fields and responses are close to linear and can be accurately described so as to further refine models of function. We can, for example, specify the interaction between spatial and temporal lateral inhibition.

Additional work on the LMCs focuses on the anatomy of the individual cells. An analytical model of the cable properties of these non-spiking cells is being developed, because the axonal structure may alter output properties of LMCs at different sites in the medulla. Deeper in the visual system, we are looking at small field interneurones in the medulla. Sophisticated stimuli are now based on refinements of white-noise techniques. Here, they are used to characterize the non-linear medulla cells. Anatomical work to establish the functions of sub regions of the medulla complement the physiology. For example, directional-motion computation seems to occur very early, probably by cells receiving inputs in the layer at which LMCs terminate.

Role of Lamina Large Monopolar Neurons in Visual Behaviour

Investigator: P. Coombe

Little is known about the role of the large lamina monopolar neurons (LMC) in insect behaviour. The optomotor response is the best known visual behaviour. It has long been assumed that the LMCs are part of the optomotor pathway in flies. There is increasing evidence that this may not be entirely true. Experiments using a random grating as the stimulus have shown that the directionally-selective neuron H1 must receive a tonic input, whereas the LMCs are purely phasic when identically stimulated. Injection of current into an LMC also has no effect on H1. The LMCs respond optimally to a higher contrast frequency than the optomotor response and there is poor correlation between degeneration of LMCs in a mutant of *Drosophila* and the loss of optomotor behaviour. In addition, the optomotor response of *Drosophila* is sensitive to the plane of polarization whereas *Drosophila* LMCs are not.

A visual mutant of *Drosophila*, isolated by hybrid dysgenesis, has been examined genetically and electrophysiologically. The mutant is an allele of *nonC* , (an ERG mutant isolated some years ago) and the gene has been mapped to a single chromosome band. Mosaic analysis has shown that the ERG defect is probably in the retinula cells. Electrophysiologically, all measurements to date on these retinula cells have shown a normal response, but LMCs show a smaller response and increased latency. Since the latency of receptors is normal, the synaptic delay from receptor to LMC is some 3–4 times longer in the mutant than the wild type. This suggests that *nonC* is a synaptic mutant, with the defect presynaptic to the LMCs. Probably a deficiency of transmitter is implicated.

Understanding the Behaviour of 'Complex' Systems

Investigators: Z. Aleksic and S. Marcelja†

New forms of computation by distributed computational systems relate to the currently unsolved problem of coping with complexity. These novel computational systems are reminiscent of biological and social organizations. One way to cope with complexity is to examine how nature 'solved' the problem. We are seeking ways of understanding the behaviour of systems consisting of several interconnected components, reminiscent of some biological and computational systems.

Computational Models and Hardware for Motion Perception, leading to a Seeing Device for the Blind.

Investigators: G.A. Horridge, M.V. Srinivasan, S. Jin, J. Dalczynski, M. Nagel, R. Brent†, I. Macleod†, and T. Heyes +.

New algorithms for the detection of motion and motion parallax are being developed and their feasibility for machine vision assessed in computer simulations. We are also interested in examining how circuits composed of real neurons can match the computational algorithms for motion detection, for example, the gradient model. Hardware incorporating some of these algorithms is being designed and constructed, an immediate objective being a new type of visual aid for the blind.

Artificial seeing systems achieve little between simple photocells on automatically opening doors, and video-cameras which register pictures, but cannot make sense of their contents. Our aim is to provide aids for people with impaired vision by copying relatively simple insect visual processing mechanisms. A grant from the Centre for Information Sciences was followed by a more substantial grant from the Department of Industry, Technology and Commerce. Our collaborating private company is SEETEC (the technical subsidiary of the Royal Association for provision of Guide Dogs for the Blind) of which Dr T Heyes is the Managing Director.

Theoretical Studies on Human Vision.

Investigators: D. Osorio, T.R.J. Bossomaier† and A.W. Snyder†

A long standing problem in primate vision is why the spectral sensitivity peaks of the long (red) and medium (green) wavelength cones are so close together. The large overlap in spectral sensitivities is not ideal for colour vision and various explanations have been proposed. Modelling suggests that (i) there is a trade-off between chromatic and achromatic information to maximise the information capacity of the entire visual system and that (ii) a greater separation of the cone pigment spectral sensitivity peaks than is observed would compromise analysis of fine detail. A computer model encapsulating our measurements of the spatial and spectral properties of the natural world is testing this hypothesis. Preliminary calculations suggest that there is indeed a trade-off between spatial and spectral vision, and that the green reflectance of chlorophyll in leaves may have crucially constrained the extent to which a medium wavelength pigment could have evolved towards shorter wavelength sensitivity.

The human retina can encode the highest spatial-frequencies transmitted by the optics, but these frequencies are noisy and of low contrast; they may be of little use in later visual processing. Recently it has been suggested (especially by Livingstone and Hubel) that many aspects of vision do not need high spatial frequency information, but depend on a coarse retinal sampling of information provided by ganglion cells projecting to the magnocellular layer of the lateral geniculate nucleus

(M-cells). Psychophysical tests show that detection of shape, even when excellent optics are needed (for instance in reading the bottom line of an optician's test chart) is unaffected by the presence of high spatial frequency interference but is badly impaired when the interference is in the lower frequency range, known to be used for other tasks. Good optics are not needed to see the finest possible grating but to get reliable, high contrast information at lower spatial frequencies.

Retinal Circuits, Neurotransmitters and Visual Processing

Investigators: I. Morgan, Z.K. Li, P. Miethke, J. van der Valk, G. Yang, R. Poznanski, D. Dvorak*, L. Davies*.

We attempt to explain how vertebrate retinas turn the visual inputs registered in an eye by photoreceptors as a rather stereotyped response, 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 identified retinal cells, pharmacological manipulation of inputs to identified cells, and intracellular electrophysiology. Uniquely, we use 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.

In 1988 we continued to study interactions between cholinergic and GABAergic amacrine cells and displaced ganglion cells. They determine the property of directional selectivity. Dendrites of cholinergic amacrine cells and directionally-selective ganglion cells colaminate precisely within the inner plexiform layer; there may plausibly be synaptic connections between them. Destruction of cholinergic amacrine cells silences directionally-selective units in basal optic root nuclei which are driven by directionally-selective ganglion cells. Presumably, neurotoxic manipulation removes their major exicitatory drive.

The organization of GABAergic amacrine cells has also been studied. Cholinergic cells may also be GABA-immunoreactive; thus, a single cell might provide both the excitatory drive and the inhibitory veto functions needed for directional selectivity. We find that, at least in the chicken, cholinergic and GABA-immunoreactive displaced amacrine cells are not immunoreactive for the synthetic enzyme glutamic acid decarboxylase. This raises the question of whether GABA-immunoreactivity actually represents transmitter GABA, or GABA inactivated by uptake.

We are conducting a mathematical analysis of the dendritic functioning of directionally-selective ganglion cells and cholinergic amacrine cells, to determine how they cooperate to generate directional selectivity.

Neuropeptide Processing and Function

Investigators: I. Morgan, M. Boelen+, M. Dowton+, I. Chubb+.

Previous work on enkephalin-immunoreactive and somatostatin immunoreactive amacrine cells showed that peptide levels increase in the light and decrease in the dark. Now, we have shown that while levels of penta-peptides vary, those of their higher molecular weight precursors do not. Light decreases release of these peptides *in vivo*. Thus, peptides may be released at key sites of modulation, and there may be little if any regulation of gene expression in relation to physiological demand. Increases in peptide levels in the light may be due to the fact that the cells are inactive in the light, so that synthesis is more rapid than release and subsequent degradation. Decreases in peptide levels in the dark can be attributed to the activity of cells in the dark, in which state synthesis perhaps cannot keep up with release and degradation.

By varying light intensity, we have shown that the activity of somatostatin-immunoreactive cells is depressed by increasing light intensity, with a linear relationship between activity and the log of light intensity.

Enkephalin-immunoreactive amacrine cells change from a highly active state to a state of low activity when lighting conditions change from photopic to mesopic, but there is no further change in activity with increasing light intensity. Thus a somatostatin-immunoreactive cell seems to function as an inverse light meter, and may be involved in functions such as driving luminosity or dimming detectors or light adaptation, and could be involved in other functions such as control of pupil size. Enkephalin-immunoreactive amacrine cells seem to be active when rods are active, and inactive when cones are active; they may have some role in selective processing in rod or cone pathways. These are the first real clues about the function of any of the retinal neuropeptide systems.

By pharmacological manipulation of peptide levels *in vivo* and peptide release *in vitro*, we have shown that enkephalin-and somatostatin-immunoreactive cells receive powerful cholinergic drive in the dark. Excitatory amino acids do not seem to provide major excitatory drive to these cells. For enkephalin-immunoreactive cells alone, there also appears to be a powerful light-activated glycinergic inhibition, but no GABAergic inhibition. Neither source of inhibitory input seems to be important for somatostatin-immunoreactive cells. Thus activity of enkephalin-immunoreactive cells seems to be determined by a combination of excitatory (cholinergic) and inhibitory (glycinergic) input, with excitation high and inhibition low in the dark. When light intensity reaches mesopic levels, excitation decreases and inhibition increases. In contrast, for somatostatin-immunoreactive cells, only an excitatory (cholinergic) drive has been detected, which is high in the dark and which decreases with increasing light intensity. This difference in input may explain the different nature of the responses to light of the two cell types.

MOLECULAR GENETICS

Introduction

Eukaryotic structural genes are unevenly distributed along DNA molecules. Sequences separating genes can vary enormously in size and in base composition which raises the important question: what influences do these regions have on gene expression? A related question is posed by the observation that gene order is variable between different organisms; we would like to know whether changing the arrangement of genes can alter phenotypes? These issues impinge on the question of what factors underlie abnormal gene expression in malignant cells? One postulate is that the translocation of a proto-oncogene leads to aberrant expression because influences of bounding sequences are altered.

To study such questions, experimentally amenable systems are necessary. Four such systems are being studied in our laboratories. One involves the ability to manipulate the mitochondrial genome in bakers yeast *Saccharomyces cerevisiae*, the second entails studying gene expression in interspecific yeast hybrids. The third, using higher eukaryotes, and, in particular, fibroblast cells from the mouse, involves the specific nature of oncogene expression (which is readily assayed). The fourth includes studies of tightly regulated gene expression on normal murine and human chromosomes which show enhanced expression in translocated chromosomes.

Mitochondrial Biogenesis and Mitochondrial Genome Evolution in Yeasts.

Investigators: Des Clark-Walker, Richard Maleszka, Anne Mathews, Onn Choon Wong[#], Patrick Skelly, Chris Hardy, Robin Chapple[†], Alexandra Plazinska and Erika Wimmer.

Manipulation of the mitochondrial genome in bakers yeast *Saccharomyces cerevisiae* can produce both rearrangements in gene order and deletion of the adenine plus thymine-rich intergenic regions. Strains containing various rearrangements and deletions are being examined for alterations to gene expression and for the influence of these changes on mitochondrial recombination and transmission. In general we have found that rearrangements do not change gene expression, nor do deletions of two intergenic regions. However intergenic regions do influence recombination and transmission as in crosses of deleted strains with wild-type there is a strong bias towards recovery of the latter genome. Therefore we can conclude from this experimental system that sequences in DNA, lacking structural or regulatory genes, can nevertheless confer selective advantage to a molecule.

Mitochondrial genomes of strains containing rearrangements are being characterized at the molecular level to determine sequences at the novel junction sites. Similarly, sites of deletions are being examined in mitochondrial DNA from the yeast *Kluyveromyces lactis*. This yeast, which normally does not form deletions in mitochondrial DNA, has been altered by fusion to *S. cerevisiae* so that one putative hybrid can now manifest such deletions. In addition this altered strain is being studied for chromosomal changes consequent on the fusion. It has been found using electrophoretic separation of chromosomes, that the hybrid has one smaller chromosome relative to wild-type. This chromosome also contains the reiterated ribosomal RNA locus which raises the possibility that a change in this region may be related to the altered physiological properties. Investigations are proceeding on:

a Sequence analysis of novel junction regions in rearranged mitochondrial genomes

b Influence of base-biased regions on mitochondrial genome expression, recombination and transmission.

c Characterization of deletion sites in *K. lactis* mitochondrial genomes.

d Chromosomal changes in hybrids resulting from fusion between *K. lactis* and *S. cerevisiae*.

e Mitochondrial genome evolution in yeasts by nuclear and mitochondrial genome sequence analysis.

Cancer Cell Biology

Investigators: Hiroto Naora, Kaoru Miyahara, Lun-Quan Sun[#], Felice Driver, Kyoko Koishi, David Buckle and Helen Liszczynsky.

The object of this study is to investigate the regulatory mechanism of a gene expression network in the cell. Cellular oncogenes are involved in basic processes required for cell function. Most, and perhaps all, cancer cells develop in several steps, probably as a result of the sequential activation of more than one oncogene. Therefore, we believe that cellular oncogenes are appropriate targets to examine the problem.

The project includes a range of related topics. The following observations should be highlighted:

a Molecular characterization of the novel gene, *nbl* abundantly expressed in Burkitt lymphoma, has been carried out. Nucleotide sequences of *nbl* cDNA were determined, suggesting a membrane-spanning protein. It was found that *nbl* shares sequences with those at the *c-abl* locus and is located on human chromosome 9 as well as several other sites.

b In order to investigate cis-acting gene-to-gene interaction, we have established various cell lines which possess oncogenes linked together on the same or different DNA strands with short intergenic distances. The mode of expression of these linked genes is being studied.

c The gene expression network in which *c-myc* and *c-mos* are involved has been investigated. A novel gene, approximately 15–30 kb long, closely linked to and

likely to give transcriptional interference to *c-myc* was discovered. This opened a new way to examine the regulation of *c-myc* expression.

d Studies on the origin of contemporary gene structures have been continued, with particular emphasis on 'stop codon' distribution at the splicing sites. A surprising finding was that the sites at both the 5′– and 3′–terminals of an intron contain stop codons, generally out of phase with adjacent coding sequences.

POPULATION GENETICS

Introduction

The Population Genetics Group uses molecular and biochemical techniques to investigate genetic variation in natural populations of insects in Australasia.

The research focuses on studies of allozyme variation and evolutionary constraints on enzyme structure and function in *Drosophila* and on the molecular analyses of chromosome structure and the evolutionary significance of chromosome change.

Population and Molecular Genetics of *Drosophila*

Investigators: John Gibson, Allan Freeth, Chengshan Jiang, Jane Symonds, Anne Wilks, Anh Cao and Darryl Read.

This program aims to understand the micro-evolutionary factors affecting genetic variation in natural populations of *Drosophila melanogaster*. The current work includes studies of large scale geographic variation and molecular analyses of variant genes encoding enzymes with altered properties.

Allozyme variation

Extensive surveys, carried out in a number of laboratories, of allozyme variation in natural populations of the cosmopolitan species *Drosophila melanogaster* have shown that some polymorphic loci e.g. alcohol dehydrogenase (*Adh*) and esterase-6 (*Est-6*) vary latitudinally, whereas others e.g. phosphoglucomutase (*Pgm*) are relatively homogenous across zoogeographic zones. Consistent latitudinal differentiation on continents in both hemispheres has been claimed as evidence for natural selection imposed by latitudinally varying environmental factors, although it remains possible that the focus of selection is on phenotypes controlled by gene(s) in ubiquitous disequilibria with the enzyme locus. *D. melanogaster* populations occur in Australia from 10° to 45° which is similar to the latitudes of the People's Republic of China (P.R.C.) (20° to 55°N). In order to test the generality of the latitudinal differentiation previously found in Australia, geographic variation at eight allozyme loci in eight natural population of *D. melanogaster* from the P.R.C. was collated with data from Japanese populations and compared with reports for other continents. $G6pd^{F}$, $Est\text{-}6^{1.00}$ and Adh^{6} were significantly correlated with latitude. Whilst the variation in $Est\text{-}6^{1.00}$ was opposite to that previously reported, Adh^{S} showed latitudinal clines consistent with data from the northern and southern hemispheres. A thermostable variant, Adh^{FChD}, was found at high frequency in the southern P.R.C. populations and it is suggested that the mutation occurred in this region and was then dispersed to other continents.

Interactions between allozyme genotypes and environmental variation

The relationships between genetic variation at the alcohol dehydrogenase locus in *Drosophila melanogaster*, the relative abundance of *D. melanogaster* and *D. simulans* and environmental ethanol variation were investigated in populations exposed to markedly different levels of ethanol. It was found that ethanol levels in *Drosophila* breeding sites were higher in a winery storing fortified wines than in nearby grape pressings or in orchard fruits. The relative abundance of *D. simulans* to *D. melanogaster* was negatively correlated with ethanol levels. In *D. melanogaster* there were no significant differences in Adh^F frequency between the orchard and winery populations. The ethanol tolerance of wild caught *D. melanogaster* males paralleled the levels of ethanol in the breeding sites but *Adh* alleles and ethanol tolerance segregated largely independently of each other. Levels of ADH activity were positively associated with the ethanol tolerance of the different populations and with levels of ethanol in the breeding sites, but it is argued that the ethanol levels are not causative. Flies from inside the winery had higher ADH levels due mainly to greater amounts of ADH-F. The difference in activity persisted for at least one generation in the laboratory. After ten generations of laboratory culture the differences in ethanol tolerance were still present but there were no significant differences in ADH activity. These data show that the *Adh* polymorphism is unperturbed by environmental heterogeneity in ethanol levels although *D. melanogaster* populations do adapt to different levels by some mechanism unrelated to ADH activity.

Molecular analyses of low activity allozyme variants

Previous studies have identified null activity alleles at the alcohol dehydrogenase locus at frequencies up to 4% in some Tasmanian populations of *D. melanogaster*. Restriction endonuclease variation in the 12kb region surrounding the *Adh* locus indicated that the Tasmanian null alleles shared a common ancestry and were derived from the same mutation, which affects splicing. A representative null allele has been cloned and is being sequenced to determine the cause of the reduction in mRNA levels. *Adh* null alleles from other Australian populations have been isolated and shown to include types similar to the Tasmanian allele but alleles with a different molecular structure have also been found.

A series of low activity variants at the sn-glycerol-3-phosphate dehydrogenase locus have been isolated from natural populations and shown to fall into four categories on the basis of electrophoretic mobility, dominance relationships in heterozygotes with normal activity alleles and mRNA composition. Representatives of these groups are being cloned and sequenced for comparison with the common alleles in natural populations.

Genome Evolution and Chromosome Organisation in the Genus *Caledia*

Investigators: D.D. Shaw, N. Contreras

Our research effort continues to be directed towards the molecular analyses of chromosome structure and the evolutionary significance of chromosomal change.

Despite its fundamental role during the evolution of the eukaryotic cell and cell division, the molecular structure and organisation of the centromere of any higher eukaryote remains totally unknown. From the analysis of yeast centromeres, that contain only one centromeric unit per chromosome for attachment to a single microtubule, it can be safely assumed the larger chromosomes of higher eukaryotes will contain tens or hundred of such units. The lack of data for higher eukaryote centromeric DNA probably arises from the fact that most of their centromeres are flanked by highly repeated sequences (c-heterochromatin) that has precluded their molecular isolation. In *Caledia*, however, the centromeres of the Moreton taxon do not carry such highly repeated sequences.

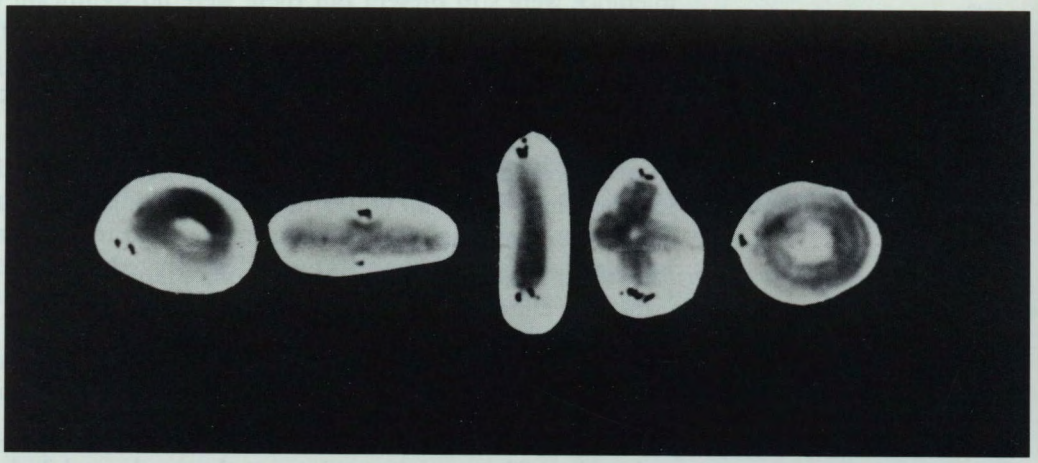
We have isolated and cloned a moderately repeated DNA family which appears to represent the centromere of a higher eukaryote. The region is 400 base pairs long and is currently being sequenced.

In situ hybridization to both mitotic and meiotic chromosomes has revealed that the sequence is located within the centromere itself and is not simply part of those highly repeated DNA families commonly found to flank the centromeric regions of many higher eukaryotes. On meiotic chromosomes, the DNA sequence we have isolated can be clearly seen to be detached from the chromosome arm itself and is associated with the region involved in the spindle fibre attachment at anaphase. This is the first time that DNA from a higher eukaryote has been isolated and shown, definitively, to be part of the centromeric structure.

We are currently sequencing several clones to determine their molecular structure, assessing its interaction with proteins to form the kinetochore and devising a bio-assay method to assess its behaviour during cell division. The ultimate goal will be to synthesise an artificial chromosome that can be injected into mature oocytes and assessed for its mitotic stability and inclusion into the genome.

BREAKTHROUGH IN UNDERSTANDING CHROMOSOME ORGANISATION IN HIGHER ORGANISMS

For the first time highly specialised regions of the DNA (the centromere) have been cloned and sequenced in a project to elucidate the molecular organisation of the chromosome in higher organisms.



The photograph shows the chromosome of *Caledia species nova* 1 with the hybridisation of radioactively labelled DNA (black dots) to the centromeres of each pair of chromosomes during meiotic cell division. The centromeres are specialised regions of the DNA responsible for segregating the chromosomes during cell division. After replication of the DNA they attach to the spindle fibres during mitosis and meiosis to ensure that each of the dauther cells has a normal complement of chromosomes.

PLANT CELL BIOLOGY

Introduction

The general objective of the group is to elucidate the cellular basis of plant growth. Cell division, the most basic aspect of plant development, is a rigorously controlled process. Thus continuous cell division is confined to special tissues termed meristems while limited periods of cell division occur in the development of most organs. The mechanisms that control division are obscure, represent a major unsolved problem in cell biology and are of great significance in relation to agricultural crops. The cytoskeleton, a structural framework within cells, provides spatial controls to establish the necessary intracellular dispositions and orientations necessary for division and the subsequent cell expansion and cell differentiation which leads to a whole plant. A third area of cellular control involves the plant cell surface. The cell wall and plasma membrane can no longer be regarded simply as a structural envelope; they are in dynamic interaction with the enclosed cytoplasm and cytoskeleton and participate in mediation of developmental events. Cell surface components are crucial in the interaction between plant cells and both pathogenic and symbiotic microorganisms. A fourth mechanism of control of cell development centres on the plant hormones termed cytokinins and on calcium ions. Cytokinins are intercellular chemical messengers and move through the plant to coordinate cellular development; they can induce cell division (hence their name, which is derived from cytokinesis, the division of the cytoplasm), control orientation of cell expansion, and finally retard cell senescence markedly. Free calcium level, however, is an intracellular controller of development which acts through calcium binding proteins, e.g. calmodulin. All the above four cellular control systems, which are interrelated, are under study using a diversity of techniques—recombinant DNA technology, protein biochemistry, immunocytology, microscopy, tissue culture, and organic chemistry.

Control of Cell Division and Cell Development

The genetic controls of cell assembly, division and development are being investigated to determine essential genes, the nature of their products and how their expression is regulated. The unicellular plant *Chlamydomonas* is being used for the rapid screening of large mutagenised populations to identify genes involved in cell division, because its cycle of cell division can be manipulated to study the temporal pattern of expression in these genes. The flowering plant *Arabidopsis* is being used to identify and study genes that are important in the development and proliferation of cells making multicellular tissues, especially of the root.

i Control mechanisms

Investigators: Peter John, Jeremy Carmichael, John Harper, Frank Sek, Janet Elliott, David McCurdy, Suchirat Sakuanrungsirikul

In this project we are investigating genes that regulate cell division in plants. Particular attention has been focused on conserved genes that function at the 'start division' control in late G1. Our analysis of division control in *Chlamydomonas* indicated that control points operate in plants at the start of cell division and later at the initiation of mitosis in G2. We have identified the protein product of a key 'start' gene in plants by detection of epitopes in common with the equivalent yeast and human proteins. This protein kinase enzyme is potentially regulated by phosphorylation. We have observed changes in the amount of the protein and in the extent of its phosphorylation that correlate with a potential role at the start of division and in the control of mitosis. In multicellular plants we have observed changes in amount that correlate with the incidence of cell division in the tissue. The gene has been cloned from expression libraries of plant genes and sequences are being obtained from *Chlamydomonas* nuclear and cDNA and from *Arabidopsis* nuclear DNA copies. Acquisition of these genes is an important step in one of our long term objectives; the manipulation of plant cell proliferation. Transfer of division control genes between other taxonomic groups has indicated that regulation is impaired, so that use of the plant genes will be necessary.

The spatial and temporal controls that integrate the component events of plant cell division are being investigated by genetic inactivation of single proteins. This form of analysis, only possible in plants by virtue of the conditional cell division mutants which we have isolated, reveals those earlier events that must be completed to trigger later events in division. We have developed methods for the study of the very large cells that result when division is blocked but growth continues and in which we can detect, by immunofluorescence and electron microscopy, the deployment of key components of the cytoskeleton. We have detected that separate sequences of events can proceed in parallel after the 'start division' trigger in late G1 and we are building up a picture of how these interrelate and culminate in division.

We are identifying signal molecules that can trigger the initiation and termination of some of the many processes that lead to division. A selection method has been developed that has yielded mutants defective in normal cyclic AMP metabolism and able to divide only when their endogenous cyclic AMP is supplemented. The nature of events dependent upon this signal molecule and its biochemical mode of action are being investigated and we focus particular attention on mitotic controls.

ii Genetics of cell division in roots

Investigators: Peter John, Rosslyn Hoggart, Brian Gunning, Kim Ballantyne

Genetic analysis of the flowering plant *Arabidopsis* allows us to study how cell division is regulated during the formation of the numerous tissues that determine the structure and function of the root.

One strategy has been to identify previously unknown genes by their effects when mutagenised and obtained in homozygous form by selfing. We have begun to characterise mutations that affect cell division by comparing them with the effects of interrupting cell division by radiation. Another approach is to introduce known genes that may regulate cell division.

Cellular and Molecular Studies of Morphogenesis and the Plant Cytoskeleton

Morphogenesis and cytoskeletal function are being studied using cellular, molecular and genetic approaches. Several major advances have been made during 1988: plant myosin, the motor for actin-based motility, has been localized, partially purified and its gene is being cloned; mutants of *Arabidopsis* have been generated that have temperature-sensitive defects in the microtubule-based processes that determine cell shape, proteins have been purified that bind to microtubules, a new arrangement of actin related to determination of the plane of cell division has been discovered; several studies of the origin and development of microtubules using herbicide-induced depolymerisation have been completed; and we have established that in tissue cultures which are unable to regenerate into plants, there is a correlated loss of capacity of dividing cells to make preprophase bands of microtubules—a cytoskeletal structure that predicts where plant cells will divide.

i Myosin and cytoplasmic streaming

Investigators: Franz Grolig[#], Lin Qiao, Peter Jablonsky, Jacek Plazinski, Richard Williamson and Ursula Hurley

Myosin is a widely distributed actin-activated ATPase generating movement in cells as diverse as muscles, amoebae and algae. A monoclonal antibody raised to a mouse myosin heavy chain detects myosin in lower and higher plants. The giant internodal cells of the alga *Chara* contain two immunoreactive bands that may represent members of the myosin I and myosin II categories. These myosins are associated with organelles in the streaming endoplasm but not the stationary cortical cytoplasm, strengthening the longstanding hypothesis that myosin-coated organelles move along stationary bundles of actin filaments. To characterise plant myosins fully and examine the mechanism for their postulated regulation by Ca^{2+}, we are purifying myosin from mung beans and cloning genes for its heavy chain from *Arabidopsis thaliana*.

ii Experimental and genetic studies of microtubules and cell shape control

Investigators: Rosslyn Hoggart, Geoffrey Wasteneys, Kim Ballantyne, Richard Williamson, Peter Jablonsky

We are studying one of the most characteristic and important features of plant growth—the ability of cells to grow as long cylinders. Transversely aligned microtubules beneath the plasma membrane align cellulose microfibrils outside the membrane which in turn determines the shape into which the cell expands. Without aligned microtubules, the cells swell into spheres, and roots and shoots cannot elongate towards nutrients and light.

Internodal cells of the alga *Nitella tasmanica* provide unusually favourable material for cell biological studies of these processes. The reassembly of microtubules is favoured in localised areas so that branching clusters of microtubules are generated. While the first microtubules to reassemble are transversely oriented, those subsequently assembled are not. Only when net microtubule assembly is complete is their transverse alignment progressively effected.

Such experimental analysis of the processes that determine cell shape in *Nitella* is now being supplemented by molecular analysis of the factors determining cell shape in roots of the flowering plant *Arabidopsis thaliana*. Just as in *Nitella*, disassembly of cortical microtubules causes the normally cylindrical cells of the root to swell. We have selected mutants of *Arabidopsis* that show cell swelling at elevated temperatures. These temperature-sensitive mutants are being characterised to determine whether the mutations affect microtubules directly or disrupt the steps that precede or follow their participation in cell shape determination.

The definition of cell shape is only one of the range of functions of microtubules. Their versatility probably depends on the ability of various proteins to associate with microtubules and endow them with the specialised properties required for each function. We have purified a 33,000 M_r protein from mung beans that binds to microtubules. It also binds to immobilised tubulin dimers through the same part of the tubulin monomers as various well characterised microtubule-associated proteins from mammalian cells. The protein's effects on microtubules and its location in plant cells are being studied.

iii Cellular and molecular analysis of regulation by Ca^{2+}

Investigators: Jacek Plazinski, Peter Jablonsky, Rosali Fabricius#, Ursula Hurley, Richard Williamson

Many cytoskeletal and developmental events in plant cells are regulated by changes in the concentration of free Ca^{2+} in the cytoplasm. Proteins that specifically bind Ca^{2+} at the relevant concentrations are the first stage in transducing those concentration changes into physiological effects. Calmodulin is well established as a mediator of Ca^{2+} regulation. We have detected it in *Arabidopsis thaliana* using monoclonal antibodies and are cloning it from an *Arabidopsis* gene library. Because calmodulin may be only one of many Ca^{2+}-binding proteins, we have fractionated mung bean extracts to identify and purify further proteins with Ca^{2+}-binding activity. There is strong binding activity in partially purified fractions that lack immunologically detectable calmodulin.

iv The cytoskeleton and cell division

Investigators: Janet Gorst, David McCurdy, Margaret Sammut, Brian Gunning, Mary Webb, Cathy Busby, Mark Clements, Bruce Knox+

When plants make new organs or extend roots and shoots they generally regulate where they insert new cells among the existing ones. Previous Annual Reports have documented our work on the preprophase band of microtubules, a cytoskeletal structure which arises inside cells before division and predicts where they will divide. We have now been able to prove by optimised methods for double labelling dividing cells with antibodies to actin and tubulin that when the microtubule system of the cell makes a preprophase band, the internal actin cytoskeleton breaks down and takes up the form of a previously undetected array of cortical actin, oriented parallel to the preprophase band microtubules. Thus the preparations for cell division involve both the actin and microtubule components of the cytoskeleton.

The importance of these spatial controls is highlighted by our work on regeneration of whole plants from tissue cultures. Many tissue cultures are unable to form the

meristems that are necessary for regeneration *via* shoot or embryo formation. This is a major limitation in plant biotechnology. We have established a correlation between lack of morphogenetic capacity and loss of the ability to make preprophase bands in tissue culture conditions. Regenerative species retain their preprophase band system throughout all of the cell divisions leading to callus formation on an explant. We have isolated cultures which regenerate that have preprophase bands during division, and others that lack them and do not regenerate. We are proceeding to compare their cytoskeletons in detail.

Orientation of cell division is especially important in meiosis, where two successive divisions separate homologous chromosomes into four haploid sets. Using spore mother cells of the moss *Funaria* as a model, we have worked out how the microtubule cytoskeleton forms a tetrahedral cage which defines four poles, the ultimate destinations of the four products of meiosis. Video recordings of experiments with the anti-microtubule drug oryzalin confirm that the microtubules do indeed provide spatial guidance.

Very little is known about the mode of development of the female reproductive tissue of flowering plants—the megaspore mother cell and the embryo sac. We have developed methods for isolating and immunolabelling these vital cells from *Arabidopsis*, which turns out not to have the 'textbook' (linear tetrad) mode of megaspore development. Its actin and microtubule systems clearly play important roles in positioning nuclei and cells during embryo sac formation. A related study of orchid reproductive tissues has begun, in collaboration with staff of the Australian National Botanic Gardens.

v Microtubular cytoskeleton in developing stomata

Investigators: Adrienne Hardham, Ann Cleary

We have combined immunofluorescence microscopy and cryosectioning to establish an effective method of studying microtubule arrays in developing stomatal cells. The technique allows all microtubule arrays to be observed in cells of known cell type and stage of development and in the context of those in neighbouring cells. This ability to observe microtubule organisation *in situ* has been lacking from most previous studies and is vital for analyses of cytoskeletal involvement in plant morphogenetic events where adjacent cells are closely coordinated. We have built up a detailed understanding of microtubule organisation in developing stomatal cells of *Lolium* and are studying the effects of loss of microtubules in this system.

The Cell Surface as Mediator of Intercellular Interactions

Investigators: Adrienne Hardham, Frank Gubler, Geoffrey Hyde, Jadwiga Duniec, Janet Elliott and Jacinta Kelly

Molecules on the surface of cells are key mediators in intercellular interactions and in determining cellular responses to changing environmental conditions. Our main research project identifies and characterises cell surface molecules involved in the infection of plants by the pathogenic dieback fungus, *Phytophthora cinnamomi*. This year we have characterised the adhesive properties of material secreted by the fungus early in infection. It bonds the fungal cells firmly to the plant surface and prevents their removal prior to invasion of the plant. We have discovered that adhesion is non-specific in that the cells can stick to a variety of surfaces, and that it is dependent on the presence of divalent cations. We have also found that if the fungal cells are not adjacent to the root when the adhesive is released, then they rapidly (within 2 minutes) lose their ability to adhere.

In addition we have begun a collaborative project with Dr J.V. Jacobsen of the CSIRO in which we will attempt to identify cell surface receptors for the phytohormones gibberellic acid and abscisic acid on the surface of barley aleurone protoplasts. In this well-studied system, biochemical responses to hormone induction have already been characterised but we still have little understanding of hormone recognition or signal transduction.

The Control of Plant Development by Cytokinins and other Regulatory Compounds

Investigators: D.S. Letham, C.W. Parker, D.A. Willcocks, S.A. McKinney, Xue-Dong Zhang, Jian Wang, L.M.S. Palni[#]

Studies of cytokinin translocation and metabolism in relation to plant development and leaf senescence were continued. In work at the cellular level, procedures for detecting cytokinin receptors progressed and in a collaborative project with Plant Industry (CSIRO), the cytokinin biosynthesis gene was transferred from bacteria *(Agrobacterium tumefaciens)* to tobacco leaf tissue. This single gene transfer had marked effects on cell growth, differentiation and hormone levels. The resulting tissue constitutes a novel system to study hormonal control of cell growth. Selected significant areas of work are discussed below.

The first is an extension of earlier work concerning cytokinin translocation in lupin plants in which unknown nucleotide-like metabolites were detected. These are considered to be important in uptake of cytokinins by cells and in movement from cell to cell. During the year, two such metabolites were purified, identified by mass spectrometry and other methods, and synthesized chemically. These compounds were *O*-acetyl-9-β-D-ribofuranosylzeatin 5'-monophosphate and the corresponding derivative of dihydrozeatin. They represent a new group of potentially important cytokinin derivatives. Chromatographic studies indicate that the corresponding ribosides also occur in lupin and their formation in daffodil bulbs is promoted markedly by chilling. Hence they appear to be novel and ubiquitous cytokinins. The acetyl moiety in these compounds is unstable and is cleaved under conditions normally used for cytokinin purification. This may explain why these metabolites have not been recognised earlier.

Considerable circumstantial evidence indicates that root-produced cytokinin moves in the xylem to control shoot development and especially leaf senescence. However, one key piece of evidence to support this concept has remained elusive because of technical problems associated with cytokinin quantification in xylem sap. Thus it has never been established whether changes in cytokinin level actually occur in sap over the range which would evoke a physiological response. By measuring cytokinin levels in sap of intact and depodded soybean plants at various stages of development, and then supplying the endogenous cytokinins to soybean explants which mimic the intact plant as far as senescence is concerned, it was possible to show, for the first time, that the changes in cytokinin level occurring *in vivo* are sufficient to affect the onset of leaf senescence markedly.

Caffeine, a common purine which is related structurally to cytokinins is an effective inhibitor of new cell wall formation during cell division. Competitive inhibition of cytokinin function is a possible mechanism of action of caffeine. However, in collaborative work with Y. Mineyuki (former Visiting Fellow), this hypothesis was invalidated; the effect of caffeine was alleviated by guanosine but not by cytokinin or related purines. A study of the inhibition of wall formation by various methyl xanthines indicated that the 3-methyl group was a key structural feature for effective inhibition of wall formation. Accordingly, a series of new 3-substituted 1,7-dimethylxanthines, synthesized in this laboratory, were tested for inhibition of cell wall formation during cell division. Certain of these, e.g. 1,7-dimethyl-3-(3-methylbutyl)xanthine, were markedly more effective than caffeine and provide new probes for study of mechanism of cell wall deposition during division.

3-substituted xanthines with a substituent which resembles the N^6-side chain of cytokinins inhibit cytokinin metabolism and one such compound, as a consequence, enhanced the senescence retarding activity of cytokinin when applied to soybean leaves. Use of chemicals to enhance the action of cytokinin represents a new approach to the control of leaf senescence.

Hormonal Control of Differentiation in Plant Tissues

Investigators: Pamela Warren Wilson[#], John Warren Wilson[†] and Robyn Overall[*]

In seeking to discover fundamental processes underlying the control by growth regulators of the spatial patterns of differentiation and polarity in tissues we have successfully exploited the sterile culturing of lettuce pith explants, which have initially neither vascularisation nor apparent polarity. Local application of auxin (IAA) has induced polarisation as indicated by the orientation of differentiating tracheary elements. Substantially preceding their differentiation there is a reversal of ionic currents such that positive currents enter at the site of auxin application—perhaps the first sign of polarisation. Another study has shown, for the first time, that tracheary element differentiation can be induced by any one of four IAA-amino acid conjugates in place of auxin. Optimal concentrations of conjugates are an order of magnitude greater than for auxin and this would accord with their acting as slow release sources of auxin.

These experiments, and others on the response of lettuce pith to temperature, have revealed marked effects on size and shape of differentiating tracheary elements. Under adverse conditions there is a preponderance of large tracheary elements which appear to result from differentiation without division.

The Biology of *Azolla-Anabaena*

Investigators: Jacek Plazinski, Rona Taylor, Lynn Croft, Qi Zhang[#], Barry Rolfe and Brian Gunning

This project concerns the basic biology of the N_2-fixing symbiotic association between the aquatic fern *Azolla* and cyanobacterium *Anabaena azollae*. It is a collaboration between RSBS and the National Azolla Research Center (NARC) in Fuzhou, People's Republic of China.

We have developed a reliable system for classifying varieties of the symbiotic cyanobacterium *Anabaena azollae* by using molecular probes isolated from plasmids found in the symbionts. The plasmid size and number vary from isolate to isolate of *Azolla-Anabaena* and clones have been obtained and used to identify more than 20 different DNA genotypes of the symbiont. Host plants can be identified by a similar procedure. Our Chinese colleagues have developed methods for making new *Azolla-Anabaena* combinations, not found in Nature. Our 'fingerprinting' techniques have given rigorous proof of the success of their methods, which now open the way for agronomic exploitation of recombinant symbiotic associations.

PLANT MOLECULAR BIOLOGY

Introduction

Three main areas of plant molecular biology are studied in the School.

One is a study of the ways that plants interact with microbes. There are probably only a limited number of ways in which plants react to invaders. By studying and comparing the responses induced by different microbes, it is possible to distinguish between the basic pathways of plant response, and those factors that modulate responses to individual microbial pathogens and symbionts. Our research is of great practical importance as it leads to the design of strategies not only for controlling plant pathogens, but also for fostering beneficial plant-microbe relations.

The second project area studies the molecular biology of fungi and is reported here even though there is increasing evidence that fungi are more closely linked to animals than to plants. Studies are being made of the regulation of transcription in *Neurospora*, of molecular factors influencing the inheritance of mitochondria in yeasts, and of the relationship between the structure and function of alcohol dehydrogenase.

A third avenue analyses the molecular basis of plant performance, especially photosynthetic performance using both nuclear and chloroplast genes from a variety of plants and cyanobacteria (whose genetics resemble those of chloroplasts). Some aspects of this program are concerned with the initial steps of CO_2 uptake and fixation, others with the regulation of and possibilities for manipulating chloroplast genes. Yet others exploit the convenient genetics and rapid life cycle of the plant, *Arabidopsis thaliana*, as a tool for studying the coordination between photosynthesis and growth and its relationship to the efficiency of water use. (See separate entry in the section on MOLECULAR ANALYSIS OF PLANT PERFORMANCE).

Interactions with Microbes

i Molecular Analysis of Bacterium-Plant Interactions

Investigators: Barry Rolfe, Michael Djordjevic, Jeremy Weinman, Steven Djordjevic, Greg Bender, Murali Nayudu, Lucy Sargent, Jim Gray, Wendy Lewis, Tony Arioli, Kate Le Strange, Jan McIver, Elena Gartner, Marie Oakes, Jerry Johnson[§], Petra Gross[§], Yuan Dacheng[§], Paul Howles.

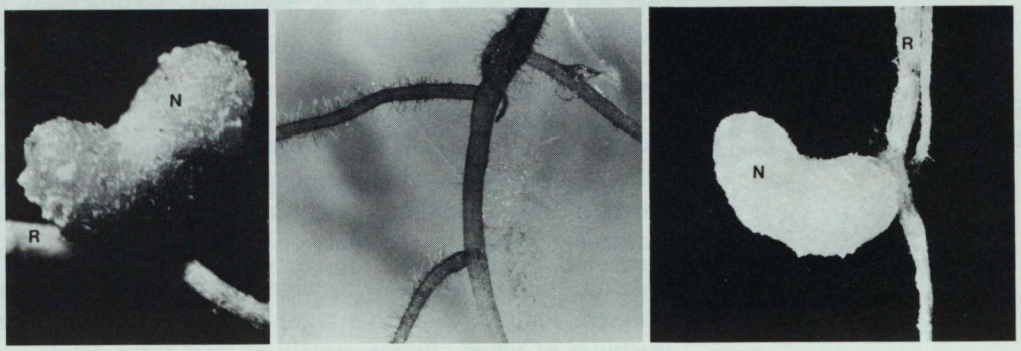
Identification of *Rhizobium nod* genes

There are twelve (*nod*) genes involved in clover nodulation. They are clustered on a 14kb DNA fragment of the Sym plasmid of the clover infecting *Rhizobium trifolii* strain ANU843 and are arranged as four separate operons (*nodABCIJO, nodD, nodFERL* and *nodMN*).

The expression of these genes is mediated through the product of the *nodD* gene and through the interaction of *nodD* product with plant-secreted inducer and anti-inducer compounds. The expression of the *nodD* gene is also autoregulated by NodD.

RHIZOBIUM TRIFOLII NODD GENE

The host specificity of the bacterium *Rhizobium trifolii* is such that it will only form nitrogen-fixing nodules on clover plants and no other legumes. This high degree of specificity can be altered by changing a single gene called *nodD*. The figures illustrate the extension of the host range of *R. trifolii* from clover (left) to *Parasponia*, a member of the Elm family which is not related to legumes (centre—no nodulation by *Rhizobium* with unaltered *nodD* gene; right—nodulation by *Rhizobium* with altered *nodD* gene).



Rhizobium trifolii nodD gene

We have mutagenized the *nodD* gene of *Rhizobium* strain ANU843 with nitrosoguanidine and have found that the ability of the mutated *nodD* products to interact with inducer and anti-inducer compounds is determined by the amino acid sequence in at least several key regions of *NodD*. Four distinct classes of mutants were recognized by phenotypic and molecular analysis of the mutant *nodD* genes. Class 1 and 4 mutants were able to induce *nodA* expression independently of the addition of inducer compounds and were unable to mediate autoregulation of the *nodD*. Class 2 and 3 mutants retained several properties of the wild type *nodD* including the ability to interact with inducer and anti-inducer compounds and the capacity to autoregulate *nodD* expression. Class 2 mutants, however, showed an inducer independent ability to mediate *nodA* expression to levels ten fold higher than levels of control strains. The class 3 mutant showed reactivity to compounds (chrysin and quercetin) which exerted little or no inducing effect on the wild-type *nodD*. DNA sequence analysis showed that single base changes were responsible for the altered phenotypic properties in the five mutants examined. The most important observation was that mutants of *nodD* possessing inducer independent ability to activate *nod* gene expression (class 1, 2 and 4), could extend the host range of *R. trifolii* to the non legume *Parasponia*.

R. trifolii host specific nodulation (*hsn*) genes

It has been known for some time that rhizobia show a distinct host specificity for the legume roots they can infect. The molecular basis of this specificity is still unknown. However, our genetic analysis argues that host specific nodulation (*hsn*) of *Rhizobium* strains involves cell-to-cell recognition phenomena and may involve plant defense systems.

The nodulation of legumes by *Rhizobium* strains provides a good model system in which to study the bacterial genes involved in subverting plant defense mechanisms and setting up what can be viewed as a acompatible parasitic infection. Encoded in a 14kb *Hind*III DNA fragment of the symbiotic plasmid of *R. trifolii* are both genes that are common nodulation genes, *nodABCDIJO*, and genes that confer host specificity to this bacterium. These genes, *nodFELMN*, and a translated open reading frame which we propose to designate *nodR*, determine the nature of the legume host that can be infected and act as dominant, positive gene functions. Mutations in *nodFERL* are compensated by the presence of *nod M & N* genes.

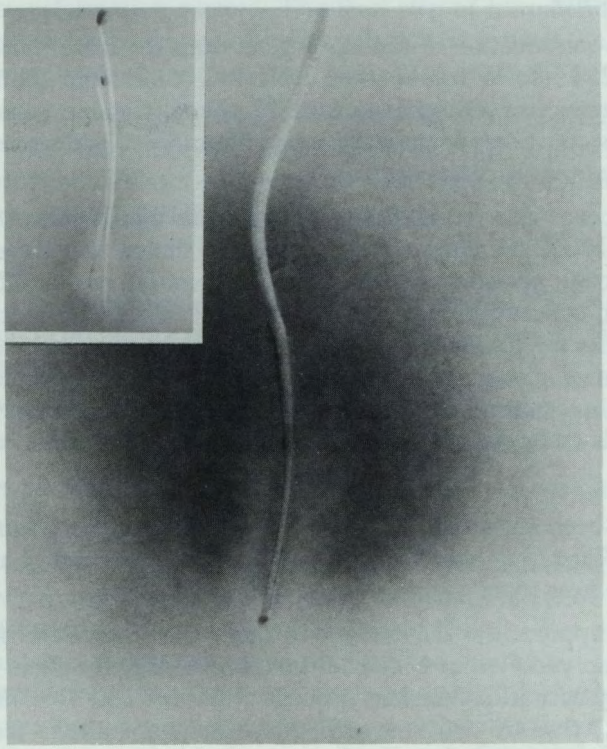
Phenolic compounds secreted by legumes

The construction of specific transcriptional and translational fusions of *Rhizobium nod* genes to the *E. coli lac* operon has helped demonstrate *nod* gene promoter activity using a simple β-galactosidase assay. In addition, these fusions have proved to be powerful assays for the demonstration of factors (intermediates in the phenylpropanoid pathway) secreted by the roots of plants.

Application of the assay to white clover seedlings shows that these compounds are released from the roots in a regulated manner from distinct locations. The root washings of white clovers contain at least three active flavonoid compounds which stimulate *nod* gene expression in *Rhizobium leguminosarum* biovar *trifolii*. The most potent inducer was 7,4'-dihydroxy flavone (DHF) which was active at concentrations as low as 50 nM and stimulated *nod* gene expression within minutes of exposure.

Other compounds present in root washings of clovers (formononetin and umbelliferone), act as anti-inducers of *nod* gene expression. *In vitro* experiments showed that the activation of the *nod* genes was determined by the ratio of inducers to anti-inducers. The amount and site of release of inducer and anti-inducer compounds vary over the developing root. At least a 10 fold concentration excess of the most potent anti-inducer is required to titrate inducer molecules secreted from plant cells near the root tip. The cells behind the root tip have been shown to be the most

susceptible to infection, so it is probably not a coincidence that this constitutes the major site of the release of stimulatory compounds in clovers and other legumes.



NEW BIOASSAY FOR *NODD* GENE EXPRESSION IN *R. TRIFOLLI*

Demonstration of stimulatory and inhibitory compounds released from the root tips of white clovers. This bioassay of nodulation (*nod*) gene expression in *Rhizobium trifolii* detects stimulatory (dark zone) and inhibitory (clear zone) compounds which induce or repress reporter gene (*nodA218:lac* fusion) expression in the bacteria. The gene expression is indicated by the cleavage of a colourless dye which is incorporated in the soft agar overlay surrounding the root tip (cleaved dye goes blue—indicated by the dark zone in the photograph). Expression of the reporter gene fusion occurs only in the vicinity of the roots where the release of the stimulatory and inhibitory compounds appears from several distinct zones. The centre of the inhibitor zone is approximately the root tip and for the stimulator the emerging root hair region.

Phenolic compounds induced in white clovers as a result of infection by *Rhizobium* bacteria

Currently we are using a combination of new plant gene probes and chromatography to examine the expression of different steps of the phenylpropanoid pathway as a consequence of *Rhizobium* infection of both clovers. When a *R. leguminosarum* strain (which does not infect white clovers) is used as an inoculum, the flavonoid content of clover rapidly rises to 4 times that seen when *R. trifolii* is exposed to roots. This enhanced level does not decline over a six day period. A similar result is observed when *R. meliloti* or the *nodF* and *nodE* mutants of *R. trifolii* is used as the inoculum strain. *Rhizobium hsn* genes appear to be involved in the induction and/or regulation of the plant phenylpropanoid biosynthetic pathway.

The *nodD* gene and the extension of host range

Parasponia species are the only non-legumes known to form a nitrogen-fixing root nodule symbiosis with either *Rhizobium* or *Bradyrhizobium*. *Parasponia* roots have a zone of infection similar to that found in legumes, however the mode of infection is quite different. Despite the differences found in the mode of infection between *Parasponia* and legumes, the *Rhizobium nodABC* genes and the *nodD* gene are essential.

Rhizobium strain NGR234 has a broad host range which includes *Parasponia*. We have found that the narrow host range of *Rhizobium leguminosarum* biovar *trifolii* strain ANU843 can be extended from clovers to the nonlegume *Parasponia* and tropical legumes by the addition of the *nodD1* gene from the broad host range *Rhizobium* strain NGR234. The presence of the *nodD1* gene from NGR234 enables *nod* gene induction to occur in strain ANU843 following exposure to seedling extracts from *Parasponia* and other nonlegumes that include *Trema* (a tree genus closely related to *Parasponia*), *Casuarina* (a genus that forms symbiotic relationships with the

actinomycete *Frankia*) and the cereals wheat, rice and maize. Although the presence of the *nodD1* gene from NGR234 enables the induction of *nod* genes by a range of non-legume extracts, no nodules were elicited on any nonlegumes other than *Parasponia*.

The introduction of the *nodD* gene from the broad host-range *Rhizobium* strain NGR234 into *R. trifolii* strain ANU843 confers the ability of this strain to respond to the presence of a broad spectrum of phenolic compounds to induce *nod* gene expression. These include flavones, flavanones, isoflavones, coumestans, coumarins and hydroxy benzoic acids.

Soybeans also release several compounds which stimulate *nod* gene expression in the strain NGR234. Analysis by HPLC has shown that these compounds, naringenin (a flavanone), genistein and daidzein (isoflavones), are found in the root and shoot tissue in high concentrations. It is possible that *Rhizobium* species have evolved two strategies for response to plant phenols. Expression of nodulation genes in narrow host-range species requires flavones with specific substituents, while expression in a broad host-range *Rhizobium* can be stimulated by simpler and more widely distributed phenols or by degradation products of more complex substances.

Bacterial cell surface polysaccharides

It has been suggested that EPS has several important functions in the plant-*Rhizobium* symbiosis, including a role in bacterial adhesion to the root surface and in host specificity.

Our approach to the analysis of the role of the cell surface carbohydrates and the infection process has been the isolation of large numbers of non-mucoid exopolysaccharide-deficient mutants from different *Rhizobium* strains. In general, mutants that are deficient in EPS synthesis are able to form fewer nodules on their test plants and they are unable to induce a nitrogen-fixing response. The plant 'appears' to be able to recognize and reject or greatly debilitate infections made by a polysaccharide-defective strain.

We have made three important findings relevant to the long term studies of this program.

First, we have isolated a series of different *Rhizobium* mutants that appear to trigger the host plant's *hypersensitive* reaction, thought to be a major component of the resistance mechanism in plants.

Secondly, in conjunction with Drs John Redmond and Michael Batley (Macquarie University) we have developed methods for rapidly extracting and determining the basic repeating units of the surface exopolysaccharides of rhizobia.

Thirdly, we have found that many of our non-mucoid (Exo^-) mutants cannot form nitrogen-fixing nodules on the roots of their respective legume hosts. However, normal nodulation ability can be restored by the application of specific oligosaccharides isolated from *Rhizobium* cultures to the inoculated plants. Thus it may be possible to affect the expression of plant genes involved in defense mechanisms by the addition of *Rhizobium* polysaccharide molecules.

ii Plant-Fungal Pathogen Recognition

Investigators: Brett Tyler, Wendy Thompson, Sue Moody, Areelak Kashemsanta, Yuxin Mao.

This study was initiated in 1988 to ask how the defence mechanisms of plants recognize invading fungal (or other) pathogens, and how successful pathogens evade that recognition. We have focused on the infection of soybeans by the root rot fungus *Phytophthora megasperma* because of the devastation that *Phytophthora* pathogens cause to agriculture and forestry internationally, and because the biochemistry and physiology of this system has already been studied.

Our major goal has been the establishment of a procedure for introducing cloned

DNA into *Phytophthora megasperma* in order to enable genetic analysis of this organism. So far we have completed two of the three steps towards this goal, namely the identification of appropriate selection conditions and the construction of transformation vectors. The final step of introducing the DNA into the organism is presently underway. We have also characterized the genome of *Phytophthora megasperma*.

In collaboration with Dr Peter Dart (University of Queensland) we (Moody and Tyler) have also used DNA sequence polymorphisms to genetically characterize different isolates of *Aspergillus flavus* and *Aspergillus parasiticus* which cause mycotoxin contamination of peanuts.

iii Molecular Evolution of Plant Viruses

Investigators: Adrian Gibbs, Shou-wei Ding, Jennifer Howe, Paul Keese, Anne Mackenzie, Drew Meek, Pattana Srifah, Marjo Torronen.

The molecular evolution of the tymoviruses is being studied, initially by sequencing and comparing the genomes of several viruses of this group. This information will provide clues about:

- the pattern and rate of evolution of this virus group, and the role of mutational drift and recombination in that evolution;
- the molecular basis of the host ranges and virulence of viruses. and how these traits may be manipulated.

In 1988 the genomic sequences of the Blue Lake isolate of turnip yellow mosaic virus and the Jervis Bay isolate of kennedya yellow mosaic virus were completed and further analyses made of sections of the genomes of other isolates of kennedya yellow mosaic, dulcamara mottle, belladonna mottle and erysimum latent viruses. All genomes show significant similarities, both in nucleotide sequence and in the encoded amino acid sequences. Analyses have shown that a simple, but weak, stem-loop structure probably forms at the 5'-end of the main and overlapping reading frames, and the sequence contributing to this structure is duplicated in ononis yellow mosaic virus (a duplication that is found in all isolates examined). A more complex stem-loop structure probably forms in the genomic region encoding the 5' terminus of the virion protein mRNA; 15 out of 16 nucleotides in a portion of this region are conserved in all tymoviruses examined.

Molecular Biology of Fungi

i Transcriptional Regulation in Eukaryotes

Investigators: Brett Tyler, Yuguang Shi, Jurij Piskur, Karin Harrison

Using the fungus *Neurospora crassa* as a model, this study has focused on the 500 or more key genes which encode ribosomal RNAs and proteins, asking how the transcription of these genes is co-ordinated to provide a balanced supply of ribosomal components in eukaryotes. Previously we have demonstrated that a sequence designated the ribo box is commonly required for transcription of *Neurospora* 5S and 40S ribosomal RNA genes.

In 1988, we set out to test whether ribosomal protein genes from *Neurospora* also required ribo boxes for transcription. We cloned, sequenced and characterized the transcription of a *Neurospora* ribosomal protein gene (designated *crp*-2), and found that indeed the promoter region of the gene contained three ribo boxes. The results clearly demonstrate for the first time in a eukaryote a mechanism by which the transcription of different sets of ribosomal RNA protein genes could be directly co-ordinated.

A genetic analysis of the function of mitochondrial intergenic sequences in yeast has also been carried out (Piskur). Yeast mitochondrial DNAs lacking intergenic sequences and marked by specific antibiotic resistance mutations have been constructed and used to study the inheritance of the mitochondrial genome. It has been shown that the presence of intergenic sequences increases the transmission capacity of the genome. Thus, selection discriminating between various molecules operates during transmission to the progeny.

ii Protein Engineering

Investigators: E.H. Creaser, C. Murali and K. Britt

Protein engineering can change the structure of proteins in a predictable manner by altering the nucleotide sequences in their structural genes. This technology is of fundamental importance, both for the elucidation of structure and function relationships in proteins and in biotechnology where enzymes play an increasingly important role in the catalysis of commercial processes. Alcohol dehydrogenases are very suitable enzymes for this type of investigation. The 3-D structure of the enzyme from horse liver has been determined by X-ray crystallography; it is possible to deduce the structure of other members of this homologous family. One of the most interesting features of ADH enzymes is the wide variation in their activity profiles towards different substrates. This variation is most noticeably expressed in the size of the alcohol molecules which can be metabolised. At one extreme, horse ADH attacks a wide variety of large and small alcohols; at another, yeast ADH is virtually restricted to ethyl alcohol. To determine the structural basis for this restriction we are changing the active site of yeast ADH by protein engineering to enable it to oxidise larger molecules.

The active site of alcohol dehydrogenase is at the bottom of a deep hydrophobic pocket. Comparative protein chemistry has shown that the amino acids in different ADH molecules vary in three areas: Firstly in close proximity to the active centre; secondly in the throat of the pocket; lastly, at the mouth of the pocket where the substrates must first enter. We have shown that the double amino acid change in the active site area [48 thr to ser and 93 trp to phe] produces an enzyme that has enhanced activity towards alcohols larger than ethanol. However, this improved catalytic activity is not of sufficient magnitude to enable the new enzyme to oxidise large alcohols such as benzyl alcohol and cyclohexanol. We think that amino acids in the walls of the substrate pocket are hindering access of such large molecules. This year we have investigated the effects of changing amino acids in the throat of the pocket as well as those of single changes in the active site area.

Our results to date show that changing amino acids which are close to the active site has the greatest effect on modifying the substrate activity profile whereas altering those in the throat of the pocket has little significant effect. None of our engineered mutants gained the ability to oxidise benzyl alcohol or cyclohexanol. We must investigate other aspects of the ADH protein structure if we mean to solve the problem of how substrate specificity relates to the sizes of target molecules.

iii Genes and Enzymes of Alcohol Metabolism in *Aspergillus*

Investigators: T.L. Cross, E.H. Creaser

In *Aspergillus*, ethanol is metabolised by alcohol dehydrogenase and acetaldehyde dehydrogenase. The formation of these two structural genes is controlled by the regulatory gene *alcR*. We are investigating the molecular mechanisms involved in this control. Preliminary observations showed last year that the *alcR* protein may have structural zinc fingers which could possibly bind DNA and control transcription. Several lines of enquiry are under way; we have cloned the *alcR* gene onto an expression vector so that it can be used for *in vitro* protein synthesis and also for protein engineering.

We intend to engineer the control protein to study DNA and effector binding and have already constructed the appropriate oligonucleotides. We have also found an *alcR* mutant whose growth on alcohol is increased in the presence of excess zinc salts, indicating a possible alteration of zinc binding by zinc fingers. A second gene in the *alcR* region has been subcloned and is now being sequenced.

Biological Information Systems

Computerised data banks; sedges, legumes and angiosperm families

Investigators: L. Watson, M.J. Dallwitz +, M. Henwood, J. Lenz and S. Perry.

In a project commenced in 1970, we have developed a computerised data bank of morphological, anatomical, physiological, cytological and geographical information on grasses, which now incorporates data on over 400 characters, recorded for 764 genera. Significant additions and improvements in 1988 included incorporation of extensive data on rust and smut host ranges, cytology and 2C DNA values. The observations are encoded in a format that permits uses ranging from information retrieval and correlation-seeking to classification, automated generation of printed descriptions and keys, and interactive identification. The system is linked directly with automatic typesetting and microfiche generation, and most operations (notably interactive identification) can now be done on microcomputers. The descriptions currently are being used for continuing studies of grass classification and for preparing an account of the grasses of Southern Africa, for which the data are being extended to species level (in collaboration with Dr. G.E. Gibbs Russell).

Highlights of 1988 have been the generation of a book with descriptions, keys and a classification, 'Grass Genera of Greece' (in collaboration with M. Damanakis); and the issue of 'Grass Genera of the World', comprising printed illustrations, 4 microfiches with complete generic descriptions, and floppy disks carrying the data in a form permitting interactive identification and information retrieval using MS-DOS microcomputers.

Work commenced in 1988 on automated leaf anatomical and physiological descriptions of the species of Australian grasses, which will be appended to automated floristic treatments already completed here (Paniceae) and in preparation (Pooideae: commenced August 1988, funded by the Australian Bureau of Flora and Fauna). In addition, a complete operational data base for the 177 genera of Leguminosae-Caesalpinoideae is being maintained; another for the families of Angiosperms (which now contain a complete, automated classification) is being developed as time permits; and one for the genera of Cyperaceae, nearing completion, provides background for a study of the taxonomy of sedges with special reference to variation in photosynthetic pathways.

Systematic studies of plant structure and function

Investigators: V. Amarasinghe, J. Bruhl, and L. Watson

A long term interest of the Taxonomy Laboratory is trying to enhance understanding of plant structure/function relationships, by application of taxonomic expertise; and conversely, to extend taxonomic knowledge by feeding back the new insights obtained. 1988 saw publication of the discovery in Cyperaceae of a new C_4 anatomical type, along with demonstration of previously unsuspected C_3/C_4 variation within the genus *Eleacharis*; and publication of the first in a series of articles arising from an ultrastructural/functional study of grass microhairs. The latter have previously been described indiscriminately as 'salt glands', but our studies have demonstrated, (a) that most of them do not secrete salt, and (b) that all of them—including those which secrete salt—secrete protein and polysaccharide (or glycoprotein). Thus the ecological and economic significance of these taxonomically useful structures is probably greater than was previously supposed.

The Virus Identification Data Exchange (VIDE) Project: A databank for plant viruses

Investigators: Adrian Gibbs, Alan Brunt, Cornelia Buchen-Osmond, Karen Crabtree and George McLean

The VIDE project, which involves the editors listed, is compiling a database of all information of value for the identification for all the plant viruses of the world.

We use the DELTA taxonomic database system devised and maintained by Dr Mike Dallwitz of the C.S.I.R.O. Division of Entomology. During the year work has concentrated on collation of information on viruses identified in Australia and these data have been published. Work has continued on compiling data on viruses of legumes, and viruses of tropical crop plants. The main database now contains detailed information for over 400 viruses. An INTKEY (interactive key) version of the 'virus groups' database for use in IBM compatible PCs has also been completed.

MOLECULAR ANALYSIS OF PLANT PERFORMANCE

Introduction

Investigators: John Andrews, Murray Badger, Anne Gallagher, Heather Kane, Josette Masle, Matthew Morell, Dean Price, Kam Chau Woo.

A number of Groups in RSBS, including Plant Cell Biology, Plant Environmental Biology and Plant Molecular Biology, are using molecular biological techniques to try to understand and improve plant performance response to environmental stress or disease. Because of the close interaction of the work of the Plant Environmental and Molecular Biology Groups in this area, details of research projects are reported in this separate section for convenience. However, publications, staff listings, etc. appear under the relevant Group. Details of the work carried out in the Plant Cell Biology Group are found under that Group.

In the Plant Environmental and Plant Molecular Biology Groups, the work has focussed on the initial stages of photosynthetic uptake and fixation of CO_2. Much of the efficiency of photosynthesis, in terms of its use of light, water and other nutrients, is determined at these initial stages. Biochemical and molecular genetic approaches have been used to study the preliminary acquisition of inorganic carbon from the environment (which is particularly well developed in cyanobacteria) and its actual fixation into organic compounds by the enzyme, ribulose bisphosphate carboxylase-oxygenase (Rubisco). In conjunction with these studies, preliminary assessments have been commenced of possible approaches for manipulation of the prokaryote-like genome of the photosynthetic organelle, the chloroplast, and for obtaining *Arabidopsis* mutants which reveal the coordination between photosynthesis and growth.

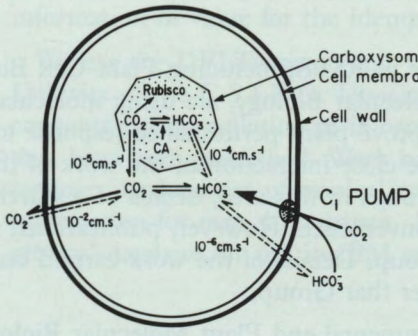
CO_2 Concentrating Mechanism in Cyanobacteria

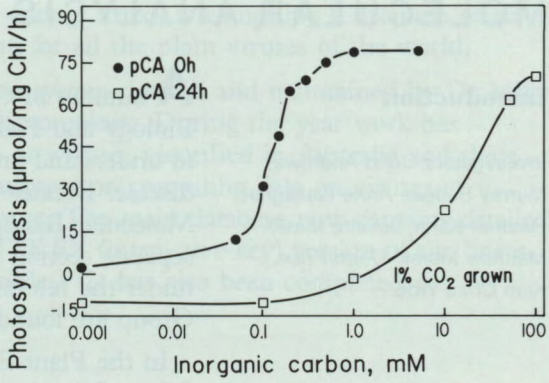
Work has continued on characterizing the high-CO_2 requiring mutants of *Synechococcus* PCC7942 that were reported last year (Badger, Price). All 24 mutants were able to accumulate inorganic carbon (C_i) to levels similar to or higher than wild-type cells, but were apparently unable to generate CO_2 intracellularly from this pool. On the basis of a number of physiological analyses, two distinct types of mutants were identified together with a number of possible intermediates between these two phenotypes. The characteristics of Type I mutants appear to be consistent with a scenario where carboxysomal carbonic anhydrase (CA) activity has been shifted from a carboxysomal to a cytoplasmic location. This leads to an inability to concentrate CO_2 in the carboxysome and an increased efflux of CO_2 from the cytosolic C_i pool. The nature of the Type II mutant is less clear. Some physiological measurements appear to be consistent with the total absence of CA from the cell, but enzymatic assays reveal relatively normal levels of CA. More work will be necessary to identify the primary lesions in both types of mutants.

We have been able to express the human carbonic anhydrase gene (HCAII) in *Synechococcus* PCC7942 by means of an expression vector which functions in both *Synechococcus* and *Escherichia coli* and have achieved a level of expression of around 0.3% of total cell protein (Badger, Price, Kirby). The expression of this CA activity, presumably in the cytosol, has dramatic effects on the photosynthetic physiology of the cell, leading to inability to grow at low levels of external C_i. In addition, the effects of this expressed CA can be largely reversed by specific inhibition with the CA inhibitor, ethoxyzolamide. As a result of these findings, we are able to conclude that the operation of the CO_2 concentrating mechanism is dependent upon: (1) the absence of CA activity from the cytosol and (2) the specific localization of endogenous CA activity in the carboxysome. A theoretical model of photosynthesis and C_i accumulation has been developed, in which the carboxysome plays a central role as both the site of CO_2 generation from HCO_3^- and the resistance barrier to CO_2 diffusion out of the cell. There is good agreement between this model and the physiological effects of CA expressed in the cytosol of *Synechococcus* cells.

CO_2 CONCENTRATING MECHANISM IN CYANOBACTERIA

Evidence for the carboxysome model of the CO_2 concentrating mechanism in cyanobacteria, showing the theoretical role of carbonic anhydrase (CA) (left) and the effect on photosynthesis of expressing a foreign CA in the cytosol of *Synechococcus* PCC7942 cells.





Molecular and Biochemical Analysis of Rubisco

Rubisco catalyzes the primary incorporation of CO_2 into organic matter. Understanding of Rubisco's structure and mechanism at the molecular level has highlighted apparent gross inefficiencies in its catalytic specificity and throughput which may reflect very slow evolutionary progress or may indicate that there are unrecognised mechanistic constraints preventing further refinement. The following group of related projects conducted this year are part of an on-going program of assessment of the prospects of engineering improvements in Rubisco.

Cyanobacterial Rubiscos resemble the higher-plant enzyme and have the advantage that their large and small subunit genes may be expressed in *Escherichia coli* to produce the correctly-assembled and fully catalytically active L_8S_8 enzyme (Andrews, Ross). Studies last year showed that, when the gene for the small subunit was omitted, the large subunits still assembled into L_8 octamers which were about 1/100th as active as the complete enzyme. This year, this project was completed with a characterisation of structural and solubility aspects of the L_8 complex.

C_4 Rubiscos have poorer affinities for CO_2, but faster rates of catalytic throughput at saturating CO_2, than their C_3 counterparts and this is a cornerstone of C_4 photosynthetic metabolism, enabling an approximately 50% reduction in the amount of nitrogen devoted to Rubisco, which greatly benefits the nitrogen use efficiency of C_4 plants. To study the molecular basis of this adaptation, the sequences of the Rubisco large subunit genes have been determined for a pair of closely related species, one C_4 and one C_3, from each of three genera containing both C_3 and C_4 species. *Neurachne* (*N.tenufolia* and *N.munroi*) and *Flaveria* (*F.pringlei* and *F.trinervia*) were sequenced last year and the project was completed this year with *Atriplex* (*A.patula* and *A.rosea*) (Hudson$^+$, Mahon$^+$, Anderson$^+$, Gibbs$^+$, Badger, Andrews, Whitfeld$^+$). Differences in the inferred amino acid sequences are few and conservative, ranging from three in *Flaveria* to six in *Neurachne*. Only one substitution is common to all three pairs and this provides a clue about catalytic involvement which might be tested in a future project by site-directed mutagenesis of the cyanobacterial enzyme, which resembles the C_4 sequence at this position.

Hybrids have been produced between the C_3-like C_3/C_4 intermediate species, *Flaveria linearis*, and the C_4 species, *F.trinervia* (Badger, Andrews). These crosses have been performed in both senses and we have confirmed that the kinetic properties of the Rubiscos in the resultant hybrids resemble those of the maternal Rubisco. This supports the notion that variance in kinetic properties is due to alterations in the plastid-encoded large subunit. However, to establish this we must be certain that the enzyme from the hybrid does in fact contain a mixture of the two types of small subunits. Initial attempts to do this by separation of the two types of small subunits

by isoelectric focussing have been unsuccessful due to negligible charge differences between the polypeptides. We are currently pursuing this further by N-terminal sequence analysis.

Rubiscos from the purple non-sulphur bacteria are unique in that they lack small subunits. However, the L_2 enzyme from *Rhodospirillum rubrum* has a short sequence at its carboxyl terminus which shows homology to a highly conserved section of the small subunit of the L_8S_8 type Rubisco. Partial or complete removal of this sequence by site directed insertions of stop codons has been conducted this year (Morell, Ross, Andrews). These truncations do not impair the ability of the subunits to dimerize and have no effect on the catalytic functions. Therefore, this sequence manifestly does not serve the same function in the L_2 enzyme as the small subunit does in the L_8S_8 Rubisco (see above). More extensive truncation, beyond the homologous sequence, causes deterioration in the affinity for both CO_2 and ribulose bisphosphate and serious reduction in the expression levels in *E.coli*.

Genetic Manipulation and Analysis

A program has been initiated this year whose ultimate aim is to insert altered and foreign genes into the maternally inherited chromosome of the plant subcellular organelle, the plastid (Morell, Kane, Ross, Andrews). The plastid genome, or plastome, is an attractive target for genetic manipulation in higher plants. Incorporation of foreign DNA into this genome may yield valuable scientific and commercial opportunities. Because the plastome is small and basically prokaryotic in organisation, it has many potential advantages for manipulation in comparison with the very much larger and more complex eukaryotic nuclear genome.

Stable plastome transformation has so far been achieved only for the green alga, *Chlamydomonas*. In our attempts to extend this achievement to higher plants, we are taking a modular approach. This strategy separates independently testable components of the overall system allowing verification that they function as hoped and providing a means for testing refinements aimed at improving modules that perform below requirements. Our approach recognizes that successful plastid transformation is most likely to be achieved when suitably designed DNA constructions are delivered into the plastids of appropriate plant material, which is then subjected to selection for the expressed products of the foreign DNA. At each stage of this process, the experiments are designed to give feedback so that strategies can be evaluated and refined. A number of plasmids have been constructed containing inserts with elements considered necessary for stable integration into, and proper function within, the plastid genetic system. These constructs will be introduced using a variety of available gene delivery systems and tested for stable integration. They will also be tested by transient expression *in vivo*, and in a plastid-derived expression system *in vitro*, so that they can be tailored to function optimally in the plastid environment. The information gathered from these experiments will allow us to identify obstacles and to progressively refine the overall strategy.

Another program studies the molecular evolution of C_4-photosynthesis. Efforts have been made to establish cDNA libraries from close C_3 and C_4 relatives (Woo, Badger, Andrews). Functional mRNA was successfully isolated from the C_4 monocot, *Neurachne munroi*, the C_4 dicot, *Flaveria trinervia*, and the C_3 dicot, *Atriplex hastata*. The isolation of mRNA from other matching species is continuing. Genes for PEP carboxylase in these species will be isolated using cDNA expression plasmid libraries.

Our continuing program of selection of photosynthetic and growth mutants in *Arabidopsis* has continued to be hampered by prolonged delays in the construction of the controlled environment facilities required for screening mutants under specified atmospheric conditions. Nevertheless, during the delay, large quantities of M2 mutant seed have been propagated (Masle, Gallagher, Badger, Andrews).

PLANT ENVIRONMENTAL BIOLOGY

Introduction

The Plant Environmental Biology Group encompasses three interacting themes, the Molecular Analysis of Plant Performance (see separate entry in previous MOLECULAR ANALYSIS OF PLANT PERFORMANCE section), Biochemistry and Physiology of Photosynthesis and Plant Physiological Ecology. The Group is interested in how environmental and genetic changes affect plant performance, with emphases on the acquisition of carbon, and, in higher plants, on the associated loss of water. The use of molecular biological techniques is increasing, so that greater attention is being paid to transformation techniques.

Biochemistry and Physiology of Photosynthesis

Investigators: Murray Badger, John Andrews, Daryl Edmondson*, John Evans, LinKe Huang, Barry Osmond*, Ichiro Terashima*, Kam Chau Woo, Jianwei Yu.

Studies of photosynthetic processes continue to proceed at levels ranging from individual enzymes and membranes of the chloroplast, to the protoplast and the whole leaf.

A study of an inhibitor which slowly accumulates on the active sites of purified Rubisco during catalysis, perhaps as a side reaction which runs at 1/1000th to 1/5000th of the rate of the carboxylation reaction, has been completed this year with a study of its chemical properties (Edmondson*, Andrews and Badger).

An ACIAR sponsored collaborative project continues to examine the basis for the differences between rice cultivars in their sensitivity to chilling temperatures. (Osmond*, Woo, Huang, Terashima*). Although these differences are reflected in properties related to thylakoid functioning, we were able to show this year that rice thylakoids themselves are quite resistant to chilling treatments (Terashima*, Huang, Osmond*). These results are in contrast to those obtained in cucumber, and indicate that the sensitivity in some of the cultivars may arise from a mismatch of the capacities for carbon assimilation, carbohydrate translocation, and synthesis of compounds for growth.

Metabolite transport in chloroplasts is being investigated in relation to the photorespiratory release and refixation of NH_3 (Yu and Woo). It was found that the kinetics of glutamine transport in oat chloroplasts were different from those in spinach chloroplasts. This difference appeared to be related to the presence of cytosolic glutamine synthetase in oat but not in spinach leaf cells. A three-translocator model, involving dicarboxylate translocator, 2-OG translocator and glutamine translocator, was proposed to explain the re-assimilation of photorespiratory NH_3 in C_3 species. In this model, the transport of cytosolic glutamine into the chloroplast was coupled to the export of glutamate via the glutamine translocator.

Plant Physiological Ecology

Investigators: Ian Cowan, Graham Farquhar, David Bagnall, William Bowman§, Susanne von Caemmerer, Sally Henderson, Kerry Hubick, Candido Lopez-Castaneda, Josette Masle, Barry Osmond*, Jim Virgona, Chin Wong, Kam Chau Woo.

A central interest is the compromise made in terrestrial plants between carbon fixation and water use. Much of our previous work has concentrated on the adaptive functions of stomata at the leaf level. This year greater attention was paid to the consequences at the crop level of genetic differences in the ratio of photosynthetic carbon gain to stomatal transpiration (transpiration efficiency).

Using a simplified representation of CO_2, vapour and heat transfer in the atmospheric boundary layer, we showed that transpiration efficiency is likely to be adversely affected by an increase in stomatal resistance if the increase in resistance obtains over a sufficiently long fetch of cropped land surface (Cowan). The length of fetch resulting in this reversal of the expected influence of stomata depends on wind speed, crop roughness, leaf area index, and the absolute magnitude of the stomatal resistance. For freely-growing, tall annual crops having a leaf area index of two or more, it is of the order 100 to 1000 metres. No general conclusions can be drawn

Genotypic differences in growth and water use of plants with the C_3 pathway of photosynthesis

about the effects of a decrease in stomatal resistance on transpiration efficiency, for it depends on the non-linear dependence of photosynthetic metabolism on CO_2 concentration. On the other hand, we showed that transpiration efficiency is likely to be increased at the crop level to a similar extent as occurs in individual plants if the increase is caused by increased capacity for photosynthesis per unit area of leaf. The above effects were also related to the expected carbon isotope discrimination of a crop (Farquhar, Hubick, Condon, Richards).

We have previously shown that, for individual plants, genetic differences in the transpiration efficiency of individual plants with the C_3 pathway of photosynthesis are negatively correlated with the discrimination against $^{13}CO_2$ uptake exerted during carbon fixation. We tested this relationship in the field by growing eight genotypes of peanut that we had already determined to be individually diverse with respect to transpiration efficiency and discrimination (Wright+, Hubick and Farquhar). We have previously shown that much of this variation is caused by variation in photosynthetic capacity.

Cultivars originated from Australia, the USA, Israel, and Indonesia. Individual plants of each cultivar were grown in large pots sunk into small plots under a rainout shelter. Plants were watered well and the transpiration efficiency for each pot was calculated for the period from canopy closure to early pod-filling. Transpiration efficiency varied genetically, and a strong negative correlation between transpiration efficiency and carbon isotope discrimination was found. This was as expected from theory and showed that, at least in small canopies, the relationship between discrimination and water-use efficiency was robust for the genotypes chosen.

We previously reported that genetic variation in discrimination is negatively related to that of transpiration efficiency of cotton cultivars. This was again confirmed in longer-term experiments (Hubick and Farquhar). However, it was found that water stress had unexpected effects. It caused a reduction in discrimination, but with no change in transpiration efficiency. Other results were as expected: the rankings of cultivars in terms of discrimination (assessed from lint material) and of transpiration efficiency were largely unchanged by stress. It is thought that the compensation may have been caused by greater leaf temperatures and proportionally greater respiratory losses under stress.

A survey was made of carbon isotope discrimination among cotton lines presently grown in Australia (Hubick, Lawrence+, Reid+, Farquhar). Leaf material was collected from 30 genotypes of the Australian Cotton Cultivar Trials at ten different sites in Queensland and northern New South Wales. There were some small differences in carbon isotope discrimination among genotypes at particular sites, but they were not significant among genotypes over all sites. We suggest that the genetic variation in isotope discrimination, and therefore, transpiration efficiency, is not large in cotton presently used in Australia, and that efforts be made to include more diverse material in breeding programs.

We have pursued other aspects of plant functioning in relation to discrimination and transpiration efficiency of sunflower genotypes (Virgona and Farquhar). We found a negative relationship between the ratio of plant biomass to leaf area and discrimination. A similar relationship was found for diverse wheat genotypes. By itself the result would mean faster relative growth rates of genotypes with greater discrimination. However net assimilation rate of sunflower genotypes decreased even more with increasing discrimination, with the net effect that relative growth rate in the vegetative stage decreased. The results suggest that selecting for low discrimination should be useful for improving transpiration efficiency in the field, as the major source of variation of discrimination seems to be in photosynthetic capacity, rather than in stomatal conductance.

We have become interested in soil factors which may influence growth and its relation to water use. This year we found that the form of nitrogen nutrition was important for potted peanut plants (Hubick and Farquhar). When nitrogen was only available through symbiosis with *Rhizobium*, growth and transpiration efficiency were reduced compared to controls supplied with nutrient solution containing nitrogen. As with the cotton experiment described above, water stress had no effect on transpiration efficiency.

We previously showed for one genotype of wheat that increased mechanical resistance of the soil to root penetration (soil strength) results in slow leaf expansion, decreased stomatal conductance and carbon isotope discrimination, and greater water use efficiency. Using a wide range of landrace and modern wheats and barleys, we have now shown that there is significant genetic variation in these responses (Masle and Farquhar). All genotypes exhibited reduced growth (leaf expansion, accumulation of dry-weight) and stomatal closure, but to a very variable extent. The genotypes which were the most affected in terms of growth tended to be the ones which a) grew faster on loose soil, b) showed the largest reduction of stomatal conductance and c) did not increase their root to shoot ratio in response to high soil strength. There were, however, interesting genotypes which after a few days performed nearly as well on tough as on loose soil.

In the above study, the young barley plants generally grew faster than the wheat. We are now examining factors underlying these differences in leaf area development among current Australian lines (Lopez-Castaneda, Richards +, Hubick and Farquhar).

Leaf appearance rate is an important component of the rate of leaf area establishment. It also constitutes an expression of the potential rate of tiller production, since leaf and tiller appearance in cereals have been shown to be closely coordinated. We analysed leaf numbers observed in the field in France for several wheat genotypes over a wide range of sowing dates (October to May) (Masle, Doussinault +, Sun +, Farquhar). Within any treatment, leaf number was a linear function of thermal time from seedling emergence (°C.d, the mean daily temperatures summed above a base temperature of 0 °C), but the slope of the relation depended on sowing date. However, when expressed on the basis of photothermal time (°C.dl, temperatures accumulated during the light time period only), much of the sowing date effect was removed, except for the latest spring sowings. The use of photothermal time rather than thermal time significantly improves the empirical prediction of leaf number but greater understanding of the effects of higher temperatures, and of vernalisation, are needed.

Carbon isotope discrimination by plants with the C_4 pathway

We previously developed a model which predicted that discrimination by C_4 plants should be affected if the ratio of mesophyll activity (PEP carboxylation) to bundlesheath (BS) activity (RuBP carboxylation) were to change. Mesophyll activity must always be slightly greater than BS activity to ensure a high concentration of CO_2 in the bundlesheath, but if this ratio increases there is wasteful overcycling, extra energy dissipation and carbon must leak back in proportionally greater amounts from the BS to the mesophyll. This should decrease the quantum yield of photosynthesis and increase discrimination.

This year carbon isotope discrimination was measured in leaf material of twelve sorghum genotypes grown at one field site in Queensland (Henderson, Hubick, von Caemmerer, Hammer +, Wade +, Farquhar). Small but significant genetic variation was found in leaf discrimination in two different sets of leaves on the plants. The discrimination correlated strongly in a negative manner with yield and radiation-use efficiency at the canopy level. It is not yet known whether the variation in discrimination was due to variation in leakage.

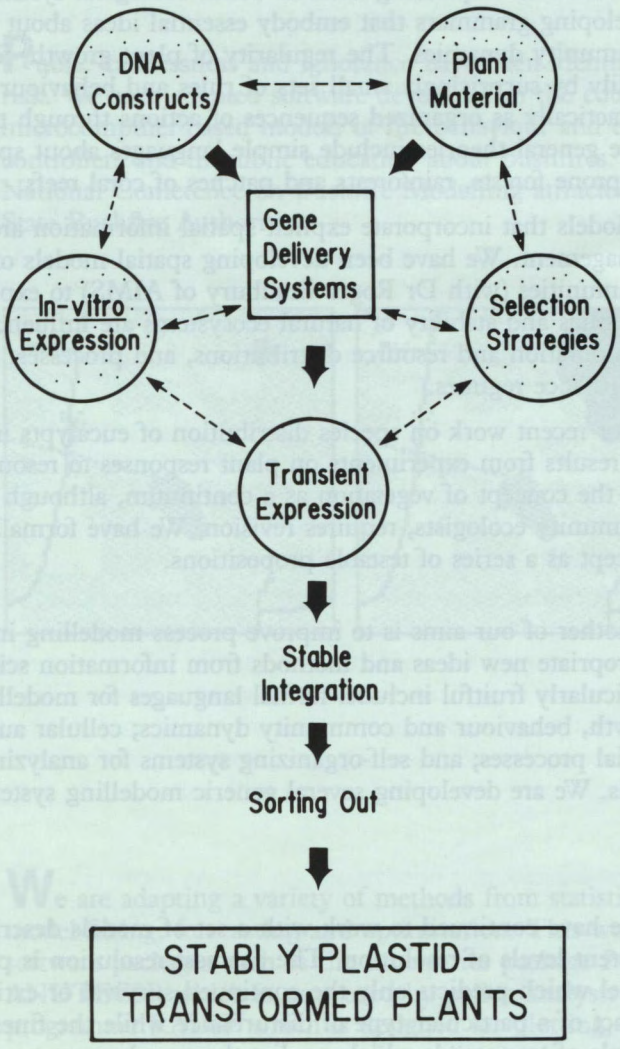
Short term carbon isotope discrimination was measured in leaves of *Andropogon*, a C_4 grass species, when the plants were given normal nutrient medium or stressed with added salt (Bowman§, Hubick, von Caemmerer, Osmond*, Farquhar). Salt-stressed plants discriminated much more against $^{13}CO_2$ than did control plants and it is possible that this may be caused by an increase in the ratio of PEP carboxylations to Rubisco carboxylations, and in the leakage from BS to mesophyll.

Global change

With the increase of global levels of atmospheric CO_2, there is an increasing interest in growth of plants at greater than normal levels of this radiatively active gas. This year we discovered marked interactions with humidity and nutrition in cotton and sunflower and these are now being investigated (Wong and Woo). The need to model the effects of increasing CO_2 concentration on plants and on climate has led to an interest in models of regional water loss and CO_2 uptake. It has added to our interest in models of whole plant growth. We have begun to collaborate with Ecosystem Dynamics and colleagues in CSIRO in this area (Farquhar).

PLASTOME TRANSFORMATION

A modular approach to plastid gene transformation in higher plants is shown. This approach allows independent testing of the functioning of the components of the complete system as well as the testing of refinements made to individual components to try to improve performance.



ECOSYSTEM DYNAMICS

Introduction

Vegetation, and the soils supporting it, form the primary resource for much of our grazing, forestry, conservation and recreation lands. These ecosystems are coming under increasing threat from human activities such as clearing, fire and global climatic change. Their successful management depends on our abilities to understand and predict the ensuing changes in plant communities. Our work aims 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.

Theoretical Studies of Ecosystem Structure and Function

Investigators: Ian Noble, Ralph Slatyer, Joe Connell#, David Green, Tom Smith, Mike Austin#

One of our goals is to develop an explicit theory of ecological succession that is readily applicable to landscape management. One particular focus of this work is exploring the role of colonisation in patch dynamics.

Another goal is to develop general ecological languages. The ability of syntactic models to capture biological organization, both succintly and 'naturally', makes them ideal tools for expressing theories about ecological systems and processes. We are developing grammars that embody essential ideas about growth, behaviour and community dynamics. The regularity of plant growth, for instance, can be captured readily by surprisingly small sets of rules and behaviour can be represented syntactically as organized sequences of actions through time. Our first steps towards more general theories include simple languages about specific ecosystems such as fire-prone forests, rainforests and patches of coral reefs.

Models that incorporate explicit spatial information are rare in research and management. We have been developing spatial models of bushfires, forests and reef communities (with Dr Roger Bradbury of AIMS) to explore how the structure, dynamics and stability of natural ecosystems are influenced by spatial patterns, such as population and resource distributions, and processes, for example dispersal and disturbance regimes.

Our recent work on species distribution of eucalypts in south eastern Australia, and our results from experiments on plant responses to resource gradients, have indicated that the concept of vegetation as a continuum, although generally accepted by plant community ecologists, requires revision. We have formally restated the continuum concept as a series of testable propositions.

Modelling of Vegetation Change and Applications for Management

Investigators: Ian Noble, David Green, Tom Smith, Andrew Moore, Mike Strasser

Another of our aims is to improve process modelling in ecology by drawing on appropriate new ideas and methods from information science. Ideas that are proving particularly fruitful include: formal languages for modelling the organization of growth, behaviour and community dynamics; cellular automata for representing spatial processes; and self-organizing systems for analyzing biological patterns of all kinds. We are developing several generic modelling systems that use these ideas.

i The functional groups approach

We have continued to work with a set of models describing vegetation change with different levels of resolution. The coarsest resolution is provided by the vital attributes model which predicts only the continued survival or extinction of species under the impact of a particular type of disturbance while the finest resolution is provided by models of tree stands which predict the year by year growth increments of individual trees.

FATE is a model with a resolution intermediate to those described above. It uses

qualitative descriptions of the functioning of individual taxa in a community and makes qualitative predictions of the changes in community composition, age, and size structure. We have continued to test the model against field data. We have developed a mathematical analysis of the behaviour of the FATE model using semi-Markov processes. It allows us to determine 'optimal' management strategies and tactics.

A version of the model for Kakadu National Park has been elaborated and is being tested by ANPWS staff. We have developed a version of the FATE model to deal with environmental gradients and the spatial distribution of vegetation. We are applying this model to help predict the impact of global climatic change on plant communities.

ii Expert systems

We have extended the application of expert systems and other computer based information handling techniques to landscape management. Applications have included the provision of advice to voluntary organisations in the UK on how to manage farm ponds and footpath construction, and on how to make modelling packages, such as the group of models described above, more readily available to users by providing advice on how to set up and run the models for new localities and scenarios.

iii Models of bushfire behaviour

Public carelessness and ignorance have been identified as the greatest source of fire risk. We have adapted software developed in the course of past research to produce microcomputer-based models of fire behaviour and effects for use in training of fire controllers and in public education about bushfires. A recent demonstration at the National Conference on Bushfire Modelling attracted a great deal of interest from State Bushfire Authorities.

MODELS OF BUSHFIRE BEHAVIOUR

Simulated bushfire across a landscape. In the scenario shown, a fire ignites in forest (speckled) and is driven initially by a north wind. Note that the firefront (black) spreads more slowly through open fields (white). Finally a strong wind shift occurs from the northeast, causing the fire to pose a threat to the town (black dots). Other features include roads and a lake. The devastated area is shown in grey. The model was developed by Dr David Green of the Ecosystem Dynamics Group for research on bushfire behaviour and is being adapted for use in public education and in training fire controllers.

iv Analytic methodologies

We are adapting a variety of methods from statistics and artificial intelligence for model-fitting, forecasting and optimisation. This work has produced some major software packages such as the time series package POLSTA (marketed by ANUTECH) which is now used by pollen analysts in several countries, and the programme RADIF which is designed for plotting, modelling, and analyzing spatial point patterns, such as maps of tree distributions.

The analysis of ecological data sets is often difficult because of discontinuities which reduce the utility of multivariate techniques. An approach that combines rule

induction techniques with multivariate analyses is being explored using a data set on water fowl distribution in the U.K. and a large data set on recruitment in a variety of rainforest sites in Queensland.

v Costing of ecological monitoring

In a collaborative project with Dr Geoff Norton of Imperial College, we have been exploring the economics of ecological monitoring for the detection of pest species. A simple ecological and economic model points out the benefits of a carefully designed monitoring system and of balancing the expense of the monitoring programme against the cost of failing to achieve stated objectives. We have prepared guidelines on balancing effort between monitoring and control programmes.

Ecophysiology of Australian Plants

i Physiological ecology of eucalypts

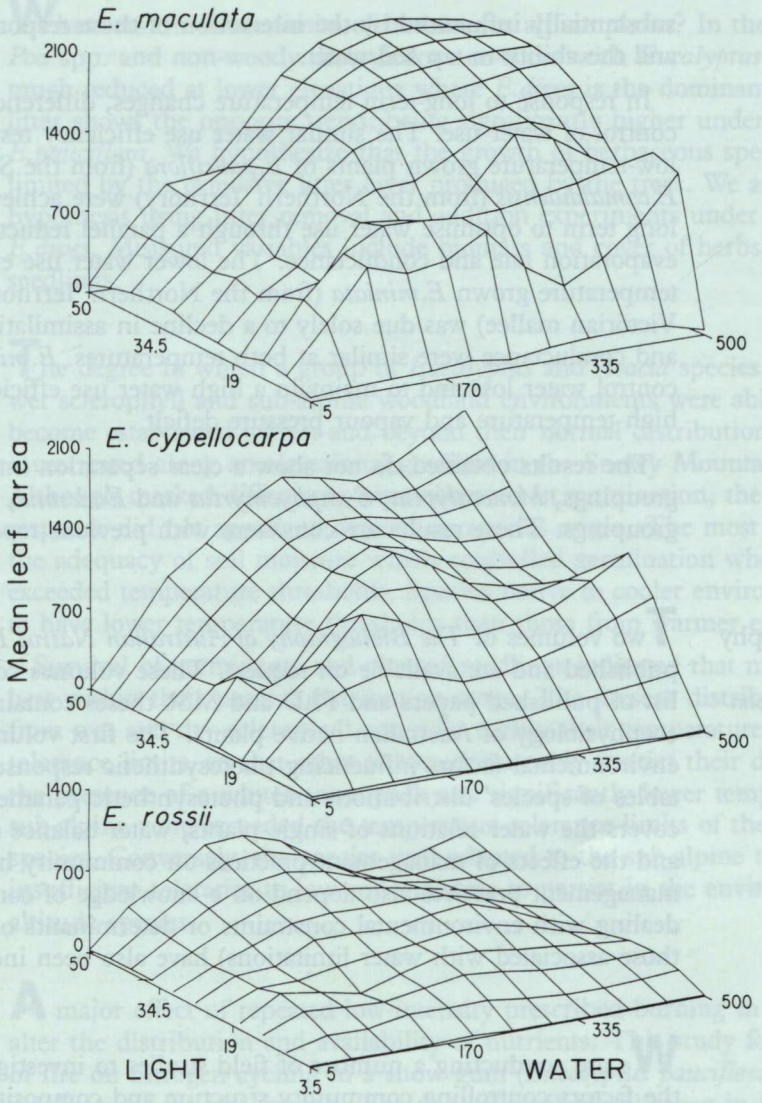
Investigators: Bruce Wellington, Mike Austin#, Tom Smith, Ian Noble

A major commitment of the group is to a series of experiments drawing together ideas that span the disciplines of ecology and physiology. They are expected to yield a general explanation for species distributions. Recent theoretical and experimental studies by members of the group suggest that there should be patterns in the trade-offs between adaptations to different levels of resource availability and that it should be possible to predict whole plant performance across resource gradients based on physiological constraints. If this is the case, the theories will provide a basis for understanding community structure and composition and thus for improved predictions of vegetation dynamics.

Experiments to date have focussed on *Eucalyptus* species, important hardwood trees dominating the mesic fringes of the continent and for which an extensive database concerning natural distributions is available. The experimental approach involves growing seedlings of selected provenances along artificial gradients of resource availability, monitoring their patterns of physiological and whole plant response, and comparing these with statistical models of individual species distributions based on distal environmental factors, such as mean annual rainfall and temperature.

Early experiments revealed good complementarity in patterns of response at the various levels of scale to resource availability. For example, species from drier sites maintained low rates of water usage at the expense of carbon assimilation, even when water was in plentiful supply. Co-occurring species from different sub-genera of *Eucalyptus* appeared to have different patterns of physiological and whole plant response to the same environmental conditions.

Later experiments have examined species from a greater range of environments and have included intra- and inter-specific competition as a factor influencing resource availability. In particular, we have investigated the cost/benefit aspect of the tradeoff between growth rate and conservatism in the exploitation of resources. Good correlations have been found between mean annual rainfall at the limits of natural distribution of a species and time to wilting and death under resource-limited experimental conditions. The most recent work has attempted to link particular strategies of resource exploitation with outcomes of competitive interactions.



PHYSIOLOGICAL ECOLOGY OF *EUCALYPTUS*

Leaf area response of *Eucalyptus* species to interacting gradients of light and water availability. Species from wetter environments (*E. maculata*, 1300 mm mean annual rainfall) develop canopies with much larger leaf areas than species from drier environments (*E. cypellocarpa*, 950 mm; *E. rossii*, 650 mm). The difference in leaf area response reflects the trade-off between growth rate and tolerance to conditions of limiting resource availability.

ii Water-use efficiency in *Eucalyptus*

Investigators: Pam Ferrar, Ralph Slatyer

Earlier work on the photosynthetic temperature acclimation of *Eucalyptus* species from habitats as diverse as near tree line in the Snowy Mountains of NSW and the wet/dry tropical woodlands of the Northern Territory, showed a range of stomatal and transpirational responses to temperature. The present study, examining the water use efficiency of the same range of eucalypt species, found that there was a high degree of similarity between their water use efficiency in response to short-term changes in measurement temperature and vapour pressure deficit. This is somewhat surprising given the differences in environmental conditions experienced by these species in their natural habitat. In the field, however, we expect that water use efficiency would be

substantially influenced by the interaction of these responses with plant water status and the ability to tap soil water.

In response to long-term temperature changes, differences were observed in species' control of water use. The similar water use efficiency responses shown by high- and low-temperature grown plants of *E.pauciflora* (from the Snowy Mountains) and *E.camaldulensis* (from the Northern Territory) were achieved by adjustments over the long term to optimise water use through a parallel reduction in assimilation rate, evaporation rate and conductance. The lower water use efficiency observed for high temperature grown *E.miniata* (from the Northern Territory) and *E.incrassata* (from the Victorian mallee) was due solely to a decline in assimilation rate, as evaporation rate and conductance were similar at both temperatures. *E.miniata* was better able to control water loss and to maintain a high water use efficiency under conditions of high temperature and vapour pressure deficit.

The results obtained do not show a clear separation into the *Eucalyptus* sub-generic groupings, *Monocalyptus*, *Symphyomyrtus* and *Eudesmia*, but fall across these groupings. These results are consistent with previous reports.

iii Annotated bibliography

Investigators: Pam Ferrar, John Vranjic†

Two volumes of *The Bibliography of Australian Native Plants* have now been published and are available on request. These volumes contain an annotated reference list of published papers and PhD and MSc theses containing information on the ecophysiology of Australian native plants. The first volume lists references on environmental factors influencing photosynthetic responses, and contains summary tables of species' distributions and photosynthetic parameters. The second volume covers the water relations of single plants, water balance of communities, hydrology and the effects of management practices on community hydrology. Since sound management practices also depend on a knowledge of community ecology, references dealing with environmental constraints or determinants of distribution (particularly those associated with water limitations) have also been included.

Field Studies on Factors Controlling Community Structure and Composition.

We are conducting a number of field studies to investigate specific hypotheses about the factors controlling community structure and composition.

i Factors leading to the lower altitudinal limit of the snow gum

Investigators: Jann Williams, Ian Noble, Bruce Wellington, Ian Cowan

This study examines the factors affecting the distribution of *Eucalyptus pauciflora* at its lower altitudinal boundary in the Brindabella Ranges, concentrating on the downslope replacement by *E.dives*. There is an environmental gradient across the zone of species replacement, with higher sites being colder, wetter and having significantly higher soil calcium, total N and total P. In a glasshouse experiment, *E.dives* showed higher growth rates than *E.pauciflora* on all soils, while within species growth was greater on soils from the higher sites. A field transplant experiment however showed growth of both species to be lower at these higher sites. The levels of herbivory of lignotuberous seedlings in the field seem to preclude this as a regulatory factor in the distribution of *E.pauciflora*. When water was completely withheld in a glasshouse experiment, both species exhibited permanent wilting at similar soil moisture contents. There were, however, differences in species responses to low and high water availability. The upper boundary of *E.dives* appears to be largely temperature/frost related, while *E.pauciflora* has an inherently slower growth rate, placing it at a disadvantage against the faster growing *E.dives*.

ii Eucalypt litter and the lower limits of sub-alpine plants

Investigators: Charles Zammit, Scott Wilson

What sets the lower limits of herbaceous alpine plants? In the Brindabella Ranges, *Poa* spp. and non-woody dicotyledons co-occur with *Eucalyptus pauciflora*, but are much reduced at lower elevations where *E.dives* is the dominant tree species. Tree litter shows the opposite trend, being significantly higher under *E.dives* than *E.pauciflora*. We hypothesize that the growth of herbaceous species under *E.dives* is limited by the extensive litter layer produced by the trees. We are testing the hypothesis using litter removal and addition experiments under both *E.pauciflora* and *E.dives*. Measured variables include biomass and cover of herbs, shrubs and eucalypt seedlings.

iii Germination and establishment beyond natural distribution limits.

Investigators: Pam Ferrar, Ralph Slatyer, Peter Cochrane

The degree to which a group of *Eucalyptus* and *Acacia* species from dry sclerophyll, wet sclerophyll and sub-alpine woodland environments were able to germinate and become established within and beyond their normal distribution limits was investigated along an elevational gradient in the Snowy Mountains area of NSW. Although marked differences were observed in germination, the overall germination response did not appear to depend on species origin. The most important factor was the adequacy of soil moisture which controlled germination whenever temperature exceeded temperature thresholds. Species native to cooler environments did not appear to have lower temperature thresholds than those from warmer environments.

Survival of germinants and planted seedlings indicated that most species persisted best within their natural distribution range. The present distributions of many species from wet and dry sclerophyll zones lie within their temperature and moisture tolerance limits, so that other factors presumably restrict their distribution. However, the presence of a winter snow pack and significantly lower temperatures in the sub-alpine zone exceeded the temperature tolerance limits of the lower altitude species. Conversely, the species well adapted to the sub-alpine tended to have insufficient tolerance to low soil moisture to persist in the environments of the lower altitude species.

iv The impact of low intensity prescribed fires on nitrogen cycling in sub-alpine forests.

Investigators: Heather Keith, Ian Noble, John Raison [+], Bruce Wellington

A major effect of repeated low-intensity prescribed burning in eucalypt forests is to alter the distribution and availability of nutrients. This study focusses on the effects of fire on nitrogen cycling in a snow gum (*Eucalyptus pauciflora*) community and the implications for tree growth. The pool of available nitrogen in the soil has been measured over two years. A higher fire frequency reduces both soil mineral-N levels and the rate of mineralization, and thus the availability for plant uptake. Measurements of tree basal area, shoot elongation, growth and morphology of tagged shoots in the canopy, and litterfall show that trees respond to nutrient supply changes in growth rate and tissue nutrient content. Investigation of the interaction between field leaf photosynthetic rates and nitrogen content is continuing.

v The ecology of rare eucalypts

Investigators: Suzanne Prober, Mike Austin[#], Ian Noble, Ralph Slatyer

Why is it that some species are rare, while others are common and widespread? We are studying the causes of rarity of *Eucalyptus paliformis*, an endemic restricted to an area of less than 5 km^2 on the Wadbilliga Plateau in south-eastern NSW. Phylogenetic relationships (estimated using allozyme data) among *E.paliformis* and eleven of its closest relatives indicate that *E.paliformis* is unlikely to be a recently diverged species, rather it is a relatively old species, more likely to be relictual or restricted to a particular habitat type. Allozyme studies indicate a low genetic variability within the species, but not so low as to suggest that the species is in danger of extinction.

Studies testing for habitat peculiarity in *E.paliformis* include an extensive botanical survey throughout areas climatically similar to *E.paliformis* sites, and a reciprocal transplant experiment of seedlings of *E.paliformis* and *E.fraxinoides* across the

boundary between these two species in the field. Although these experiments are not yet complete there is some suggestion that subtle habitat features may be controlling the distribution of *E.paliformis*. Further studies on light, temperature and soil properties across the boundary between the two species are underway, along with a glasshouse experiment examining their relative competitive abilities on two field soils with two moisture regimes.

vi The role of harvester termites in a tropical savannah

Investigators: Mike Hodda, Ian Noble, Brian Walker +, Pat Werner +

This study, based largely in Kakadu National Park, examines the impact of termites on tropical woodlands in relation to buffalo grazing, gradients of water availability, vegetation and fire regimes. The presence of buffalo has a marked effect on some termites, as does water availability. However, vegetation appears to exert the major influence on the distribution of termite communities. Detailed surveys of termite and plant species distributions have indicated strong interrelationships between the different ecological groups of termites and various components of the vegetation. The consumption by termites of various types of vegetation and litter is being characterised, and nutrient cycling by termites is being estimated. The effect of different fire regimes on these processes will be measured next year following two consecutive years' imposition of fire treatments.

vii Population dynamics of woodland species

Investigators: Ralph Slatyer, Ian Noble, Bruce Wellington, Charles Zammit, Peter Cochrane

We have been continuing long-term population studies of eucalypt and acacia communities at a number of locations, to determine key processes affecting recruitment, growth and mortality.

Measurements of growth and mortality of a cohort of seedlings of the mallee eucalypt *E.incrassata* commenced in 1979 and have continued to the present. In particular, the effects of seedling size and densities, nearest neighbours, topography, distance to nearest adult, and availability of nutrients and water on seedling growth and survivorship have been investigated.

Measurements made since 1977 of recruitment, growth and survival of tagged individuals in a stand of mulga, *Acacia aneura*, north of Alice Springs, is suggesting that the soil seed bank may have been exhausted by germination events that followed two severe fires which occurred since monitoring commenced. This work aims to link long term survival with major climatic and fire events. In addition we are following the expansion of a recently established colony of buffel grass across the plots, providing some information on rate of spread of this invasive species.

Regular monitoring is continuing of two stands of subalpine snow gum (*E.pauciflora*) regenerating after a 1973 wildfire in Kosciusko National Park. Reduction of interspecific competition, particularly in combination with insecticide and nutrient treatments, has a dramatic effect on overall growth rate and survival of seedling recruitment at the medium elevation site (1700 m), but competitive effects seem to be much less important at a treeline site (1900 m). There appears to be an interaction between the positive and negative effects of neighbouring plants (probably improved microclimate versus competition for resources such as water) which becomes less critical with increasing altitude.

A protocol has been developed for setting up permanently marked plots to monitor long term population dynamics of selected forest communities. Sixteen plots have been established in the Brindabella ranges, six in mallee communities in western NSW, and more sites are being selected.

The temporal and spatial variation in soil seed banks are poorly understood in Australian forest systems. We are examining changes in the diversity of soil seed bank species in eucalypt forests of south east Australia. In particular, we will be monitoring

the effects of forest fragmentation and local habitat variation on the dynamics of resident seed populations and weed seed invasions.

viii Fine resolution analysis of pollen records

Investigator: David Green

Pollen preserved in lake, dam, and swamp sediments is rich in information about past vegetation. Collaborative work with Gurdip Singh and Gary Dolman (RSPacS) on methods of interpreting pollen records at fine time resolution has yielded the first year-by-year pollen and charcoal histories of present and recent environmental change. In particular, analysis of a pollen history from Bega Swamp, near Cooma, has revealed the impact that fires, clearing and exotic plants have had on a eucalypt woodland from the beginning of European settlement around 1830 until the present day. This study also revealed how short-term fluctuations in rainfall affect rates of pollen production. Other work has concentrated on automating pollen counting and on obtaining records from reservoirs about the environmental effects of human disturbance around urban fringes during the 20th Century. These techniques offer the prospects of exploring vegetation change in Holocene and in recent times in greater detail than has been previously possible and of providing databases that will allow models of vegetation dynamics to be tested against precise information about past environmental change.

JOINT RESEARCH PROJECTS UNDERTAKEN WITH OTHER UNIVERSITIES AND CSIRO

DEVELOPMENTAL NEUROBIOLOGY

Studies on the physiological optics of jumping spiders, by Dr A.D. Blest with Dr P. McIntyre, Department of Mathematics, Australian Defence Force Academy, University of New South Wales, Canberra.

The roles of arthropod cysteine proteases in photoreceptors, by Dr A.D. Blest with Dr D.L. Mykles, Department of Biology, University of Colorado at Fort Collins, Colorado, USA.

Ultrastructural cytology of some *ninaC* retinal mutants of *Drosophila*, by Drs A.D. Blest, S. Stowe and S.C. Trowell with Professor W.L. Pak, University of Indiana, USA and Dr C. Montell, Johns Hopkins University, USA.

The evolution of the tiered principal retinae of cursorial spiders, by Dr A.D. Blest with Mr D.C. O'Carroll, Flinders University of South Australia, Adelaide, SA.

The properties of inositol polyphosphatases in crab photoreceptors, by Dr S.C. Trowell with Dr R.L. Irvine, A.R.C. Animal Physiology Unit, Babraham, Cambridge, UK.

The cytology and biochemistry of the light-dependent retinal degeneration mutant of *Drosophila, rdgB*, by Drs

A.D. Blest, S. Stowe and S.C. Trowell with Professor B. Minke, Department of Physiology, Hadassah Medical School, the University of Jerusalem, Israel.

The evolution of Salticid spiders, by Dr A.D. Blest with Dr R.R. Jackson, Department of Zoology, the University of Canterbury, New Zealand.

The roles of 48–49 kDa phosphoproteins in invertebrate photoreceptors, by Dr S.C. Trowell with Dr H. Matsumoto and Ms Naoka Komori, University of Oklahoma Health Sciences Center, USA.

Studies on monoclonal antibodies to muscle fibre types, by Dr I.S. McLennan and Ms M.L. Porter with Dr J. Rostas and Ms S. Shanin, University of Newcastle, and Dr P. Bartlett, Walter & Eliza Hall Institute, Melbourne, Victoria.

Studies on the embryological origins of mature muscle fibres, by Dr I.S. McLennan with Dr J. Ho, University of Sydney.

Development of the wallaby retina, by Dr L.R. Marotte with Professor A. Spira, The University of Calgary, Canada.

Cortical bands in the somatosensory cortex of the wallaby, by Professor R.F Mark and Dr L.R. Marotte with Dr P. Waite, University of Sydney.

Optokinetic reflexes after early eye rotation in the wallaby, by Dr L.R. Marotte and Professor R.F. Mark with Professor K.-P. Hoffman, University of Bochum, FRG.

An atlas of the wallaby brain, by Professor R.F. Mark with Dr. L. Mayner, Warrnambool College of Advanced Education and Dr C.H. Tyndale Biscoe, CSIRO Division of Wildlife and Ecology, Canberra.

Changes in amplitude of the H reflex in human subjects, by Professor R.F Mark with Dr U. Proske and Dr E. Gregory, Monash University, Melbourne, Victoria.

MOLECULAR NEUROBIOLOGY

Synaptic mechanisms of auditory information processing in the moth, by Dr G.S. Boyan with Dr J.H. Fullard, University of Toronto, Canada.

Neural correlates of behaviour: synaptic mechanisms in an insect CNS with restricted sensory input, by Dr G.S. Boyan with Dr L.A. Miller, Odense University, Denmark.

Neuromuscular development in embryonic locust, by Dr C. Myers and Dr E. Ball with Dr P. Whitington, University of New England, Armidale, NSW.

Embryonic development of the locust nervous system by Dr E. Ball with Dr H.G. de Couet, University of New South Wales, Kensington, and Dr M. Bastiani, University of Utah, Salt Lake City, Utah, USA.

Cloning and characterization of locust homeo-box genes by Dr E. Ball with Prof. C.S. Goodman and several members of his laboratory, University of California, Berkeley, California, USA.

Germline clone analysis of genes at the base of the X-chromosome of *D.melanogaster*, by Dr G. Miklos with Prof. N. Perrimon, Harvard University, Boston, Massachusetts, USA.

Isolation of large *Drosophila* DNA molecules from the base of the X-chromosome in yeast artificial chromosome (YAC) vectors, by Dr G. Miklos with Prof. N. Perrimon, Harvard University, Boston, Massachusetts, USA.

Molecular biology of the *small optic lobes* locus, by Drs S. Delaney, D. Hayward and G. Miklos with Prof. K.F. Fischbach, University of Freiburg, Freiburg, FRG.

Cloning and characterization of the *flightless* chromosomal region by Dr G. Miklos with Dr H.G. de Couet, University of NSW, Kensington, NSW.

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

Protein-DNA binding studies on repetitive DNA sequences, by Dr G. Miklos and James Cotsell with Dr T.C. James, Wesleyan University, Middletown, Connecticut, USA.

Molecular cloning of the *shaking* gene complex, by Dr G. Miklos with Dr J. Davies, University of Glasgow, Glasgow, Scotland.

Molecular cloning of the *stoned* and *uncoordinated-like* genes, by Dr G. Miklos with Dr L. Kelly, University of Melbourne, Parkville, Victoria.

Cross reactivities of mammalian and *Drosophila* DNA sequences, by Dr G. Miklos with Dr I. Young, and Dr H. Campbell, John Curtin School of Medical Research, ANU, Canberra.

Molecular cloning of the *folded gastrulation* gene, by Dr G. Miklos with Dr E. Wilson, Princeton University, Princeton, New Jersey, USA.

Neurophysiological studies of the *shaking* gene, by Dr G. Miklos with Prof. R. Wyman, Yale University, New Haven, Connecticut, USA.

VISUAL SCIENCES

The Centre for Visual Sciences was established by the ANU Council in 1987 to promote collaboration between RSBS, JCSMR and RSPysS. An extension to RSBS, built to accommodate the Developmental Neurobiology Group has been completed, and will also house many members of the Vision Centre, including Professor W.R. Levick and Professor A.W. Snyder. We anticipate many benefits from this concentration of Vision scientists on campus.

Sensitivity of ganglion cells to excitotoxic amino acids, by Dr I. Morgan with Dr D. Ehrlich, Monash University, Melbourne, Victoria.

Location of Thy1 and Ox-2 antigens in the chicken retina, by Dr I. Morgan with Dr P. Jeffrey, Children's Medical Research Foundation, Sydney, NSW.

Effects of cholinotoxins on rabbit retina, by Dr I. Morgan with Prof. A. Spira, University of Calgary, Canada.

Peptide processing in the retina, by Dr I. Morgan with Prof. I. Chubb, University of Wollongong.

Mechanisms of range estimation in freely-flying bees, by Dr. M.V. Srinivasan with Dr. W. Kirchner, University of Wurzburg, FRG.

Mechanisms of visual discrimination in freely-flying honeybees, by Dr. M.V. Srinivasan and Prof. G.A. Horridge with Dr M. Lehrer, University of Zurich, Switzerland.

Target tracking and other aspects of visual behaviour in honeybees, by Dr M.V. Srinivasan with Prof. Zhang, S.W., Institute of Biophysics, Academia Sinica, People's Republic of China.

Modeling the spatiotemporal properties of peripheral visual neurons and predicting the consequences for visual fixation behaviour of flies, by Dr M.V. Srinivasan and Dr D. Osorio with Prof. R. Pinter, University of Washington, USA.

Anatomy and synaptic connections of LMC cells in the medulla, by Prof. G.A. Horridge with Dr W. Ribi, University of Tubingen, FRG.

Spectral sensitivity of cricket visual cells, by E. Warrant with Dr. W.G. Wu, Institute of Biophysics, Academia Sinica, Beijing, People's Republic of China.

Design and construction of artificial seeing systems by Prof. G.A. Horridge and Dr M.V. Srinivasan with Prof. R. Brent and Dr I. MacLeod, RSPhysS and Dr T. Hayes, Royal Australian Guide Dogs for the Blind, and SEETEC Pty. Ltd. Melbourne, Victoria.

MOLECULAR GENETICS

Characterization of mitochondrial and nuclear chromosomal changes in yeast hybrids by Dr G.D. Clark-Walker, Dr R. Maleszka and Mr C. Hardy with Dr C. Galeotti, Sclavo Research Centre, Siena, Italy.

Isolation and characterization of metallothionein genes of yeasts by Dr G.D. Clark-Walker with Dr I. Macreadie, CSIRO division of Biotechnology, Parkville, Victoria.

Structure and function of the transfer RNA processing locus in the mitochondrial genome of *Torulopsis glabrata* by Dr G.D. Clark-Walker with Dr N. Martin, University of Louiseville, Kentucky, USA.

Investigation of the mitochondrial genome in a new species of *Kluyveromyces* by Dr. G.D. Clark-Walker with Dr H.J. Phaff, University of California, Davis, California, USA.

Studies on the activation and regulation of the oncogenes in human gastric cancers by Drs H. Naora and L.-Q. Sun with Prof. C.-Z. Su, the Fourth Military Medical University, Xi'an, People's Republic of China.

Studies on regulatory mechanisms of *c-myc* expression in tumour cells by Drs L.-Q. Sun and H. Naora with Dr N.J. Deacon, University of Melbourne.

Characterization of a novel gene, *nbl*, isolated from Burkitt lymphoma by Dr H. Naora and Mrs F. Driver with Dr N.J. Deacon, University of Melbourne, Dr G. Webb, John Curtin School of Medical Research and Dr T. Tsujii, Shigei Medical Research Institute, Okayama, Japan.

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

POPULATION GENETICS

Evolutionary relationships of the Australian avifauna by Dr D.D. Shaw and Ms S. Maynes with Dr L. Christidis, Museum of Victoria, Melbourne.

Evolution of the Australian avifauna by Dr D.D. Shaw and Ms S. Maynes with Dr R. Schodde, CSIRO Division of Wildlife and Ecology, Canberra.

Population genetics of *Drosophila* by Dr J.B. Gibson with Prof. Z. Liu and Prof. C.C. Tan, Institute of Genetics, Fudan University, People's Republic of China.

Gene-enzyme systems in *Drosophila* by Dr J.B. Gibson with Prof. G. Bewley, North Carolina State University, USA.

PLANT CELL BIOLOGY

Research on the biology of *Azolla* by Professor B. Gunning, Prof. B. Rolfe, and Dr J. Plazinski with Professor Liu Chung Chu and Mr Zhang Qi, National Azolla Research Centre, Fuzhou, People's Republic of China.

Cell Biology of embryo sacs in flowering plants by Ms M. Webb and Professor B. Gunning with Professor R. B. Knox, University of Melbourne.

Isolation of preprophase bands of microtubules by Professor B. Gunning with Professor L. Fowke, University of Saskatchewan, Canada.

Video-microscope immunofluorescence of microtubules and actin in pollen tubes by Professor B. Gunning with Professor R. B. Knox and J. Kenrick, University of Melbourne.

Regeneration and the cytoskeleton of pine tissue cultures by Dr J. Gorst with Dr S. Chandler, Calgene Pacific, Melbourne, Victoria.

Reproductive tissues of orchids by Professor B. Gunning with M. Clements and Dr J. Armstrong, Australian National Botanic Gardens, Canberra.

Identification of hormone receptors on plant cell surfaces by monoclonal antibodies by Dr A.R. Hardham and Dr F. Gubler with Dr J.V. Jacobsen, CSIRO Division of Plant Industry, Canberra.

Application of immunoassays for the diagnosis of diseases caused by *Phytophthora* and *Erwinia* by Dr A.R. Hardham with J. Maughan and C. Richardson, Victorian Department of Agriculture and Rural Affairs, Burnley, Victoria.

Conserved cell division control proteins by Dr P.C.L. John with Professor P. Nurse, Oxford University, UK.

Initiation of polarity in plant tissues by Dr P. Warren Wilson with Professor J. Warren Wilson, Botany Department, ANU and Dr R. Overall, School of Biology, University of Sydney.

IAA conjugates and differentiation patterns by Dr P. Warren Wilson with Dr P. Hall, Michigan State University, USA.

Myosin and cytoplasmic streaming by Drs R.E. Williamson and F. Grolig[#] with Dr J. Parke, Pall Europe, Portsmouth, Dr C. Miller, University of Leicester and Dr B.H. Handerton, University of London, UK.

Actin-binding proteins by Drs R.E. Williamson, J. Plazinski and P.P. Jablonsky with Dr M. Fechheimer, University of Georgia, Athens, USA.

Localisation of calcium-dependent protein kinase in plant cells by Dr D.W. McCurdy with Dr A.C. Harmon, University of Georgia, Athens, USA.

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

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

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

Biochemical effects of auxins on stability of cytokinins by Dr L. Palni with Drs L.R. Burch and R. Horgan, University College of Wales, Aberystwyth, UK.

Growth regulating activity of humic acids by Dr L.M.S. Palni with Dr J.K. MacLeod, Research School of Chemistry, ANU, Canberra.

PLANT MOLECULAR BIOLOGY

Sequencing of the Rubisco large subunit genes from closely related C_3/C_4 relatives by Drs. T.J. Andrews and M.R. Badger (Plant Environmental Biology) with Drs. P. Whitfeld, W. Bottomley, G. Hudson and J. Mahon, CSIRO Division of Plant Industry, Canberra.

Enzyme kinetics of *Aspergillus* alcohol dehydrogenase by Dr. E.H. Creaser with Professor J. McKinley-McKee, Oslo University, Norway.

Protein Engineering of p-hydroxybenzoate hydroxylase by Dr. E.H. Creaser with Dr. B. Entsch, University of New England, Armidale, NSW.

Analysis of lipopolysaccharides (LPS) of *R. trifolii* by Prof. B. Rolfe with Professor R.W. Carlson, Eastern Illinois University, Charleston, Illinois, USA.

Regulation of *R. trifolii* nodulation genes by Prof. B. Rolfe, Drs J.J. Weinman and M. Djordjevic with Drs P. Kuempel and R. Innes, University of Colorado, Boulder, Colorado, USA.

Complementation and functional analysis of *R. trifolii nod* genes by Prof. B. Rolfe with Dr C.A. Wijffelman, University of Leiden, The Netherlands.

Analysis of plant resistance genes by Prof. B. Rolfe with Drs D. Gabriel and D. Loschke, University of Florida, Gainesville, Florida, USA.

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

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

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

Characterization of acid tolerant *R. trifolii* strains by Prof. B. Rolfe with Dr R. Simpson, University of Melbourne, Parkville, Melbourne, Victoria.

Public Interest Project, Section 39 by Prof. B. Rolfe with Drs P. Gresshoff and B. Carroll, The Faculties, ANU, Canberra; for field testing of genetically engineered microorganisms (GEMS) by Prof. B. Rolfe with Dr J. Brockwell, Microbiology Section, CSIRO Division of Plant Industry, Canberra.

Virus Identification Data Exchange (VIDE) Project, by Drs A.J.Gibbs, C. Buchen-Osmond, Ms K. Crabtree and Mr L. Watson with about 200 virologists around the world including, in particular, Dr A.A. Brunt, AFRC Institute of Horticultural Science, Littlehampton, UK, Dr G.D. McLean, Bureau of Rural Sciences, Canberra and Dr M.J.Dallwitz and Ms T.A.Paine, CSIRO Division of Entomology, Canberra.

Molecular genetic typing of the *Aspergillus flavus/parasiticus* group, by Dr B. Tyler with Dr P. Dart, University of Queensland.

Transcription of fungal genes, by Dr B. Tyler with Prof. J. Fincham, Cambridge University, UK.

Molecular genetics of *Phytophthora megasperma*, by Dr B. Tyler with Dr D. Kuhn, Purdue University, Indiana, USA.

PLANT ENVIRONMENTAL BIOLOGY

Studies on C_4 metabolite pools by by Dr S. von Caemmerer with Dr R. Leegood, University of Sheffield.

Isotope discrimination in barley genotypes by Dr K.T. Hubick and Prof. G.D. Farquhar and Drs D.H.B. Sparrow and R. Lance, Waite Research Inst., Adelaide, Dr P. Cornish, Agricultural Research Station, Gosford, Dr B. Read, Agric. Research Institute, Wagga Wagga, and Dr C. Walker, CSIRO Division Soils, Adelaide.

Isotope discrimination in cotton genotypes by Dr K.T. Hubick and Prof. G.D. Farquhar with Dr P. Lawrence, Queensland Dept. Primary Industry, Biloela and Mr P. Reid, CSIRO Cotton Research Unit, Narrabri.

Isotope discrimination in peanut by Dr K.T. Hubick and Prof. G.D. Farquhar with Dr R. Shorter, Qld Dept. Primary Industry, Brisbane, Dr G. Wright & Mr A. Cruikshank, Qld Dept. Primary Industry, Kingaroy, and Dr R.C.N. Rao, ICRISAT, India.

Water-use efficiency of crop growth by Prof. G.D. Farquhar and Dr S.C. Wong with Mr F. Dunin, Drs R.A. Fischer and R. Richards, CSIRO Division of Plant Industry, and Dr O.T. Denmead, CSIRO Division of Environmental Mechanics.

Studies on the activation and regulation of the oncogenes in human gastric cancers by Drs H. Naora and L.-Q. Sun with Prof. C.-Z. Su, the Fourth Military Medical University, Xi'an, People's Republic of China.

Studies on regulatory mechanisms of *c-myc* expression in tumour cells by Drs L.-Q. Sun and H. Naora with Dr N.J. Deacon, University of Melbourne.

Characterization of a novel gene, *nbl*, isolated from Burkitt lymphoma by Dr H. Naora and Mrs F. Driver with Dr N.J. Deacon, University of Melbourne, Dr G. Webb, John Curtin School of Medical Research and Dr T. Tsujii, Shigei Medical Research Institute, Okayama, Japan.

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

POPULATION GENETICS

Evolutionary relationships of the Australian avifauna by Dr D.D. Shaw and Ms S. Maynes with Dr L. Christidis, Museum of Victoria, Melbourne.

Evolution of the Australian avifauna by Dr D.D. Shaw and Ms S. Maynes with Dr R. Schodde, CSIRO Division of Wildlife and Ecology, Canberra.

Population genetics of *Drosophila* by Dr J.B. Gibson with Prof. Z. Liu and Prof. C.C. Tan, Institute of Genetics, Fudan University, People's Republic of China.

Gene-enzyme systems in *Drosophila* by Dr J.B. Gibson with Prof. G. Bewley, North Carolina State University, USA.

PLANT CELL BIOLOGY

Research on the biology of *Azolla* by Professor B. Gunning, Prof. B. Rolfe, and Dr J. Plazinski with Professor Liu Chung Chu and Mr Zhang Qi, National Azolla Research Centre, Fuzhou, People's Republic of China.

Cell Biology of embryo sacs in flowering plants by Ms M. Webb and Professor B. Gunning with Professor R. B. Knox, University of Melbourne.

Isolation of preprophase bands of microtubules by Professor B. Gunning with Professor L. Fowke, University of Saskatchewan, Canada.

Video-microscope immunofluorescence of microtubules and actin in pollen tubes by Professor B. Gunning with Professor R. B. Knox and J. Kenrick, University of Melbourne.

Regeneration and the cytoskeleton of pine tissue cultures by Dr J. Gorst with Dr S. Chandler, Calgene Pacific, Melbourne, Victoria.

Reproductive tissues of orchids by Professor B. Gunning with M. Clements and Dr J. Armstrong, Australian National Botanic Gardens, Canberra.

Identification of hormone receptors on plant cell surfaces by monoclonal antibodies by Dr A.R. Hardham and Dr F. Gubler with Dr J.V. Jacobsen, CSIRO Division of Plant Industry, Canberra.

Application of immunoassays for the diagnosis of diseases caused by *Phytophthora* and *Erwinia* by Dr A.R. Hardham with J. Maughan and C. Richardson, Victorian Department of Agriculture and Rural Affairs, Burnley, Victoria.

Conserved cell division control proteins by Dr P.C.L. John with Professor P. Nurse, Oxford University, UK.

Initiation of polarity in plant tissues by Dr P. Warren Wilson with Professor J. Warren Wilson, Botany Department, ANU and Dr R. Overall, School of Biology, University of Sydney.

IAA conjugates and differentiation patterns by Dr P. Warren Wilson with Dr P. Hall, Michigan State University, USA.

Myosin and cytoplasmic streaming by Drs R.E. Williamson and F. Grolig[#] with Dr J. Parke, Pall Europe, Portsmouth, Dr C. Miller, University of Leicester and Dr B.H. Handerton, University of London, UK.

Actin-binding proteins by Drs R.E. Williamson, J. Plazinski and P.P. Jablonsky with Dr M. Fechheimer, University of Georgia, Athens, USA.

Localisation of calcium-dependent protein kinase in plant cells by Dr D.W. McCurdy with Dr A.C. Harmon, University of Georgia, Athens, USA.

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

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

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

Biochemical effects of auxins on stability of cytokinins by Dr L. Palni with Drs L.R. Burch and R. Horgan, University College of Wales, Aberystwyth, UK.

Growth regulating activity of humic acids by Dr L.M.S. Palni with Dr J.K. MacLeod, Research School of Chemistry, ANU, Canberra.

PLANT MOLECULAR BIOLOGY

Sequencing of the Rubisco large subunit genes from closely related C_3/C_4 relatives by Drs. T.J. Andrews and M.R. Badger (Plant Environmental Biology) with Drs. P. Whitfeld, W. Bottomley, G. Hudson and J. Mahon, CSIRO Division of Plant Industry, Canberra.

Enzyme kinetics of *Aspergillus* alcohol dehydrogenase by Dr. E.H. Creaser with Professor J. McKinley-McKee, Oslo University, Norway.

Protein Engineering of p-hydroxybenzoate hydroxylase by Dr. E.H. Creaser with Dr. B. Entsch, University of New England, Armidale, NSW.

Analysis of lipopolysaccharides (LPS) of *R. trifolii* by Prof. B. Rolfe with Professor R.W. Carlson, Eastern Illinois University, Charleston, Illinois, USA.

Regulation of *R. trifolii* nodulation genes by Prof. B. Rolfe, Drs J.J. Weinman and M. Djordjevic with Drs P. Kuempel and R. Innes, University of Colorado, Boulder, Colorado, USA.

Complementation and functional analysis of *R. trifolii nod* genes by Prof. B. Rolfe with Dr C.A. Wijffelman, University of Leiden, The Netherlands.

Analysis of plant resistance genes by Prof. B. Rolfe with Drs D. Gabriel and D. Loschke, University of Florida, Gainesville, Florida, USA.

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

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

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

Characterization of acid tolerant *R. trifolii* strains by Prof. B. Rolfe with Dr R. Simpson, University of Melbourne, Parkville, Melbourne, Victoria.

Public Interest Project, Section 39 by Prof. B. Rolfe with Drs P. Gresshoff and B. Carroll, The Faculties, ANU, Canberra; for field testing of genetically engineered microorganisms (GEMS) by Prof. B. Rolfe with Dr J. Brockwell, Microbiology Section, CSIRO Division of Plant Industry, Canberra.

Virus Identification Data Exchange (VIDE) Project, by Drs A.J.Gibbs, C. Buchen-Osmond, Ms K. Crabtree and Mr L. Watson with about 200 virologists around the world including, in particular, Dr A.A. Brunt, AFRC Institute of Horticultural Science, Littlehampton, UK, Dr G.D. McLean, Bureau of Rural Sciences, Canberra and Dr M.J.Dallwitz and Ms T.A.Paine, CSIRO Division of Entomology, Canberra.

Molecular genetic typing of the *Aspergillus flavus/parasiticus* group, by Dr B. Tyler with Dr P. Dart, University of Queensland.

Transcription of fungal genes, by Dr B. Tyler with Prof. J. Fincham, Cambridge University, UK.

Molecular genetics of *Phytophthora megasperma*, by Dr B. Tyler with Dr D. Kuhn, Purdue University, Indiana, USA.

PLANT ENVIRONMENTAL BIOLOGY

Studies on C_4 metabolite pools by by Dr S. von Caemmerer with Dr R. Leegood, University of Sheffield.

Isotope discrimination in barley genotypes by Dr K.T. Hubick and Prof. G.D. Farquhar and Drs D.H.B. Sparrow and R. Lance, Waite Research Inst., Adelaide, Dr P. Cornish, Agricultural Research Station, Gosford, Dr B. Read, Agric. Research Institute, Wagga Wagga, and Dr C. Walker, CSIRO Division Soils, Adelaide.

Isotope discrimination in cotton genotypes by Dr K.T. Hubick and Prof. G.D. Farquhar with Dr P. Lawrence, Queensland Dept. Primary Industry, Biloela and Mr P. Reid, CSIRO Cotton Research Unit, Narrabri.

Isotope discrimination in peanut by Dr K.T. Hubick and Prof. G.D. Farquhar with Dr R. Shorter, Qld Dept. Primary Industry, Brisbane, Dr G. Wright & Mr A. Cruikshank, Qld Dept. Primary Industry, Kingaroy, and Dr R.C.N. Rao, ICRISAT, India.

Water-use efficiency of crop growth by Prof. G.D. Farquhar and Dr S.C. Wong with Mr F. Dunin, Drs R.A. Fischer and R. Richards, CSIRO Division of Plant Industry, and Dr O.T. Denmead, CSIRO Division of Environmental Mechanics.

Isotope discrimination in cowpea by Dr K.T. Hubick and Prof. G.D. Farquhar and Prof. A.E. Hall, University of California, Riverside.

Isotope discrimination, ABA control and water-use efficiency in wheat by Prof. G.D. Farquhar and Dr K.T. Hubick with Dr R. Johnson, Oklahoma State University.

Isotope discrimination in barley by Prof. G.D. Farquhar and Dr K.T. Hubick with Dr Acevedo, ICARDA.

Discrimination in wheat by Prof. G.D. Farquhar and Dr K.T. Hubick with Dr Giles Waines, University of California, Riverside.

Water-use efficiency and discrimination in *Eucalyptus* by Prof. G.D. Farquhar with Dr A. Gibson and Prof. E. Bachelard, Botany Department, The Faculties.

Chilling and ABA levels in *Eucalyptus* by Dr K. Hubick with Ms R. Higa and Prof. E. Bachelard, Botany Department, The Faculties.

Isotope discrimination and growth in Western Australian wheat by Dr K.T. Hubick and Prof. G.D. Farquhar with Dr Neil Turner and Mr Neil Venn, Division of Dryland Crops, CSIRO, WA.

Association of water-use efficiency and molecular genetics of ABA in barley by K.T. Hubick with Dr Tim Close, Division of Plant Industry, CSIRO, Canberra.

Isotope discrimination and water-use efficiency and soil compaction in pigeonpea by Dr K.T. Hubick with Mr J. Kirkegaard, Agriculture Department, University of Queensland.

Analysis of high-CO_2 requiring mutants of *Synechococcus* PCC7942 by Drs M.R. Badger and G.D. Price with Dr. T. Ogawa, Riken Institute of Physical and Chemical Research, Japan.

ECOSYSTEM DYNAMICS

Ecological languages and modelling by Dr D.G. Green with Dr R.H. Bradbury, Australian Institute of Marine Science, Townsville, Queensland.

Spatially explicit ecosystem models by Dr D.G. Green with Dr R.E. Reichelt, Australian Institute of Marine Science, Townsville, Queensland.

Interactive bushfire simulation by Dr D.G. Green with Dr A.M. Gill, CSIRO Division of Plant Industry, Canberra.

Fine resolution pollen analysis by Dr D.G. Green with Dr G. Singh and Dr G. Dolman, Department of Biogeography and Geomorphology, RSPacS, ANU, Canberra.

Self-organizing, syntactic approaches to gene sequence analysis by Drs D.G. Green and I.R. Noble with Drs A.J. Gibbs and P. Keese of the Plant Molecular Biology Group, RSBS, ANU, Canberra.

The application of rule induction to the analysis of ecological data by Dr I.R. Noble with Dr H. Gitay, The Wildfowl Trust, Slimbridge, UK.

Review of biotic succession by Dr I.R. Noble and Professor R.O. Slatyer with Prof. J.H. Connell, University of California, Santa Barbara, USA.

Vegetation dynamics in the wet/dry tropics by Dr I.R. Noble with Professor P.A. Werner, CSIRO Division of Wildlife and Ecology, Darwin, NT.

Models of plant succession in the wet/dry tropics by Dr I.R. Noble and A.D. Moore with Dr A. Press, ANPWS, Jabiru, NT.

Application of expert systems to land management by Dr I.R. Noble with Dr G. Norton, Imperial College, London, UK.

Bibliography of fire ecology by Dr I.R. Noble with Dr A.M. Gill, CSIRO Division of Plant Industry, Canberra.

Functional attributes of savannah ecosystems by Dr I.R. Noble with Professor B.H. Walker, CSIRO Division of Wildlife and Ecology, Canberra.

Modelling weed seed biology by Dr I.R. Noble with Dr P. Weiss, School of Horticulture, Woden TAFE, Canberra.

Models of forest dynamics by Dr T.M. Smith with Professor H.H. Shugart and Dr D. Urban, University of Virginia, USA.

Plant successional theory by Dr T.M. Smith with Dr M. Huston, Oak Ridge National Lab., Tennessee, USA.

Allozyme variation in the green ash group of eucalypts by Ms S.M. Prober with Dr G. Moran, CSIRO Division of Forestry and Forest Products, Canberra.

Physiological responses of eucalypt species across interacting resource gradients by Drs A.B. Wellington, T.M. Smith, with Dr M.P. Austin, CSIRO Division of Wildlife and Ecology, Canberra

Interactions between disturbance, nutrients and competition in plant communities by Dr S.D. Wilson with Professor D. Tilman, University of Minnesota, USA.

Convergence of community structure along environmental gradients by Dr S.D. Wilson with Dr C. Nilsson, Umea University, Sweden.

Population dynamics and resprouting ability in selected chaparral shrubs along a gradient of time since fire by Dr C.A. Zammit with Professor P.H. Zedler, San Diego State University, California, USA.

Morphological and anatomical studies of vegetative buds in lignotubers of *Adenostoma fasciculatum* (chamise) by Dr C.A. Zammit with Dr S. Fink, Albert Ludwigs University, FRG.

CONFERENCES

This section lists the conferences at which staff and students of the school presented their research findings and gives the titles of their papers.

DIRECTOR'S UNIT

Local

Slatyer, R.O. Alpine and valley bottom treelines. 'The Scientific Significance of the Australian Alps'. Aust. Acad. Sci., Canberra, September.

DEVELOPMENTAL NEUROBIOLOGY

Local

Carter, M. and Stowe, S. The importance of mounting media for cryosections. Poster. Australian Electron Microscopy Society Conference, Adelaide, February.

Flett, D.L., Marotte, L.R. and Mark, R.F. Effects of binocular enucleation on the dorsal lateral geniculate of the wallaby. Australian Neuroscience Society Conference, Canberra, February.

Gummer, A.W. Reflections from the basilar membrane in pigeon. Australian Physiological and Pharmacological Society Meeting, Adelaide, August.

Hill, K.G. and Stange, G. Dualism in auditory sensory transduction. Australian Physiological and Pharmacological Society Meeting, Adelaide, August.

McClean, A.* and Trowell, S.C. 4-nitrophenylphosphatase cytochemistry performed on invertebrate retinae. Poster. Australian Electron Microscopy Society Conference, Adelaide, February.

Mark, R.F., Gregory, J.E.†, Morgan, D.L.† and Proske, U†. Changes in amplitude of the H reflex in human subjects after conditioning contractions of the triceps surae muscle at long and at short lengths. Australian Society of Experimental Biology, Bicentennial Meeting, Canberra, February.

Marotte, L.R. Development of topography of retinal connections to the dorsal lateral geniculate and superior colliculus of the wallaby. Australian Neuroscience Society Conference, Canberra, February.

Mo, J. and Hill, K.G. Auditory responses in chick embryo. Australian Physiological and Pharmacological Society Meeting, Adelaide, August.

Sheng, X.-M., Marotte, L.R. and Mark, R.F. Development of visual cortical connections in the wallaby. Australian Neuroscience Society Conference, Canberra, February.

Trowell, S.C. Visual transduction in rhabdomeric photoreceptors: flies, crabs and living fossils. Australian Dipteran Society Meeting, Corowa, September.

International

Blest, A.D. and O'Carroll, D.C.§ The evolution of the tiered principal retinae of jumping spiders. Invited contribution. International Congress on the Neurobiology of Sensory Systems, Goa, India, September.

Blest, A.D., Stowe, S., Trowell, S.C. and Carter, M. The cytoskeletal organisation of arthropod photoreceptors: some ambiguities and their interpretation. Invited contribution. 2nd International Congress of Comparative Physiology and Biochemistry, Baton Rouge, Louisiana, USA, August.

Gummer, A.W., Smolders, J.W.Th.+ and Klinke, R.+ Determinants of high-frequency sensitivity in the bird. Triennial NATO Advanced Research Workshop on the Mechanics of Hearing, University of Keele, UK, July.

Mark, R.F. and Marotte, L.R. The development of primary visual projections in a marsupial after rotation of an eye prior to optic innervation of the visual centres. Hong Kong Society for Neurosciences, Hong Kong, September.

Marotte, L.R., Flett, D.L. and Mark, R.F. Topography of retinogeniculate projections in the wallaby after monocular enucleation prior to retinal innervation of the visual centres. Hong Kong Society for Neurosciences, Hong Kong, September.

Trowell, S.C. and Carter, M. The polypeptide composition of the 4-nitro-phenyl phosphatase (4-NPPase) of invertebrate photoreceptor microvilli. XXIst Yamada Conference 'Molecular Physiology of Retinal Proteins', Kyoto, Japan, May.

Vickers, J.E.†, Mark, R.F., Zimmerman, M.S.† Plasticity in frog spinal cord: wiping reflexes and cord surface potentials after regeneration of cutaneous nerves. Australian Winter Conference on Brain Research, Queenstown, New Zealand, August.

MOLECULAR NEUROBIOLOGY

Local

Ball, E.E. Neurite outgrowth, growth factors, and the extracellular matrix in insect embryos. Invited Lecture to Australian Neuroscience Society, ANU, February.

Ball, E.E. The role of cell recognition in the development of insect nervous systems. Invited Lecture to ANZ Society for Cell Biology, ANU, February.

Boyan, G.S. The cellular basis of a behaviour: from sensory neurone to behavioural output in the flight system of the locust. Invited Lecture to Australian Neuroscience Society, ANU, February.

de Couet, H.G., Yamamoto, M.§, Davies, J.*, Pirrotta, V.+ and Miklos, G.L.G. Molecular approaches to the nervous system: genetic and molecular characterization of genes affecting neuronal and neuro-muscular functions in *Drosophila melanogaster*. Invited lecture to Australian Neuroscience Society, ANU, February.

Hennig, R.M. Cricket ascending auditory interneurones: identification and input connections. Australian Neuroscience Society, ANU, February.

Myers, C.M. and Ball, E.E. Comparative development of the femoral muscles in the legs of the locust. Australian Neuroscience Society, ANU, February.

International

Baird, D.H.+, Wyman, R.J.+, Davies, J.A.* and Miklos, G.L.G. Genetic and neurophysiological studies of the mutants *Passover* and *shaking-B*^{2} which affect neuronal connectivity in *Drosophila melanogaster*. 2nd European Drosophila Neurogenetics Meeting. Siguenza, Spain, September.

Ball, E.E. and Quinn, J.M.A. Neuromuscular development in the orthopteroid insects. XVIII International Congress of Entomology, Vancouver, Canada, July.

Barleben, F.+, Baumann, W.+, Davies, J.*, Pirrotta, V.+, Olsen, J., Hall, F., Cotsell, J., Delaney, S., Hayward, D., Schuppler, U., Fischbach, K.F. and Miklos, G.L.G. Molecular and genetic analysis of the *small optic lobes/sluggish* region of the X-chromosome of *D.melanogaster*. 2nd European Drosophila Neurogenetics Meeting, Siguenza, Spain, September.

Boyan, G.S., Williams, J.L.D.# and Fullard, J.H.# Integration at a central synapse in the auditory system of a moth (*Agrotis infusa*: Noctuidae). 16th Göttingen Neurobiology Conference, Göttingen, FRG, May.

Boyan, G.S., Ball, E.E. and Williams, J.L.D.# A comparative approach to the evolution of orthopteroid cercal receptor/giant interneurone systems. XVIII International Congress of Entomology, Vancouver, Canada, July.

Hennig, R.M. Central organization of cricket motor patterns. 16th Göttingen Neurobiology Conference, Göttingen, FRG, May.

Perrimon, N.+, Smouse, D.+, and Miklos, G.L.G. Developmental genetics of loci associated with neurological defects at the base of the X chromosome of *D.melanogaster*. 2nd European Drosophila Neurogenetics Meeting, Siguenza, Spain, September.

Whitington, P.M.#, Myers, C.M. and Ball, E.E. Pathfinding by motor axons in the locust embryo. XVIII International Congress on Entomology, Vancouver, Canada, July.

VISUAL SCIENCES

Local

Barlin, G.B.†, Davies, L.P.#, Ireland, S.J.† and Ngu, M.M.L.† Synthesis and biological activities of some imidazo (1,2-b) pyridazines. RACI, Medicinal and Agricural Chemistry Section, November–December.

Bossomaier, T.R.J.† and Osorio, D. Cone-pigment spectral sensitivity and retinal information capacity. The International Society for Comparative Psychology Meeting, Sydney, August.

Davies, L.P.#, Ngu, M.M.L.† and Barlin, G.B.† The activity of some substituted imidazo (1,2-b) pyridazines at central benzodiazepine receptors. ASCEP 22nd Ann. Meeting, Adelaide, December.

Horridge, G.A. Technical perspectives derived from insect vision. International Meeting of Associations to Assist the Blind, Melbourne, March.

Morgan, I.G. D-O-phosphoserine is both a kainic acid and quisqualic acid antagonist at horizontal, bipolar and amacrine cell receptors. Australian Neuroscience Society Meeting, Canberra, February.

Morgan, I.G. Retinal circuitry and retinal neurotransmitters. Joint Australian Physiological and Pharmacological Society/Australian Neuroscience Society Symposium on Seeing Through the Visual System, Canberra, February.

Morgan, I.G. New perspectives on excitotoxicity. Australian Neuroscience Society Meeting, Canberra, February.

Morgan, I.G. and Millar, T.J.* Localization of nicotine acetylcholine receptors in the chicken retina. Australian Neuroscience Society Meeting, Canberra, February.

Srinivasan, M.V. Visual motion processing in the invertebrate context. Annual Meeting of the Australian Neuroscience Society, Canberra, February.

Tung, N.N., Morgan, I.G. and Ehrlich, D.* Differential effects of KA and AMPA on the retinal ganglion cell layer of the chicken retina. Australian Neuroscience Society Meeting, Canberra, February.

Yang, G., Morgan, I.G. and Dvorak, D.* Ganglion cell responses in ECMA lesioned chicken retina. Australian Neurosicence Society Meeting, Canberra, February.

Yang, G., Morgan, I.G., and Millar, T.J.* Morphological studies of displaced ganglion cells in the chicken retina. Australian Neuroscience Society Meeting, Canberra, February.

van der Valk, J. Are response functions for kainic acid and quisqualic acid determined electrophysiologically in the axolotl inner retina. Australian Neuroscience Society Meeting, Canberra, February.

Warrant, E. Insect Optics. The Australian Physics Society, Sydney, February.

International

James, A. and Osorio, D. Spatiotemporal white-noise studies of fly lamina cells. Annual Meeting of European Neuroscience Association, Zurich, Switzerland, September.

Horridge, G.A. Insect vision as a guide to the design of artificial seeing systems. 11th European Conference on Vision, Bristol, UK, September.

Horridge, G.A. Primitive vision based on sensing change. Introductory speaker and keynote address at the International Conference on Neurobiology of Sensory Systems, Goa, India, September.

Kirchner, W.H.[+] and Srinivasan, M.V. Estimation of distance using retinal image motion in freely-flying honeybees. Neurobiologen Tagung, Göttingen, FRG, June.

Lehrer, M.V.[#], Srinivasan, M.V. and Wehner, R.[+] Bees perceive motion induced colour illusions. Annual Meeting of the European Neuroscience Association, Zurich, Switzerland, September.

Morgan, I.G. Functional studies on enkephalin- and somatostatin-immunoreactive amacrine cells in the chicken retina. NATO Workshop on the Neurobiology of the Inner Plexiform Layer, Oldenburg, FRG, August.

Morgan, I.G. Diversity of retinal interneurons and retinal function. Hong Kong Society for Neurosciences Meeting, Hong Kong, September.

Srinivasan, M.V. Motion sensitivity in insect vision: roles and neural mechanisms. International Conference on Neurobiology of Sensory Systems, Goa, India, September.

Srinivasan, M.V., Lehrer, M.[#], Kirchner, W.[§], Zhang, S.W.[#] and Horridge, G.A. How honeybees use motion cues to estimate range and discriminate objects. IEEE International Conference on Systems, Man and Cybernetics. Academia Sinica, Beijing, People's Republic of China, August.

Srinivasan, M.V., Lehrer, M.[#], Kirchner, W.[§], Zhang, S.W.[#] and Horridge, G.A. How motion cues extend honeybee vision into the third dimension. Annual Meeting of the European Neuroscience Association, Zurich, Switzerland, September.

Warrant, E. Superposition optics. The IEEE Systems, Man and Cybernetics Conference, Beijing, People's Republic of China, September.

Yang, G., Millar, T.J.* and Morgan, I.G. Morphological studies of displaced ganglion cells in the chicken retina. American Society for Neuroscience Meeting, Toronto, Canada, November.

MOLECULAR GENETICS

Local

Naora, H. and Sun, L.-Q.* A regulatory mechanism for oncogene expression in normal and tumour cells. 7th Annual Meeting of Australia and New Zealand Society for Cell Biology, Canberra, February.

International

Clark-Walker, G.D. The Genome of Bakers Yeast—the benchmark for a Eukaryotic Cell. VII International Symposium on Yeasts, Perugia, Italy, August.

Clark-Walker, G.D. and Skelly, P.J. Influence of base-biased sequences on recombination, transmission and expression of the mitochondrial genome in *Saccharomyces cerevisiae*. XIV EMBO Symposium, 'Organelles and the Nucleus', Heidelberg, FRG, September.

Naora, H. and Sun, L.-Q.* A possible regulatory mechanism for *c-myc* expression in normal and tumour cells. 4th International Congress of Cell Biology, Montreal, Canada, August.

Sun, L.-Q.* A possible regulatory mechanism for *c-myc* activation in some cancer cells. The Meeting of the Chinese Biochemical Society of Military Medicine, Beijing, People's Republic of China, August.

POPULATION GENETICS

Local

Jiang, C. and Gibson, J.B. Comparisons of allozyme frequencies in Chinese and Australian populations of *Drosophila melanogaster*. 35th Annual Conference of the Genetics Society of Australia, La Trobe University, Melbourne, May.

Marchant, A.D. Zonemodel: a computer package for investigating genetic interactions in hybrid zones. 35th Annual Conference of the Genetics Society of Australia, La Trobe University, Melbourne, May.

Rowell, D.M. The origin of complex sex-linked translocation heterozygosity in *Delena cancerides* (Sparassidae: Arachnida). 35th Annual Conference of the Genetics Society of Australia, La Trobe University, Melbourne, May.

Symonds, J.E. and Gibson, J.B. Biochemical characterisation of low activity variants of glycerol-3-phosphate dehydrogenase from natural populations of *Drosophila melanogaster*. 35th Annual conference of the Genetics Society of Australia, La Trobe University, Melbourne, May.

International

Kohlmann, B.C. Environmental Predictions and Distributional Limits of Chromosomal Taxa in the Australian Grasshopper *Caledia captiva*. XVIII International Entomology Congress, UBC, Vancouver, Canada, July.

Shaw, D.D. Evolutionary and Ecological Consequences of Hybridization in Insects. Invited Symposium speaker. XVIII International Entomology Congress, UBC, Vancouver, Canada. July.

PLANT CELL BIOLOGY

Local

Cleary, A.L. and Hardham, A.R. Use of the herbicide oryzalin to study microtubule dynamics in root tip cells of sensitive and resistant plants. Twenty-eighth general meeting of the Australian Society of Plant Physiologists, Adelaide, May.

Gubler, F. and Hardham, A.R. Monitoring adhesiveness of zoospores and cysts of the dieback fungus *Phytophthora cinnamomi*. Twenty-eighth general meeting of the Australian Society of Plant Physiologists, Adelaide, May.

Hardham, A.R. Lectin and antibody labelling of surface components of spores of the dieback fungus *Phytophthora cinnamomi*. Plant micro-organism interfaces: Structure and function. Pre-conference workshop associated with the twenty-eighth general meeting of the Australian Society of Plant Physiologists, Adelaide, May.

Pogson, B.J.$^{+}$, Ashford, A.E.* and Gubler, F. Localisation of α-amylase in the scutellum, germ and normal aleurone of intact germinated barley grains by immunofluorescence. Twenty-eighth general meeting of the Australian Society of Plant Physiologists, Adelaide, May.

Webb, M. C. and Gunning, B. E. S. The microtubular cytoskeleton during embryo sac development in *Arabidopsis thaliana*. Pollination 88 Symposium, University of Melbourne, July.

White, R.G.$^{+}$, Hyde, G.J. and Overall, R.O.* Elongation of initially non-polar protoplasts is oriented by electric fields. Twenty-eighth general meeting of the Australian Society of Plant Physiologists, Adelaide, May.

International

Busby, C. and Gunning, B. E. S. Spatial control of meiosis in *Funaria* sporogenesis by a quadripolar apparatus of microtubules: normal development and recovery from oryzalin depolymerization. Gordon Research Conference on The Cellular and Molecular Biology of the Plant and Fungal Cytoskeleton, Andover, New Hampshire, USA, August.

Carmichael, J.P. and John, P.C.L. Cloning a gene from *Chlamydomonas* homologous with the start division gene of yeast and humans. Third International Phycological Congress, Melbourne, August.

Cleary, A.L. and Hardham, A.R. Oryzalin-induced depolymerization of microtubule arrays in root tip cells, and their recovery with modified nucleation patterns. Gordon Conference on The Cellular and Molecular Biology of the Plant and Fungal Cytoskeleton, Andover, New Hampshire, USA, August.

Cleary, A.L. and Hardham, A.R. Immunofluorescence microscopy of microtubules during development of stomatal complexes in *Lolium rigidum*. Gordon Conference on The Cellular and Molecular Biology of the Plant and Fungal Cytoskeleton, Andover, New Hampshire, USA, August.

Davis, A.R. Nectaries: secretory structures important to beekeepers. Second Australian and International Bee Congress, Surfers Paradise, Queensland, July.

Davis, A.R. Contamination of honeybee larval food by insecticide: some possible pathways. Second Australian and International Bee Congress, Surfers Paradise, Queensland, July.

Galway, M.E. and Hardham, A.R. Effects of the microtubule inhibitor oryzalin on microtubule reorganization in algal protoplasts. Fourth International Congress on Cell Biology, Montreal, Canada, August.

Gorst, J. and Gunning, B. E. S. Preprophase bands in callus and suspension cultures. Gordon Research Conference on The Cellular and Molecular Biology of the Plant and Fungal Cytoskeleton, Andover, New Hampshire, USA, August.

Grolig, F.$^{\#}$, Lin Qiao, Jablonsky, P.P. and Williamson, R.E. Immunodetection and localization of myosin in higher plants and the green alga *Chara*. 4th International Congress of Cell Biology, Montreal, Canada, August.

Gunning, B.E.S. Preprophase band development. Gordon Research Conference on The Cellular and Molecular Biology of the Plant and Fungal Cytoskeleton, Andover, New Hampshire, USA, August.

Gunning, B.E.S. The preprophase band *in vivo* and *in vitro*. 4th International Cell Biology Congress, Montreal, Canada, August.

Gunning, B. E. S., McCurdy, D. and Sammut, M. Development of preprophase bands and associated actin in wheat root tip cells. Gordon Research Conference on The Cellular and Molecular Biology of the Plant and Fungal Cytoskeleton, Andover, New Hampshire, USA, August.

Hardham, A.R. Microtubule reorganisation in regenerating protoplasts of the green alga *Mougeotia*. Gordon Conference on The Cellular and Molecular Biology of the Plant and

Fungal Cytoskeleton, Andover, New Hampshire, USA, August.

Hardham, A. Ultrastructure and immunocytology of zoospores and cysts of *Phytophthora cinnamomi*. Fifty-third meeting of the Mycological Society of America, Davis, CA, USA, August.

Harper, J.D.I. and John, P.C.L. Analysis of the *Chlamydomonas* cell division cycle by conditional mutant isolation. American Society for Cell Biology Conference: Algal experimental systems in cell biological research, Airlie, Virginia, USA, June.

Harper, J.D.I. and John, P.C.L. Genetical analysis of the *Chlamydomonas* cell division cycle. Third International Phycological Congress, Melbourne, August.

Hoggart, R., Williamson, R.E., John, P.C.L., Ballantyne, K., Croft, L. Temperature-sensitive mutations affecting the control of cell shape in the roots of *Arabidopsis thaliana*. Gordon Conference on The Cellular and Molecular Biology of the Plant and Fungal Cytoskeleton, Andover, New Hampshire, USA, August.

Horgan, R.$^{+}$, Burch, L.R.$^{+}$ and Palni, L.M.S.$^{\#}$ The degradative metabolism of cytokinins. 13th International Conference on Plant Growth Substances, Calgary, Canada, July.

Jablonsky, P.P. and Williamson, R.E. A microtubule-associated protein isolated from mung bean hypocotyl segments. Gordon Research Conference on The Cellular and Molecular Biology of the Plant and Fungal Cytoskeleton, Andover, New Hampshire, USA, August.

John, P.C.L. *Chlamydomonas* and controls in plant cell division. Cellular and Molecular Biology of *Chlamydomonas*, Cold Spring Harbor, New York, USA, May.

John, P.C.L., Sek, F.J. and Elliott, J. Cell division in *Chlamydomonas*: conservation of a start division control point and of a start protein cdc-2. Third International Phycological Congress, Melbourne, August.

Letham, D.S., Parker, C.W., Zhang, R.$^{\#}$, Singh, S., Upadhyaya, M.N.*, Dart, P.J.* and Palni, L.M.S.$^{\#}$ Xylem translocated cytokinin – metabolism and function. 13th International Conference on Plant Growth Substances, Calgary, Canada, July.

McCurdy, D. and Gunning, B. E. S. Secretion of a carbohydrate epitope into cell walls of a higher plant. 4th International Cell Biology Congress, Montreal, Canada, August.

Nandi, S.K., de Klerk, G.J.M.*, Parker, C.W., Wong, O.C. and Palni, L.M.S.$^{\#}$. Endogenous cytokinins and their metabolism in relation to genetic tumour formation in tobacco hybrids. 13th International Conference on Plant Growth Substances, Calgary, Canada, July.

Noodén, L.D.§, Guianét, J.$^{+}$, Singh, S., Letham, D.S., Tsuji, J.$^{+}$ and Schneider, M.J.$^{+}$ Hormonal control of senescence. 13th International Conference on Plant Growth Substances, Calgary, Canada, July.

Palni, L.M.S.$^{\#}$ The biochemistry and molecular biology of cytokinin production and metabolism. International Congress of Plant Physiology, New Delhi, India, February.

Palni, L.M.S.$^{\#}$, Nandi, S.K, Singh, S. and Letham, D.S. An overview of cytokinin biosynthesis. 13th International Conference on Plant Growth Substances, Calgary, Canada, July.

Parker, C.W., Badenoch-Jones, J.$^{\#}$ and Letham, D.S. A radioimmunoassay for quantifying the cytokinins, *cis*-zeatin and *cis*-zeatin riboside and its application to xylem sap samples. 13th International Conference on Plant Growth Substances, Calgary, Canada, July.

Sakuanrungsirikul, S. and John, P.C.L. Cyclic AMP and *Chlamydomonas reinhardtii* cell division cycle. Third International Phycological Congress, Melbourne, August.

Wasteneys, G.O., Jablonsky, P.P., Williamson, R.E. Microtubule assembly in giant internodal cells of *Nitella*. Gordon Research Conference on The Cellular and Molecular Biology of the Plant and Fungal Cytoskeleton, Andover, New Hampshire, USA, August, and 4th International Congress of Cell Biology, Montreal, Canada, August.

Williamson, R.E, Grolig, F.$^{\#}$, Lin, Q., Jablonsky, P.P. Localisation and detection of myosin in plants and its relation to cytoplasmic streaming. Gordon Research Conference on The Cellular and Molecular Biology of the Plant and Fungal Cytoskeleton, Andover, New Hampshire, USA, August.

Williamson, R.E, Wasteneys, G.O., Grolig, F.$^{\#}$, Lin, Q., Jablonsky, P.P. The characean cytoskeleton. International Congress of Histochemistry and Cytochemistry, Washington, D.C., USA, August.

PLANT MOLECULAR BIOLOGY

Local

Bruhl. J.J., Stone, N.E. and Hattersley, P.W. Variations in photosynthetic pathways in sedges (Cyperaceae). 28th Annual Meeting, Australian Society of Plant Physiologists, Adelaide, May.

Ding, S.-W. Molecular evolution of tymoviruses. 32nd Annual Conference of the Australian Biochemical Society, May.

Gibbs, A.J., Keese, P., Osorio-Keese, M. and Ding, S.-W. Tymovirus relationships. Poster. Tenth Annual Conference on The Organization and Expression of The Genome, Lorne, February.

Gibbs, A.J. Turnip yellow mosaic virus—a significant migrant to the Australian Alps. 1st Fenner Conference of the Australian Academy of Science on 'The scientific significance of the Australian Alps', September.

Gibbs, A.J. ANCA-CSIRO Workshop on 'Development of an Australian Antiviral Industry for AIDS'.

McIver, J., Djordjevic, M.A. and Rolfe, B.G. Determination of *nodD* functional domains by chemical mutagenesis using nitrosoguanidine. Poster. Tenth Annual Conference on The Organization and Expression of The Genome, Lorne, February.

Morell, M.K. and Andrews, T.J. The role of a carboxylterminal sequence of ribulosebisphosphate carboxylase from *Rhodospirillum rubrum* studied by site-directed mutagenesis. Annual Meeting, Australian Biochemical Society, Adelaide, May.

Morell, M.K. and Price, G.D. Australian science: problems at the coalface. National Science and Technology Analysis Group Forum, Canberra, November.

Nayudu, M. and Rolfe, B.G. *Rhizobium nod D* regulatory gene key element of nodulation host specificity, Poster. Tenth Annual Conference on The Organization and Expression of The Genome, Lorne, February.

Tyler, B.M. and Harrison, K. Transcriptional sequences common to ribosomal component genes transcribed by RNA polymerase I, RNA polymerase II and RNA polymerase III. Tenth Annual Conference on The Organisation and Expression of the Genome, Lorne, February.

Tyler, B.M. and Harrison, K.H. Promoter elements common to ribosomal genes transcribed by RNA polymerases I, II and III in *Neurospora*, Thirty-second Annual Aust. Biochem. Society Meeting, Adelaide, May.

Weinman, J.J., Djordjevic and Rolfe, B.G. A molecular analysis of the host range genes of *Rhizobium trifolii*. Poster. Tenth Annual Conference on The Organization and Expression of The Genome, Lorne, February.

International

Bassam, B.J.*, Djordjevic, M.A., Redmond, J.W.+, Batley, M.+ and Rolfe, B.G. *Rhizobium* strain NGR234 *nodD1* gene product interacts with a wide range of plant-secreted and commercial phenolic factors, Fourth International Symposium on the Molecular Biology of Plant-Microbe Interactions, Acapulco, Mexico, May.

Bender, G.L. The genetic basis of *Parasponia* nodulation by *Rhizobium*, Fourth International Symposium on the Molecular Biology of Plant-Microbe Interactions, Acapulco, Mexico, May.

Creaser, E.H. Redesigning alcohol dehydrogenase by protein engineering, International Congress of Biochemistry, Prague, Czechoslovakia, July.

Dazzo, F.B.+, Hollinsworth, R.I.+, Salzwedel, J.L.+, Philip Hollinsworth, S.+, Robeles, M.+, Olen, T.A.+, Apenzeller, L.+, Wong, S.+, Foro, I.+, Squartini, A.+, Anderson, S.F.+, Chen, J.+, Chapman, K.A.+, Maya-Flores, J.+, Cargill, L.C.+, Djordjevic, M.A. and Rolfe, B.G. Signal-recognition responses in the *Rhizobium trifolii*—white clover symbiosis. Fourth International Symposium on the Molecular Biology of Plant-Microbe Interactions, Acapulco, Mexico, May.

Gray, J., Batley, M.+, Chen, H.*, Redmond, J.+, Arioli, T., Djordjevic, M. and Rolfe, B.G. Regulation of exopolysaccharide synthesis in *Rhizobium* strain NG234. Fourth International Symposium on the Molecular Biology of Plant-Microbe Interactions, Acapulco, Mexico, May.

Le Strange, K., Batley, M.+, Redmond, J.+, Bender, G., Lewis, W., Rolfe, B.G. and Nayudu, M. Plant signals for nodulation by *Rhizobium*: Broad and narrow host-range strategies. Fourth International Symposium on the Molecular Biology of Plant-Microbe Interactions, Acapulco, Mexico, May.

McIver, J., Djordjevic, M.A., Weinman, J.J. and Rolfe, B.G. Point mutants in *Rhizobium leguminosarium* biovar *trifolii nodD* result in mutants with altered function. Fourth International Symposium on the Molecular Biology of Plant-Microbe Interactions, Acapulco, Mexico, May.

Nayudu, M., Bender, G., Lewis, W. and Rolfe, B.G. Broad host range *Rhizobium nodD* regulatory gene key element of nodulation host specificity and non-legume host-specific interactions. Fourth International Symposium on the Molecular Biology of Plant-Microbe Interactions, Acapulco, Mexico, May.

Piskur, J. Selective inheritance of intergenetic sequences of the yeast mitochondrial genome, International Congress of Biochemistry, Prague, Czechoslovakia, July.

Rolfe, B.G., Batley, M.+, Redmond, J.W.+, Richardson, A.E.*, Bassam, B.*, Sargent, L., Weinman, J.J. and Djordjevic, M.A. Phenolic compounds induced in white clovers as a result of infection by *Rhizobium trifolii*, International Congress on Nitrogen Fixation, Cologne, FRG, March.

Thompson, W., Kashemsanta, A., Mao, Y. and Tyler, B.M. Molecular genetics of *Phytophthora megasperma* f.sp. *glycinea*, UCLA Colloquium on Molecular Biology of Plant-Pathogen Interactions, Steamboat Springs, Colorado, USA, March–April.

Tyler, B.M., Shi, Y. and Harrison, K. A transcriptional element common to ribosomal RNA and protein genes in *Neurospora*. UCLA Symposium on DNA-Protein Interactions in Transcription, Keystone, Colorado, USA, April.

Weinman, J.J. A molecular analysis of the host range genes of *Rhizobium trifolii*. Poster. UCLA Plant-Pathogen

Interaction and Plant Development Symposia, Steamboat Springs, Colorado, USA, March.

Weinman, J.J., Djordjevic, M.A., Sargent, C.L., Dazzo, F.B.$^{+}$ and Rolfe, B.G. A molecular analysis of the host range genes of *Rhizobium trifolii*. Fourth International Symposium on the Molecular Biology of Plant-Microbe Interactions, Acapulco, Mexico, May.

PLANT ENVIRONMENTAL BIOLOGY

Local

Badger, M.R. and Price, G.D. Carbonic anhydrase activity associated with the cyanobacterium *Synechococcus* PCC7942. Annual Meeting, Australian Society of Plant Physiologists, Adelaide, May.

Edmondson, D.L., Andrews, T.J. and Badger, M.R. Slow inhibition of ribulosebisphosphate carboxylase during catalysis, unrelated to decarbamylation. Annual Meeting, Australian Biochemical Society, Adelaide, May.

Evans, J.R. Leaf photosynthesis in relation to growth irradiance and nitrogen content. Invited lecture, Riverina Murray Institute of Higher Education residential school for Plant Science and Viticulture Science, Wagga, September.

Farquhar, G.D. Atmosphere-land plant interactions. International Geosphere-Biosphere Programme on Global Change, Canberra, February.

Hubick, K.T. and Farquhar, G.D. Carbon isotope discrimination—a selection criterion for improving cotton yield, Fourth Australian Cotton Conference, Surfers' Paradise, Qld., August.

Hubick, K.T., Farquhar, G.D. and Shorter, R.$^{+}$ Carbon isotope discrimination in C_3 plants: Physiology and genetics. Annual Meeting, Australian Society of Plant Physiologists, Adelaide, May.

Hubick, K.T., Millar, D. von Caemmerer, S. and Farquhar, G.D. Stable carbon isotope application and measurement in biological problems, 11th Conference of the Australian and New Zealand Society for Mass Spectrometry, Inc. Brisbane, May.

Hubick, K.T., Richards, R.A.$^{+}$, Condon, A.G. and Farquhar, G.D. Variation in carbon isotope discrimination and water-use efficiency within C_3 species, IXth Australian Plant Breeding Conference. Wagga Wagga, June.

Price, G.D. and Badger, M.R. Evidence for a 'carbonic anhydrase-like' step in the uptake of CO_2 by the cyanobacterium *Synechococcus* PCC7942, Annual Meeting, Australian Society of Plant Physiologists, Adelaide, May.

Price, G.D. and Badger, M.R. Isolation and characterization of high-CO_2 requiring mutants of the cyanobacterium PCC7942, Annual Meeting, Australian Society of Plant Physiologists, Adelaide, May.

Richards, R.A.$^{+}$, Hubick, K.T., Condon, A.G., and Farquhar, G.D. Carbon isotope discrimination: a selection criterion for improved water-use efficiency in C_3 species, IXth Australian Plant Breeding Conference. Wagga Wagga, June.

Shorter, R.$^{+}$, Hubick, K.T. and Farquhar, G.D. Water-use efficiency and carbon isotope discrimination in peanuts (*Arachis hypogaea* L.)—heritability and genotype x environment interactions, IXth Australian Plant Breeding Conference. Wagga Wagga, June.

Woo, K.C., Berger, M.G.$^{+}$ and Wong, S.C. Interaction between photosynthesis and nitrogen metabolism at normal and high CO_2, Annual Meeting, Australian Society of Plant Physiologists, Adelaide, May.

Yu, J. and Woo, K.C. Regulation of glutamine transport on photorespiratory ammonia assimilation in isolated chloroplasts, Annual Meeting, Australian Society of Plant Physiologists, Adelaide, May.

International

Evans, J.R. Photosynthesis—the dependence on nitrogen partitioning. Genotypic variation in growth rate and productivity. Physiological, biochemical and morphological backgrounds; ecological and agronomic consequences. Utrecht, The Netherlands, December.

Evans, J.R. and Farquhar, G.D. Modelling canopy photosynthesis from the biochemistry of the C_3 chloroplast, American Society of Agronomists—Crop Science Society of America. Anaheim, California, USA, November.

Farquhar, G.D. Models of integrated photosynthesis of cells and leaves, Royal Society meeting on Measurement of Photosynthesis, London, UK, May.

Farquhar, G.D. Chairman, Form and function of the photosynthetic apparatus, Photosynthesis Symposium, Stanford, USA, July.

Farquhar, G.D. Terrestrial Photosynthesis, U.S.–Australia Workshop on Remote Sensing of Biosphere Functioning, Honolulu, USA, July.

Farquhar, G.D., Wong, S.C., Evans, J.R. and Hubick, K.T. Photosynthesis and gas exchange, Experimental Biology—Symposium on Plants under Stress, Lancaster, UK, March.

Hubick, K.T. Water-use efficiency and stable carbon isotopes, Invited lecture, Gordon Conference on chemistry and physics of stable isotopes, Tilton, NH, USA, June.

Terashima, I. Productive structure of a leaf, C.S. French symposium on photosynthesis, Stanford, CA, USA, July.

Terashima, I. Effects of light and nitrogen on leaf photosynthesis, US–Japan seminar on stress physiology and biochemistry, Fairbanks, Alaska, USA, July.

Terashima, I. Non-uniform photosynthesis in stressed leaves, US–Japan seminar on stress physiology and biochemistry, Fairbanks, Alaska, USA, July.

Wong, S.C. and Woo, K.C. Effects of humidity and nutrition during growth on photosynthesis and carbon partition of cotton and sunflower plants, International Symposium on Regulation and Efficiency of Photosynthesis, Shanghai, People's Republic of China, September.

Woo, K.C. Regulation of metabolic transport in the chloroplast during photorespiratory NH_3 assimilation, Invited lecture, Chinese Society of Plant Physiologists (Guangzhou Branch), People's Republic of China, September.

Yu, J. and Woo, K.C. Regulation of glutamine transport on photorespiratory ammonia assimilation in isolated chloroplasts, International Symposium on Regulation and Efficiency of Photosynthesis, Shanghai, People's Republic of China, September.

ECOSYSTEM DYNAMICS

Local

Green, D.G. Interactive bushfire simulation. (Demonstration) Conference on Bushfire Modelling and Fire Danger Ratings Systems, Canberra, July.

Green, D.G. Cellular automata models of Crown-of-Thorns outbreaks. The Acanthaster Phenomenon: a modelling approach, Townsville, August.

Green, D.G. The use of process models for interpreting pollen records. 7th International Palynological Congress, Brisbane, September.

Green, D.G. Statistical interpretation of fine resolution pollen records. 7th International Palynological Congress, Brisbane, September.

Green, D.G. Interactive pollen time series analysis. (Demonstration) 7th International Palynological Congress, Brisbane, September.

Hodda, M. The role of harvester and forager termites in an Australian savanna. Ecological Society of Australia Open Forum, Geraldton, September.

Keith, H. Effects of prescribed burning on nitrogen cycling and tree growth in a snowgum forest. Ecological Society of Australia Open Forum, Geraldton, WA, September (Winning the 1988 student prize for presentation).

Keith, H. Effects of low-intensity prescribed burning and N-fertilization on soil mineral-N dynamics in a snowgum forest. Poster. Australian Soil Science Society, Canberra, May.

Moore, A.D. and Noble, I.R. Fire in Kakadu: predicting vegetation structure. Symposium on Responses of Savannas to Stress and Disturbance, CSIRO Darwin, October.

Noble, I.R. and Norton, G. Costing of ecological modelling. CONCOM meeting, Sydney, February.

Noble, I.R. Integrative and Predictive Approaches to Terrestial Biospheric Processes. Symposium on Global Change, Aust Academy of Science, Canberra, March.

Prober, S.M. Bell, J.C. and Moran, G. Inferences on rarity in *Eucalyptus paliformis* from a phylogeny of the green ash group of eucalypts, estimated from allozyme data. Ecological Society of Australia Open Forum, Geraldton, September.

Williams, J.E. The effect of herbivory on the distribution of *Eucalyptus pauciflora* in the Brindabella Ranges, south eastern Australia. Ecological Society of Australia Open Forum, Geraldton, September.

International

Austin, M.P. and Smith, T.M. A new model of the continuum concept. International Association of Vegetation Science, Vienna, July.

Noble, I.R. Qualitative models of the dynamics of forests. Models of Forest Dynamics and Productivity, Guildford, U.K., January.

Noble, I.R. Expert systems and qualitative models in landscape management. ITE Workshop on Landscape Information Systems, Imperial College, U.K., February.

Noble, I.R. Qualitative models of vegetation change. International Association of Vegetation Science. Vienna, Austria, July.

SYMPOSIA, VISITORS AND SEMINARS

The School hosts a large number of Visiting Fellows. Set out below is a list of visitors and an indication of some of the seminars and lectures given.

1988 ROBERTSON SYMPOSIUM

The 1988 Robertson Symposium (Nov 30th to Dec 2nd), opened by Professor Sir Rutherford Robertson, former Director of RSBS, was on the topic 'Molecular Interactions of Viruses, etc' and was attended by over 80 virologists from 10 countries. The meeting was notable not only for the attendance of scientists from Australasia, Europe and North America, but also several scientists from South-east Asia who are leading the move by their countries into molecular genetic research.

There were many highlights in the programme of 45 papers and posters. For example, there was much discussion of experiments on plants that had been genetically modified to carry various viral genes. Such plants transformed with viral coat protein, but not polymerase genes resist infection by the parental virus. There were similar reports of resistance obtained by transforming plants with DNA copies of satellite (hyperparasitic) RNAs of viruses. Most of this work is still experimental, but Professor Tien Po of Beijing, People's Republic of China, reported successful field testing of such plants.

There was also discussion of research, mostly done in Australian laboratories, on the life cycle strategies of viroids and satellite RNAs (virusoids). This work, in the CSIRO Division of Plant Industry by Drs Wayne Gerlach and Jim Haseloff, has led to the isolation and characterization of ribozymes able to cleave RNA at specific sites; a development of very great scientific potential.

An evening session heard of the subtle interactions of antibodies and protein antigens, revealed by the collaborative work of Dr Graeme Laver of the John Curtin School of Medical Research and Dr Peter Colman of the CSIRO Division of Biotechnology. Also the origins, life cycle strategies and control of 'computer viruses', described by Mr Geoff Huston, stimulated a lively discussion of parasitic information systems.

Two recurring themes of the symposium were, firstly, the increasing body of information about the genetic and molecular factors that control disease; not only the molecular changes in the infected plants, but also the effects of deliberately mutating viral genes, on symptom production. The second theme was of the continuing value of the comparative molecular studies for distinguishing adaptive molecular 'signals' from 'evolutionary noise'.

DEVELOPMENTAL NEUROBIOLOGY

Professor B. Minke, Department of Physiology, Hadassah Medical School, the University of Jerusalem, Israel.

Professor R. Lund, Department of Neurobiology, University of Pittsburgh, School of Medicine, Pittsburgh, Pennsylvania, USA.

Professor K.-P. Hoffmann, Department of Zoology, University of Bochum, FRG.

Dr V.H. Perry, Department of Experimental Psychology, Oxford University, UK.

Professor P.H. Patterson, Biology Division, California Institute of Technology, Pasadena, California, USA.

Professor A.J. Aguayo, Neuroscience Unit, McGill University, Montreal, Canada.

Dr L. Mayner, School of Scientific Studies, Northern Rivers College of Advanced Education, Lismore, NSW.

MOLECULAR NEUROBIOLOGY

Dr J.H. Fullard, Biology Department, University of Toronto (Erindale Campus), Mississauga, Ontario, Canada.

Dr D. Grunewald, Biology Department, Princeton University, Princeton, New Jersey, USA: Early embryology and genetics of zebra fish.

Dr K. O'Hare, Biochemistry Department, Imperial College of Science and Technology, University of London, London, UK: Transposable elements in *Drosophila melanogaster*.

Dr A.H.D. Watson, Department of Zoology, Cambridge University, UK: Structure and function of spiking and non-spiking local interneurones in motor control of locust leg movement.

Dr J.L.D. Williams, Max-Planck Institut für Verhaltensphysiologie, Arbeitsgruppe Kaissling, Seewiesen, FRG.

Dr E. Wilson, Biology Department. Princeton University, Princeton, New Jersey, USA: Genetics and cell biology of the folded gastrulation gene in *Drosophila melanogaster*.

Dr P.M. Whitington, Department of Zoology, University of New England, Armidale, NSW.

VISUAL SCIENCES

Dr M. Lehrer, University of Zurich, Switzerland: Do bees possess landmark maps?

Dr W. Ribi, Max-Planck-Institut für Biologische Kybernetik, Tübingen, FRG.

Mr X. Wang, Institute of Biophysics, Academia Sinica, Beijing, People's Republic of China.

Prof S.W. Zhang, Institute of Biophysics, Academia Sinica, Beijing, People's Republic of China.

Dr H. Zhu, Institute of Biophysics, Academia Sinica, Beijing, People's Republic of China.

MOLECULAR GENETICS

Professor J-C. Mounolou, Université de Paris-Sud, Orsay, France: Concerted Evolution and Natural Selection on *Drosophila* mitochondrial DNA.

POPULATION GENETICS

Dr R. Callow, University of Manchester, UK: Speciation and evolution in the Graminae.

PLANT CELL BIOLOGY

Professor Liu Chung Chu, President, Fujian Academy of Agricultural Sciences and Director, National Azolla Research Centre, Fuzhou, People's Republic of China: Recent progress in research on *Azolla*.

PLANT MOLECULAR BIOLOGY

P. Gross, Max-Planck-Institut für Zuchtungsorschung, Koln, FRG: a 10 months sabbatical period in the laboratory of Prof. B.G. Rolfe.

Professor J. Johnson, Department of Microbiology and Biochemistry, College of Agriculture, University of Wyoming, Laramie, USA: a sabbatical period of 7 months in the laboratory of Prof. B.G. Rolfe. This visit was supported by a joint USA NSF grant to both Professor J. Johnson and Prof. B.G. Rolfe.

Professor B. Jones, Department of Chemistry, University of Toronto, Canada visited Dr E.H. Creaser's Laboratory in March.

Dr. J. Wooton, Department of Chemistry, University of Leeds, UK, visited Dr E.H. Creaser's Laboratory in April

D. Yuan, People's Republic of China, a PhD student at Macquarie University: 4 months in the laboratory of Prof. B.G. Rolfe to develop a rapid plant assay technique.

The Group also organized the 1988 Robertson Symposium 'Molecular Interactions of Viruses, etc' which was attended by over 80 virologists from 10 countries.

PLANT ENVIRONMENTAL BIOLOGY

Dr. W.D. Bowman, Botany Department, Duke University, USA: Effect of salinity on the population genetics and physiology of a C_4 nonhalophyte.

Professor H. Heldt, University of Göttingen, FRG: Recent investigations in amino acid metabolism in plants.

ECOSYSTEM DYNAMICS

Professor J. Connell, School of Biological Sciences, University of California, Santa Barbara, USA: Ecological diversity in corals.

EXTERNAL GRANTS RECEIVED

DEVELOPMENTAL NEUROBIOLOGY

Prof. R.F. Mark and Dr C.H. Tyndale-Biscoe [+], CSIRO Wildlife Division of Wildlife and Ecology, received an extension to the joint CSIRO–ANU grant for Dr L. Mayner to produce a stereotaxic atlas of the wallaby brain ($8000).

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.

MOLECULAR NEUROBIOLOGY

Drs. G.S. Boyan and L.A. Miller [+] received $10,382 from the Danish Natural Science Research Council for work on 'Neural correlates of behaviour: synaptic mechanisms in an insect CNS with restricted sensory input'.

Dr E.E. Ball received a grant from the Education Abroad Program of the University of California, to cover his travel expenses and local expenses in the context of his collaboration with Dr C.S. Goodman, The University of California at Berkeley, USA.

Dr K. O'Hare received a Royal Society Bicentennial Grant to work with Dr G. Miklos on cloning and characterization of the DNA sequences surrounding the *suppressor of forked* locus at the base of the X chromosome of *Drosophila melanogaster*. Dr A. Mitchelson was supported by the same grant.

Dr A.H.D. Watson[#] received a Royal Society Grant to work with Dr G.S. Boyan for four months on 'Neuronal development in the terminal ganglion of the CNS of the locust'.

VISUAL SCIENCES

Drs A. Duffield and D. Jamison (University of NSW, Sydney) and Dr L.P. Davies[#] received a grant from NH & MRC for 3 years to work on Pharmacology of KAVA constituents and their effect on the central nervous system.

Prof. G.A. Horridge received $105,000 over 3 years from the Centre for Information Sciences to work on artificial seeing aids for the blind.

Prof. G.A. Horridge and Prof. Brent (RSPhysS) received $338,000 from the Department of Technology, Industry and Commerce to work on artificial seeing systems which copy natural visual processing. The commercial partners are SEETEC Pty. Ltd. which is the technical development arm of the Royal Australian Association for provision of Guide Dogs for the Blind (Managing Director, Dr T. Heyes)

MOLECULAR GENETICS

Dr H. Naora continued to receive the Toyota Foundation Grant for studies on carcinogenesis with special reference to territorial effects.

Dr G.D. Clark-Walker received a renewal of funding from the CSIRO–ANU Collaborative Research Fund Grant for studies on cloning and characterization of metallothionein genes from yeasts, in conjunction with Dr I. Macreadie, CSIRO Division of Biotechnology, Parkville, Vic ($16,000).

POPULATION GENETICS

Dr. D.D. Shaw received a joint CSIRO/ANU Collaborative Research Award with Dr R Schodde, CSIRO Division of Wildlife and Ecology, Canberra to study the evolutionary relationships of the Australo–Papuan psittacid parrots ($7,100).

Dr J.B. Gibson received a grant from the Australia–China Education Co-operation Program for joint postgraduate research with the Institute of Genetics, Fudan University, People's Republic of China ($10,000).

PLANT CELL BIOLOGY

Dr F. Gubler was awarded a Queen Elizabeth II Fellowship for work on subcellular localization of sites of protein synthesis and secretion in fungal and plant cells ($32,000).

Professor B.E.S. Gunning (with Prof. B. Rolfe and Dr J. Plazinski) continued his work on The Biology of Azolla-Anabaena, funded by the Australian Centre for International Agricultural Research, in collaboration with Chinese scientists in Fuzhou, PRC, and Dr W. Shaw, Darwin Institute of Technology. ($100,000).

Professor B.E.S. Gunning was awarded a National Research Fellowship for work on the cellular basis of regeneration in plant tissue cultures (appointee Dr J. Gorst) ($29,173).

Dr A.R. Hardham and F. Gubler received $15,000 from the CSIRO/ANU Collaborative Research Fund for work on 'Identification of hormone receptors on plant cell surfaces by monoclonal antibodies'.

Dr A.R. Hardham was awarded a National Research Fellowship for work on 'Exploitation of a collection of monoclonal antibodies to the dieback fungus *Phytophthora cinnamomi*: new tools to study its distribution, development and infection of host plants' (appointee Dr F. Gubler) ($27,500).

Dr A.R. Hardham was awarded a National Research Fellowship for work on

antibodies as tools for understanding how the dieback fungus, *Phytophthora cinnamomi* infects plants ($32,000).

Dr D.S. Letham received a CSIRO/ANU collaborative research grant with Dr T.J.V. Higgins (Plant Industry, CSIRO) for molecular studies of cytokinin-delayed leaf senescence ($15,000).

Dr D.S. Letham was awarded a National Research Fellowship for molecular studies of hormonal control of leaf senescence ($31,244).

Dr D.S. Letham was awarded a grant from the Industry Research and Development Board for improvement of longevity of cut flowers by genetic engineering ($54,000).

Dr D.W. McCurdy commenced his term as a Queen Elizabeth II Fellow in September.

Dr P. Warren Wilson (with Professor J. Warren Wilson and Dr R. Overall) was awarded $21,500 to continue work on 'Initiation and Stabilisation of Polarity in Plant Tissues' and (with Professor J. Warren Wilson) was awarded $13,000 for a study of 'Positional Control of Tracheary Elements and Strands', both from the Australian Research Grants Scheme.

Dr R.E. Williamson's National Research Fellowship for the study of microtubules in *Nitella* commenced in 1988 (appointee G.O. Wasteneys) ($29,173).

PLANT MOLECULAR BIOLOGY

Dr T.J. Andrews continued to receive 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 occupies this Fellowship.

Dr T.J. Andrews was awarded 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 will take up this Fellowship in 1989.

Dr M.A. Djordjevic and Dr J.J. Weinman received a joint grant from the Australian Wool Corporation to investigate plant resistance mechanisms in subterranean clovers ($158,109).

Dr A.J. Gibbs continued to receive support for the VIDE project from the Australian Centre for International Agricultural Research and from the Rural Credit Development Fund, and from Betatene Pty Ltd of Melbourne for research on viral inhibitors.

Prof. B.G. Rolfe continued his work on *Rhizobium*-legume symbiosis funded by grants from the Australian Wool Corporation; Agrigenetics Research Corporation; a National Research Fellowship; a shared National Research Fellowship with Dr K.F. Scott; and a Public Interest Grant, Section 39, Department of Industry, Technology and Commerce for the continuation of studies on the development of a super-nodulating soybean and its optimum *Rhizobium* inoculant strains. A continuing grant from the Australian Meat and Livestock Research and Development Corporation for the analysis of the genetic basis of acid tolerance in the clover bacteria *Rhizobium trifolii*. A continuing grant from Betatene Pty Ltd. (Melbourne) for research on the development of naturally derived products for the control of plant diseases. A grant from the Lord Bruce Fund (ANU) for support to conduct controlled field tests of genetically manipulated microorganisms (GEMS). ACIAR grant (jointly with Professor B.E.S. Gunning) for *Azolla/Anabaena* studies leading to the development of molecular probes for identification of the symbiotic *Anabaena*.

Dr B.M. Tyler received a grant from the US National Institutes of Health for 'Molecular analysis of transcription' ($340,000 over 3 years).

Dr B.M. Tyler continues to receive a National Research Fellowship for work on 'Gene transfer between laboratory fungi and agriculturally important fingi' ($27,500 pa).

PLANT ENVIRONMENTAL BIOLOGY

Dr. J.R. Evans was awarded a QEII Fellowship.

Dr. G.D. Price continues to receive a National Research Fellowship (1986–1989) to study 'The CO_2 concentrating mechanism in cyanobacteria'.

Prof. G.D. Farquhar and Dr K.T. Hubick received a grant of $22,761 from the Cotton Research Council for 'Water-use Efficiency and Response to Irrigation of Cotton Genotypes'.

Prof. G.D. Farquhar and Dr K.T. Hubick received a grant of $20,115 from the Barley Research Council for 'Water-use Efficiency of Barley Genotypes'.

Prof G.D. Farquhar received an additional grant of $32,000 from the Australian Centre for International Agricultural Research (ACIAR) for 'Legume Water Use Efficiency'.

Prof. G.D. Farquhar and Dr O.T. Denmead (CSIRO) received a grant of $13,000 from the CSIRO/ANU Collaborative Research Projects Scheme for 'Genotypic variation in gas exchange and water-use efficiency of field crops'.

ECOSYSTEM DYNAMICS

Dr I.R. Noble received $15,000 from the Australian National Parks and Wildlife Service to continue work on predictive models of vegetation structure following fire in Kakadu National Park.

Drs D.G. Green and I.R. Noble received $36,000 from the Centre for Information Science Research to develop a self-organising syntactic approach to gene sequence analysis in collaboration with Drs A.J. Gibbs and P. Keese of the Plant Molecular Biology Group.

Dr M. Ball received a National Research Fellowship which she will take up in 1989.

OTHER ACTIVITIES OF THE SCHOOL'S ACADEMIC STAFF

DIRECTOR'S UNIT

In 1988, the Director continued to serve on a number of University Committees. These included the ANU Council, as representative of Heads of Research Schools, and Chairman of the CRES Advisory Board.

The Director is Chairman of the Fenner Conference Committee and a Member of the National Committee on the Environment, both committees of the Australian Academy of Science.

He presented a paper at the Australian Academy of Science 1st Fenner Conference ('The Scientific Significance of the Australian Alps') and attended the Australian Ecological Society Open Forum at Geraldton, WA.

The Director contributed to the IUCN 40th Anniversary Seminar in Fontainbleau, France in October and also visited science policy sections at OECD and UNESCO.

The Director is a Member of the Joint Japan–Australia Steering Committee for the Multi Function Polis (MFP). The Committee guides proposals for the establishment of an international complex in Australia that will attract investment and link high technology industries and services, R&D activities and facilities for advanced education.

In relation to outside bodies, the Director continued to serve as Chairman of the Advisory Committee to the CSIRO Division of Plant Industry and Chairman of the Science Advisory Council of Calgene Pacific.

DEVELOPMENTAL NEUROBIOLOGY

Dr A.D. Blest visited the Neurosciences Division, the University of Arizona at Tucson, U.S.A. and the Department of Biology, the University of Colorado at Fort Collins, Colorado in July, both visits relating to ongoing or future collaborations. He also visited the Molecular Biology Unit, the Tata Institute for Fundamental Research, Bombay, India for ten days in October, where he contributed to a one-week Course on the Visual System of *Drosophila*, and discussed options for future research on chemosensory mutants.

Dr Blest continues as an Associate Editor of the International Journal of Insect Morphology and Embryology, and joined the Board of Associate Editors of Cell and Tissue Research in September. He convened the Australian National University Transmission Electron Microscope Advisory Committee, served on the RSBS Academic Promotions Committee for 1988, and is a Member of the Board of the Institute of Advanced Studies, from August. He was a member of the International Scientific Advisory Council for the International Conference on the Neurobiology of Sensory Systems held at Goa, India in September.

Dr A. Gummer was awarded the 1987 Prize for Human Medicine by the Johann Wolfgang Goethe-Universität, Frankfurt am Main, FRG. He visited the Institute of Audiology, Groningen, the Netherlands and the Department of Physiology, Frankfurt am Main, FRG.

Professor R. Mark represented RSBS on the Graduate Degrees Committee. He is Regional Editor for two journals, *Physiology and Behavior* and *Behavioural Brain Research*.

Dr I.S. McLennan presented seminars on Hormonal Regulation of Muscle Development to the Neuroscience Division, JCSMR and the Neuroscience Group, University of Newcastle School of Medicine. He left the School in May to take up a Lectureship in the University of Otago Medical School, Dunedin, New Zealand.

Dr S.C. Trowell was awarded both a National Research Fellowship and a CSIRO Post-doctoral Fellowship, to work in the Division of Entomology, CSIRO on insect juvenile hormone binding proteins. He will take up these awards in 1989.

MOLECULAR NEUROBIOLOGY

Dr E.E. Ball spent two weeks in November working with Dr Paul Whitington in the Zoology Department, University of New England, Armidale, and gave a seminar on 'Development of neuromuscular connections in the embryonic grasshopper'. He organized the neurobiology contribution and the RSBS contribution to the National Summer Science School in January. He was elected Secretary of the ANZ Society for Cell Biology for 1988–1989. Dr Ball organized a symposium on 'Neuromuscular and skeletomuscular development in insects' for the XVIII International Congress of Entomology, Vancouver, Canada, July. He spent four months in the laboratory of Prof. C.S. Goodman, University of California, Berkeley, USA cloning specific locust genes, and updating on the newest techniques in recombinant DNA research. He gave talks in several American laboratories.

Dr G.S. Boyan spent six weeks at the Biology Institute, Odense University, Denmark, from May to July. He participated in the 16th Neurobiology Conference in Göttingen, FRG, and the XVIII International Congress of Entomology in Vancouver, Canada. He gave a demonstration to the 1987 National Science Summer School. Dr Boyan serves on the Editorial Boards of the Journal of Insect Physiology and Life Sciences.

Mr R.M. Hennig presented seminars at the following overseas institutions in May; Max-Planck Institut für Verhaltensphysiologie, Seewiesen, FRG; Institut für Zoology, Universität Erlangen-Nürnberg, FRG; Fakultät Biologie, Universität Konstanz, FRG; Department of Zoology, University of Cambridge, UK; Department of Biology, University of Newcastle, UK; Department of Zoology, University of Bristol, UK.

Dr G. Miklos lectured to the CO2 Biochemistry students, The Faculties, on Information Storage Systems, and to the School of Biological Sciences, University of NSW on Molecular approaches to nervous system functions. He also served on the editorial board of Molecular Biology

and Evolution. He visited the Applied BioSystems Company in San Francisco, USA and had research discussions at Harvard University, USA; the University of Washington, Seattle, USA; Imperial College, London, UK; the University of Glasgow, UK and the Instituto Cajal, Madrid, Spain.

VISUAL SCIENCES

Dr 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, and of the ANU Library Advisory Committee, BIOLAC. 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 3rd year biochemistry students at the ANU. Dr Morgan was coordinator of the proposed Graduate Program in Neuroscience. He gave invited seminars in the School of Biological and Biomedical Sciences, University of Technology, Sydney, April, in the John Curtin School of Medical Research, May and to the Melbourne Brain Research Group, June on 'New perspectives on excitotoxicity'. He delivered the Flow Laboratory Lecture at the University of Wollongong, May (Directional selectivity in vision: from algorithm to cellular basis). He organized a symposium on neurotoxins for the Australian Neuroscience Society Meeting.

Prof G.A. Horridge has been made a member of the Board of the ACT Research Institute for the Blind. He gave a seminar on Insect Vision at the Academia Sinica, Beijing, People's Republic of China, August and chaired a session at the Annual Meeting of the European Neuroscience Association, Zurich, Switzerland, September.

Mr A. James gave seminars on spatiotemporal white-noise studies of fly lamina cells at universities in Groningen, the Netherlands; Cambridge, UK; Rockefeller, Washington and Caltech, USA during October–November.

Dr M.V. Srinivasan gave a talk on Information processing in invertebrate visual systems, Indian Institute of Science, Bangalore, India, October and a talk on Beekeeping in China at the ACT Beekeepers' Society in May. He also gave a talk on 3-D vision in honeybees in Canberra in June.

Mr E. Warrant gave seminars on superposition optics in insect eyes at universities in Beijing, People's Republic of China; Lund, Sweden; Groningen, the Netherlands; Kingston, Canada, and Washington, USA during October–November. He also chaired a session on compound eye optics at The IEEE Systems, Man and Cybernetics Conference, Beijing, China, September.

Mr G. Yang presented a poster to the American Society for Neuroscience Meeting in Toronto, Canada. He gave seminars at the following institutions in the USA: Department of Physiology, University of California, San Francisco; Department of Neuroscience, University of California, San Diego; Baylor College of Medicine, Houston; Department of Physiology, University of Alabama, Birmingham; Department of Anatomy, University of Pittsburgh, Pittsburgh and the Department of Surgery, Harvard Medical School. He also gave seminars at the Department of Physiology, University of Cambridge, UK; the Max-Planck Institut for Brain Research, Frankfurt, FRG and the Department of Anatomy, Chinese University of Hong Kong.

MOLECULAR GENETICS

Dr Naora gave invited lectures at the following institutions in People's Republic of China: Institute of Virology, Beijing; Institute for Cancer Research, Beijing; the Fourth Military Medical University, Xi'an; the Second Military Medical University, Shanghai and the Shanghai Second Medical University, Shanghai. He was on the doctoral degree assessment committee and assessed a doctoral thesis at the Fourth Military Medical University.

Dr Sun presented a seminar at the Fourth Military Medical University, Xi'an, People's Republic of China.

Dr G.D. Clark-Walker lectured in the Molecular Evolution course in the Department of Biochemistry, The Faculties.

POPULATION GENETICS

Dr J.B. Gibson continued to serve on the Scientific Advisory Committee of the Australian NH & MRC Twin Registry and on the Editorial Board of the Annals of Human Biology (UK). He visited laboratories in Canada, USA, UK and India to discuss research on plant/insect interactions. He attended the 29th Annual Drosophila Research Conference in Toronto, Canada and gave a seminar at the Tata Institute of Fundamental Research, Bombay, India. He became a School representative on the Board of the Institute of Advanced Studies and a member of the General Policy Committee.

Dr Shaw gave two lectures on Speciation and Hybrid Zones to the Advanced Genetics C05 course, the Faculties, ANU and gave a lecture on chromosomal evolution to the Zoology Department, University of Queensland. He acted as ACT representative, The Australian Institute of Biology.

PLANT CELL BIOLOGY

Dr A.R. Hardham was awarded the Australian

Society of Plant Physiologists P.L. Goldacre Award. She gave research seminars at the Burnley Plant Research Institute, Victoria and CSIRO, Plant Physiology Section, Canberra. She also gave seminars at the following institutions in the USA: University of California, Riverside; Stanford University, California; University of Utah, Logan; Purdue University, West Lafayette and the De Pont Research Laboratories, Wilmington, Delaware. She served on the ANU Transmission Electron Microscope Advisory Committee and the Biological Sciences Library Advisory Committee.

Dr A.R. Hardham and Dr F. Gubler participated in running the ANU National Science Summer School.

Dr J. Gorst taught an 18 week course on plant tissue culture techniques at the ACT Institute of TAFE (Bruce Campus). She also participated in a one day girls careers conference hosted by the ACT Schools Authority and the Canberra College of Advanced Education.

Professor B.E.S. Gunning was a member of the Biological Sciences Advisory Committee of the Australian Research Council, Department of Employment, Education and Training, the Australian Academy of Science Boden Research Conferences Committee, the ANU Transmission Electron Microscope Advisory Committee and the RSBS-Faculties Cell Biology Honours Course Management Committee. He was Course Co-ordinator for the Cell Biology Honours Course. He was an Editor of the journal Protoplasma and a member of the Editorial Boards of the journals Botanica Acta and the Journal of Cell Science. He was a session Chairman at the Gordon Research Conference on the Plant and Fungal Cytoskeleton in Andover, New Hampshire, and gave research seminars in the Department of Biology, Stanford University, the Department of Botany, University of Massachusetts, the Marine Biology Laboratory, Woods Hole, Massachusetts, the Department of Molecular, Cellular and Developmental Biology, University of Colorado, and the John Curtin School of Medical Research, ANU.

Professor Gunning, Dr Hardham, Dr Gorst, Ann Cleary, J. Duniec and C. Busby ran a two day laboratory and tutorial course on plant cell biology for a class of 3rd year students from the School of Biological Sciences, University of Sydney.

Dr P.C.L. John, Dr J. Gorst, Dr R. Hoggart, M. Webb and J. Elliott contributed to a series of lectures and practical demonstrations in the Botany Department third year course in Plant Cell Biology.

Dr P.C.L. John was Chairman of a session on the Cell Cycle and Circadian Clocks at the Cold Spring Harbor meeting of Cell and Molecular Biology of *Chlamydomonas*. He presented seminars at Yale University, at the University of Washington and at Oxford University, UK.

Dr L.M.S. Palni gave seminars at the Hindustan Lever Research Centre, Bombay, India and the Biology Department, University of Saskatchewan, Saskatoon, Canada.

Dr R.E. Williamson continued to serve on the editorial boards of European Journal of Cell Biology and Cell Biology International Reports.

PLANT MOLECULAR BIOLOGY

Dr E.H. Creaser is a member of the Chemistry Library Committee and is Chairman of the RSBS Occupational Health and Safety Committee which is also the RSBS School Safety Committee.

Dr M.A. Djordjevic presented papers at the Fourth International Symposium on Molecular Biology of Plant-Microbe Interactions, Acapulco, Mexico; Tenth Annual Conference on the Organization and Expression of the Genome, Lorne, Victoria.

Dr S.P. Djordjevic presented papers at the Universities of Rome, Leiden, Bielefeld and Jerusalem; and presented a course in molecular biology through the Centre for Continuing Education.

Dr A. Gibbs was an invited lecturer at a course on 'Genome Evolution' organized by the Fundacion Juan March, Madrid, and at a FAO course on virus identification at Malang, East Java. On an outside studies program, he consulted with colleagues in UK laboratories in Cambridge, Dundee, Harpenden, Leeds, Littlehampton, Norwich, Oxford and in Vancouver, Canada. He convened and lectured in a 3rd year 3 week course in the Faculty of Science entitled 'Molecular Evolution', and also gave lectures on virology in other courses of the Faculty of Science, at the Department of Applied Science, CCAE and in the National Summer School.

In collaboration with Dr Wayne Gerlach of CSIRO Division of Plant Industry he organized the 1988 RSBS Robertson Symposium, which was attended by over 80 virologists from 10 countries, who discussed 'The Molecular Interactions of Viruses, etc'. Dr Gibbs is a member of the Scientific Advisory Board of Plant Pathology, of the Review of Plant Pathology, of Indian Phytopathology, and is a member of the Editorial Advisory Board of Archives of Virology, and of the Programme Committee of the International Virology Congress. He is a member of the Culture Committee of the Australian Quarantine and Inspection Service, he served as a member of the Scientific Advisory Committee of the Centre for Resource and Environmental Studies and has concluded a 7 year term on the Committee on Public Affairs and Continuing Education.

Dr B.G. Rolfe was appointed to a new Chair in plant molecular biology. He is a member of the Scientific Advisory Board of the International Symposium on Molecular Biology of Plant-Microbe Interactions. He is a member of the recombinant DNA Biosafety Committee of the ANU and an assessment officer of the rDNA projects of the ANU. He participated in the ANU National Science Summer School.

Prof. Rolfe presented invited lectures to the International Congress on Nitrogen Fixation, Cologne, FRG. He visited and consulted with the research groups at the Max-Planck-Institut für Zuchtungsforschung, Cologne, FRG; attended and participated in the First International Conference on the Release of Genetically Engineered Microorganisms, Cardiff, Wales, UK; presented a three lecture course on the *Rhizobium*-legume interaction at the University of Florida, Gainesville, Florida, USA; gave seminars at the University of Texas, Austin, Texas, USA and an invited lecture to the Fourth International Symposium on Molecular Biology of Plant-Microbe Interactions, Acapulco, Mexico.

Dr J.J. Weinman presented seminars and visited the Department of Microbiology and Biochemistry, University of Wyoming, USA; Department of Biology, Stanford University; Department of Plant Pathology, University of California, Berkeley; Tenth Annual Conference on the Organization and Expression of the Genome, Lorne, Victoria; and presented a course in molecular biology through the Centre for Continuing Education.

Dr B.M. Tyler taught a practical class on 'Cloning and manipulation of recombinant DNA' as part of the Biochemistry CO5 course, The Faculties.

Mr J. Piskur attended a symposium on 'Local changes in DNA structure and their biological implications' at Brno, Czechoslovakia in July.

Mr J. Bruhl attended the Australian Systematic Botany Society Meeting in Melbourne on 'Botanical History in Australasia'.

PLANT ENVIRONMENTAL BIOLOGY

Dr G.D. Farquhar was appointed to a new Chair in plant physiology. He was elected to a Fellowship of the Australian Academy of Science on 28 April, 1988. In February he was made chairman of the Australian working group on Terrestrial Biosphere-Atmospheric Chemistry Interactions for the International Geosphere-Biosphere Program.

Prof. Farquhar participated in two workshops in Canberra: one on 'The Effects of Climate Change on Terrestrial Ecosystems and the other, 'PI 2000', on forward planning for CSIRO Division of Plant Industry.

Drs. Hubick and von Caemmerer gave lectures in the Botany Department as part of the CO8 course on 'Water-use efficiency, carbon isotope ratios and plant growth'.

Drs. M.K. Morell, G.D. Price, K.C. Woo, K.T. Hubick and A.B. Wellington made a submission to the Senate Standing Committee on Employment, Education and Training.

ECOSYSTEM DYNAMICS

Dr I.R. Noble spent nine months at Imperial College, UK working with Dr Geoff Norton on the application of expert systems to pest management. He gave seminars at the following UK institutions: the University of East Anglia; Cambridge University; Imperial College, London; Oxford University and the University of Sussex. He was the Australian delegate to the SCOPE General Assembly in Budapest, Hungary in June and was a member of the Australian delegation to the XXIII IUBS General Assembly in Canberra in October. He was also a member of the Australian National Committee for the Man and the Biosphere Programme and a member of the National Committee for Plant Sciences, Australian Academy of Science.

Dr I.R. Noble was a member of the Editorial Boards for UNESCO/MAB Book Series and for 'Environmental Software'. He was a consultant to the Australian National Parks and Wildlife Service on fire management. He was also a consultant to the Department of the Environment, UK and the Institute for Terrestial Ecology, UK on the application of expert systems to managing changing land use.

Dr D.G. Green presented seminars at the Australian Defence Force Academy, the Australian Institute of Marine Science, the CSIRO Division of Information Technology, and the University of New England. He was convenor and chairman of a session on 'Fine resolution pollen analysis' at the 7th International Palynological Congress, Brisbane, September and contributed lectures on modelling growth in plants to undergraduate students in the Botany Department, ANU.

Peter Cochrane chaired a session of the Australian Forest History Conference at the Centre for Resource and Environmental Studies in May.

PUBLICATIONS

SYMBOLS

In this section symbols are used to indicate when authors are not members of the School. The symbols are:

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

DIRECTOR'S UNIT

Published

Cochrane, P.M. and Slatyer, R.O. Water relations of *Eucalyptus pauciflora* near the alpine tree line. Tree Physiol. 4, 45–52.

Ferrar, P.J. *Bibliography of Australian Native Plants. Part I. Photosynthetic Responses.*

Ferrar, P.J. and Vranjic, J.A.† *Bibliography of Australian Native Plants. Part II. Water Relations.*

Ferrar, P.J., Cochrane, P.M. and Slatyer, R.O. Factors influencing germination and establishment of *Eucalyptus pauciflora* near the alpine tree line. Tree Physiol. 4, 27–43.

In Press

Ferrar, P.J., Slatyer, R.O and Vranjic, J.A.† Photosynthetic temperature acclimation in *Eucalyptus* species from diverse habitats; and a comparison with *Nerium oleander*. Aust. J. Plant Physiol.

Slatyer, R.O. Science and technology advisory mechanisms in Australia. Technology in Society, Special Issue.

Slatyer, R.O. The Australian environment. UNESCO Courier

Slatyer, R.O. Alpine and valley bottom treelines. Proc. Conf. on 'The Scientific Significance of the Australian Alps', Aust. Acad. Sci., Canberra

DEVELOPMENTAL NEUROBIOLOGY

Published

Blest, A.D. Turnover of phototransductive membrane in compound eyes and ocelli. Advances in Insect Physiology 20, 1–53.

Blest, A.D. Post-embryonic development of the principal retina of a jumping spider. I. The establishment of receptor tiering by conformational changes. Phil. Trans. R. Soc. Lond. B 320, 489–504.

Blest, A.D. and Carter, M. Post-embryonic development of the principal retina of a jumping spider. II. The acquisition and reorganisation of rhabdomeres and growth of the glial matrix. Phil. Trans. R. Soc. Lond. B 320, 505–515.

Blest, A.D., McIntyre, P. and Carter, M. A re-examination of the principal retina of *Phidippus johnsoni* (Araneae, Salticidae): implications for optical modelling. J. Comp. Physiol. A 162, 47–56.

Coles, R.B.* and Guppy, A.* Directional hearing in the barn owl (*Tyto alba*). J. Comp. Physiol. A 163, 117–134.

Comans, P.E.*, McLennan, I.S.* and Mark, R.F. Mammalian motoneuron cell death: Development of the lateral motor column of a wallaby (*Macropus eugenii*). J. Comp. Neurol. 260, 627–634.

Comans, P.E.*, McLennan, I.S.*, Mark, R.F. and Hendry, I.A.† Mammalian motoneuron development: Effect of peripheral deprivation on motoneuron numbers in a marsupial. J. Comp. Neurol. 270, 111–120.

Flett, D.L.*, Marotte, L.R. and Mark, R.F. Retinal projections to the superior collicullus and dorsal lateral geniculate nucleus in the tammar wallaby (*Macropus eugenii*): Normal topography. J. Comp. Neurol. 271, 257–273.

Flett, D.L.*, Marotte, L.R. and Mark, R.F. Effects of binocular enucleation on the dorsal lateral geniculate of the wallaby. Neurosci. Letts. Suppl. 30, S67.

Gummer, A.W. Effect of accumulated decay product on the Mössbauer emission spectrum. Nuclear Instruments and Methods in Physics Research B34, 224–227.

Guppy, A.* and Coles, R.B.* Acoustical and retinal aspects of hearing in the Australian gleaning bats *Macroderma gigas* and *Nyctophilus gouldi*. J. Comp. Physiol. 162, 653–668.

Harrison, P.* Innervation and behaviour of ectopic limbs in *Xenopus*. Dev. Brain Res. 36, 89–100.

McFadden, S.A.* The binocular depth stereoacuity of the pigeon and its relation to the anatomical resolving power of the eye. Vision Res. 27, 1967–1980.

McLennan, I.S.* Characterization of a myopathy caused by prostaglandin dysfunction. Aust. Paediatr. J. Suppl., 21–23.

McLennan, I.S.* Characterization of a prostaglandin dysfunction myopathy. Muscle & Nerve 10, 801–810.

Marotte, L.R. Development of topography of retinal connections to the dorsal lateral geniculate and superior colliculus of the wallaby. Neurosci. Letts. Suppl. 30, S96.

Marotte, L.R. and Mark, R.F. Retinal projections to the superior colliculus and dorsal lateral geniculate nucleus in the tammar wallaby (*Macropus eugenii*): II. Topography after rotation of an eye prior to retinal innervation of the brain. J. Comp. Neurol. 271, 274–292.

Pilar, G.,+ Nunex, G.,+ McLennan, I.S.* and Meriney, S.D.+ Muscarinic and nicotinic synaptic activation of the developing chicken iris. J. Neurosci. 7, 3813–3826.

Sheng, X.-M., Marotte, L.R. and Mark, R.F. Development of visual cortical connections in the wallaby. Neurosci. Letts. Suppl. 30, S122.

Trowell, S.C. Partial purification and characterisation of the 4-nitrophenylphosphatase activity of invertebrate photoreceptor microvilli. Absence of *in vitro* rhodopsin phosphatase activity. Comp. Biochem. Physiol. 89B, 285–297.

Trowell, S.C. Inositol trisphosphatase and bisphosphatase activities in the retina of a crab. FEBS Letts. 238, 281–284.

Trowell, S.C. and Carter, M. The polypeptide composition of the 4-nitrophenylphosphatase (4-NPPase) of invertebrate photoreceptor microvilli. Proceedings of the XXIst Yamada Conference, Kyoto, 1988, *Molecular Physiology of Retinal Proteins*, pp 415–416 (ed. Tomiyuki Hara). Yamada Science Foundation, Osaka, Japan.

Wye-Dvorak, J.*, Levick, W.R.† and Mark, R.F. Retinotopic organization in the dorsal lateral geniculate nucleus of the tammar wallaby (*Macropus eugenii*). J. Comp. Neurol. 263, 198–213.

In press

Blest, A.D. The evolution of the visual systems of Salticid spiders: the acquisition of light guide optics in the principal eyes. National Geographic Research Reports.

Blest, A.D. and O'Carroll, D.C.§ The evolution of the tiered principal retinae of jumping spiders. In: Proceedings, 1st International Congress on the Neurobiology of Sensory Systems, Goa, 1988. (eds. R. Naresh Singh and N.J. Strausfeld). Plenum Press, New York.

Ellendorff, F.§, Tyndale-Biscoe, C.H.+ and Mark, R.F. Ontogenetic changes in olfactory neural bulb activities of pouched young Tammar Wallabies. In: *The Endocrine Control of the Foetus—Physiologic and Pathophysiologic Aspects*. Springer-Verlag, Berlin-Heidelberg.

Gummer, A.W., Smolders, J.W.Th.+ and Klinke, R.+ Mechanics of a single ossicle ear. I. Extrastapedius of the pigeon. Hearing Res.

Gummer, A.W., Smolders, J.W.Th.+ and Klinke, R.+ Mechanics of a single-ossicle ear. II. Columella footplate in the pigeon. Hearing Res.

Gummer, A.W., Smolders, J.W.Th+ and Klinke, R.+ Determinants of high-frequency sensitivity in the bird. In: *Cochlear Mechanics and Structure, Function and Models*. Proc. Triennial NATO Advanced Res. Workshop on Hearing. (eds. J.P.Wilson and D.T.Kemp). Plenum Press, New York.

Harrison, P.J.* Effects of an ectopic hindlimb on development of the brachial motoneurons in *Xenopus*. Dev. Brain Res.

Hill, C.E.§, Jelinek, H.†, Hendry, I.A.†, McLennan, I.S.* and Rush, R.A.† Penetration of the sweat glands of the rat foot pad by sensory nerve fibres following sympathectomy. Role of nerve growth factor. J. Neurosci. Res.

Hill, K.G., Mo, J. and Stange, G. Excitation and suppression of primary auditory fibres in the pigeon. Hearing Res.

Hill, K.G., Mo, J. and Stange, G. Induced suppression in spike responses to tone-on-noise stimuli in the auditory nerve of the pigeon. Hearing Res.

Hill, K.G., Stange, G. and Mo, J. Temporal synchronization in the primary auditory response in the pigeon. Hearing Res.

Hill, K.G., Stange, G, Gummer A.W. and Mo, J. A model proposing synaptic and extra-synaptic influences on the responses of cochlear nerve fibres. Hearing Res.

McLennan, I.S.* Quantitative relationships between motoneurons and muscle development in *Xenopus laevis*: implications for motoneuron cell death and motor unit formation. J. Comp. Neurol.

McLennan, I.S.* Early development and fusion of muscle cells. In: *Handbook of Human Growth and Developmental Biology*. Chapter 2, Section 18. (eds. P.S. Timiras and E. Meisami). CRC Press, Florida.

McLennan, I.S.* Differentiation of muscle fibres: Myofibrils and contractility. In: *Handbook of Human Growth and Developmental Biology*. Chapter 3, Section 18. (eds. P.S. Timiras and E. Meisami). CRC Press, Florida.

Mark, R.F. and Marotte, L.R. The development of primary visual projections in a marsupial after rotation of an eye prior to optic innervation of the visual centres. Neurosci. Letts.

Marotte, L.R., Flett, D.L.* and Mark, R.F. Effects of very early monocular and binocular enucleation on primary visual centers in the tammar wallaby (*Macropus eugenii*). J. Comp. Neurol.

Marotte, L.R., Flett, D.L.* and Mark, R.F. Topography of retinogeniculate projections in the wallaby after monocular enucleation prior to retinal innervation of the visual centres. Neurosci. Letts.

Mayner, L.* A cytoarchitectonic description of the thalamus of the wallaby, the tammar *Macropus eugenii*. Brain Behav. & Evol.

Mayner, L.* Cytoarchitectonics of the cortex of the wallaby, the tammar, *Macropus eugenii*. Brain Behav. & Evol.

Mayner, L.* A nomenclature for the cortical sulcal features of the wallaby, the tammar, *Macropus eugenii*. Brain Behav. & Evol.

MOLECULAR NEUROBIOLOGY

Published

Ball, E.E. Neurite outgrowth, growth factors and the extracellular matrix in insect embryos. Neuroscience Letters Suppl. 30, 31–32.

Ball, E.E. and Quinn, J.M.A. Neuromuscular development in the orthopteroid insects. Proceedings of the XVII International Congress of Entomology, Vancouver, Canada, p. 76.

Boyan, G.S. Presynaptic inhibition of identified wind-sensitive afferents in the cercal system of the locust. J. Neuroscience 8(8), 2748–2757.

Boyan, G.S. The cellular basis of a behaviour: from sensory neurone to behavioural output in the flight system of the locust. Neuroscience Letters Suppl. 30, 24–25.

Boyan, G.S., Williams, J.L.D.[#] and Fullard, J.H.[#] Integration at a central synapse in the auditory system of a moth (*Agrotis infusa*: Noctuidae). In: *Sense Organs, Interfaces between Environment and Behaviour*. Proceedings of the 16th Gottingen Neurobiology conference, p.153. (eds. N. Elsner and F.G. Barth). Georg Thieme Verlag, Stuttgart.

Boyan, G.S., Ball, E.E. and Williams, J.L.D.[#] A comparative approach to the evolution of orthopteroid cercal receptor/giant interneuron systems. Proceedings of the XVII International Congress of Entomology, Vancouver, Canada, p. 70.

de Couet, H.G.*, Yamamoto, M.*, Davies, J.*., Pirrotta, V.[+] and Miklos, G.L.G. (1988) Molecular approaches to the nervous system: genetic and molecular characterization of genes affecting neuronal and neuro-muscular functions in *Drosophila melanogaster*. Neuroscience Letters. Suppl.30, S26.

Haig, J.[+] and Ball, E.E. Hermit crabs from north Australian and east Indonesian waters (Crustacea: Decapoda: Anomura: Paguridae) collected during the 1975 Alpha Helix expedition. Rec. Austral. Mus. 40 (3), 151–196.

Healy, M.J.*, Russell, R.J.* and Miklos, G.L.G. Molecular studies on interspersed repetitive and unique sequences in the region of the complementation group *uncoordinated* on the X-chromosome of *Drosophila melanogaster*. Molec. Gen. Genetic. 213, 63–71.

Hennig, R.M. Ascending auditory interneurones in the cricket *Teleogryllus commodus* (Walker): comparative physiology and direct connections with afferents. J. Comp. Physiol. A. 163, 135–143.

Hennig, R.M. Central organization of cricket motor patterns. In: *Sense Organs, Interfaces between Environment and Behaviour*. Proceedings of the 16th Gottingen Neurobiology Conference, p. 128. (eds. N. Elsner and F.G. Barth). Georg Thieme Verlag, Stuttgart.

Inoue, Y.H.[§], Taira, T.[+] and Yamamoto, M.* Genetics of an unstable white mutant in *Drosophila simulans*: reversion, suppression and somatic instability. Genetics 119, 903–912.

John, B.* and Miklos, G.L.G. *The Eukaryote Genome in Development and Evolution*. 416 pp. Unwin Hyman, London.

Miklos, G.L.G., Yamamoto, M. , Davies, J.* and Pirrotta, V.[+] Microcloning reveals a high frequency of repetitive sequences characteristic of chromosome 4 and the β-heterochromatin of *Drosophila melanogaster*. Proc. Natl. Acad. Sci. USA 85, 2051–2055.

Myers, C.M. and Ball, E.E. Comparative development of the femoral muscles in the legs of the locust. Neuroscience Letters Suppl. 30, 104.

Myers, C.M. and Ball, E.E. Comparative development of the extensor and flexor tibiae muscles in the legs of the locust, *Locusta migratoria*. Development 101, 351–361.

Myers, C.M. and Evans, P.D.[+] Peripheral neurosecretory cells on the thoracic median nerves of the locust, *Schistocerca gregaria*. J. Morphol. 195, 45–58.

Whitington, P.M.[#], Myers, C.M. and Ball, E.E. Pathfinding by motor axons in the locust embryo. Proceedings of the XVIII International Congress of Entomology, Vancouver, Canada, p. 76.

Yamamoto, M.* and Miklos, G.L.G. (1987) Cytological analysis of deficiency 16-3-35 at the base of the X-chromosome of *Drosophila melanogaster*. Drosophila Information Service 66, 154–155.

Yamamoto, M.* (1987) T(2;4) and T(3;4) translocations in *D.melanogaster*. Drosophila Information Service 66, 192–193.

In Press

Baird, D.H.[+], Wyman, R.J.[+], Davies, J.A.* and Miklos, G.L.G. Genetic and neurophysiological studies of the mutants *Passover* and *shaking-B*^{2} which affect neuronal connectivity in *Drosophila melanogaster*. J. Neurogenetics.

Barleben, F.[+], Baumann, W.[+], Davies, J.*, Pirrotta, A.[+], Delaney, S., Hayward, D., Schuppler, U., Fischbach, K.F.[+] and Miklos, G.L.G. (1989) Molecular and genetic analysis of the small *optic lobes/sluggish* region of the X-chromosome of *D.melanogaster*. J. Neurogenetics.

Boyan, G.S. and Ball, E.E. Parallel inputs shape the response of a giant interneurone in the cercal system of the locust. J. Insect Physiol.

Boyan, G.S. and Fullard, J.H.[#] Information processing at a central synapse suggests a noise filter in the auditory pathway of the noctuid moth. J. Comp. Physiol. A.

Perrimon, N.[+], Smouse, D.[+] and Miklos, G.L.G. Developmental genetics of loci at the base of the X-chromosome of *Drosophila melanogaster*. Genetics.

Perrimon, N.[+], Smouse, D.[+] and Miklos, G.L.G. Developmental genetics of loci associated with neurological defects at the base of the X-chromosome of *D.melanogaster*. J. Neurogenetics .

VISUAL SCIENCES

Published

Barlin, G.B.†, Davies, L.P.# and Ngu, M.M.L.† Imidazo (1,2-b) pyridazines, III. Synthesis and central nervous system activities of some 6-chloro-3-methoxy (and ethoxy)-2-aryl (and heteroaryl) imidazo (1,2-b)-pyridazines. Aust. J. Chem. 41, 1149–1156.

Guy, R.* and Srinivasan, M.V. Integrative properties of second-order visual neurons: A study of large monopolar cells in the dronefly *Eristalis*. J. Comp. Physiol. A 162, 317–331.

Kirchner, W.H.§ and Srinivasan, M.V. Estimation of distance using motion parallax in freely-flying honeybees. Proc. of 16th Göttingen Neurobiology Conference, p 231. (eds. N. Elsner and F.G. Barth). Georg Thieme Verlag. Stuttgart, New York.

Lehrer, M.#, Srinivasan, M.V., Zhang, S.W.# and Horridge, G.A. Motion cues provide the bee's visual world with a third dimension. Nature 332, 356–357.

Lehrer, M.#, Srinivasan, M.V. and Wehner, R.+ Bees perceive motion induced colour illusions, p 276. Abstr. 11th Annual Meeting of the European Neuroscience Association, Zurich. Eur. J. Neuroscience Suppl. September 1988.

Millar, T.J.*, Winder, C.§, Ishimoto, I.* and Morgan, I.G. Putative serotonergic bipolar and amacrine cells in the chicken retina. Brain Research 439, 77–87.

Morgan, I.G., Millar, T.J.*, Yang, G. and Dvorak, D.R.* Retinal circuitry and retinal neurotransmitters. Proceedings of the Australian Physiological and Pharmacological Society 19, 25–35.

Morgan, I.G. New perspectives on excitotoxicity. Neuroscience Letters, Suppl. 30, S11–12.

Morgan, I.G. Bromowillardine is a quisqualic acid-type agonist in the chicken retina. Neuroscience Letters, Suppl. 30, S102–103.

Morgan, I.G. and Millar, T.J.* Localization of nicotinic acetylcholine receptors in the chicken retina. Neuroscience Letters, Suppl. 30, S103.

Osorio, D. Temporal properties of non-linear transient cells in the locust medulla. J. Comp. Physiol. A 161, 431–440.

Osorio, D. Temporal and spectral properties of sustaining cells in the medulla of the locust. J. Comp. Physiol. A 161, 441–448.

Osorio, D., Snyder, A.W.† and Srinivasan, M.V. Bi-partitioning and boundary detection in natural scenes. Spatial Vision 2, 191–198.

Poznanski, R.R. Membrane voltage changes in passive dendritic trees: a tapering equivalent cylinder model. I.M.A. J. Maths. Appl. in Med. Biol. 5(2), 113–145.

Srinivasan, M.V. Visual motion processing in the invertebrate context. Neuroscience Letters, Suppl. 30, S37–38.

Srinivasan, M.V. and Lehrer, M.# Spatial acuity of honeybee vision, and its spectral properties. J. Comp. Physiol. A 162, 159–172.

Srinivasan, M.V., Lehrer, M.#, Kirchner, W.§ and Horridge, G.A. How motion cues extend honeybee vision into the third dimension. Abstr. 11th Annual Meeting European Neuroscience Association, Zurich. Eur. J. Neuroscience Suppl. p 222. September 1988.

Srinivasan, M.V., Lehrer, M.#, Kirchner, W.§, Zhang, S.W.# and Horridge, G.A. How honeybees use motion cues to estimate range and discriminate objects, pp 553–556. Proc. IEEE Conference on Systems, Man and Cybernetics, Beijing and Shenyang.

Takada, M.+, Li, Z.K. and Hattori, T.+ Substantia nigra: Collateral projections from the striatum and superior colliculus in the rat. Neuroscience, 25, 563–568.

Takada, M.+, Li, Z.K. and Hattori, T.+ Single thalamic dopamine neurons project to both the neocortex and spinal cord. Brain Res. 455, 346–352.

Takada, M.+, Li, Z.K. and Hattori, T.+ Dopaminergic nigrotectal projection in the rat. Brain Res. 457, 165–168.

Tung, N.N., Morgan, I.G. and Ehrlich, D.* Differential effects of KA and AMPA on cells of the retinal ganglion cell layer of the chick: analysis of cell size. Neuroscience Letters, Suppl. 30, S133.

van der Valk, J. Dose response functions for kainic acid and quisqualic acid determined electrophysiologically in the axolotl inner retina. Neuroscience Letters, Suppl. 30, S135.

Yang, G., Morgan, I.G. and Dvorak, D.* Ganglion cell responses in ECMA lesioned chicken retina. Neuroscience Letters, Suppl. 30, S142.

Yang, G., Morgan, I.G. and Millar, T.J.* Morphological studies of displaced ganglion cells in the chicken retina. Neuroscience Letters, Suppl. 30, S142.

Yang, G., Millar, T.J.* and Morgan, I.G. Morphological studies of displaced ganglion cells in the chicken retina. Abstr. Soc. for Neuroscience 14, 1121.

In Press

Barlin, G.B.†, Davies, L.P.# and Ngu, M.M.L.† Imidazo (1,2-b)-pyridazines. IV. Synthesis and central nervous system activities of some 3-ethoxy-6-phenoxy (substituted phenoxy and napthyloxy) imidazo (1,2,-b) pyridazines. Aust. J. Chem.

Barlin, G.B.†, Davies, L.P.# and Ngu, M.M.L.† Imidazo (1,2-b) pyridazines. V. Synthesis and central nervous system activities of some 3-alkoxy-6-benzylthio (substituted benzylthio and other phenylalkylthio)-2-phenyl (and substituted phenyl) imidazo (1,2-b) pyridazines. Aust. J. Chem.

Boelen, M.K.*, Chubb, I.W.+ and Morgan, I.G. Effects of different light intensities on levels of enkephalin- and somatostatin-like immunoreactivity in the chicken retina. Neuroscience Letters.

Boelen, M.K.*, Downton, M.+, Morgan, I.G. and Chubb, I.W.+ Glycinergic and cholinergic control of diurnal variations in retinal levels of leuenkephalin in chicken. Neuroscience Letters.

Dodd, P.R.+, Davies, L.P.#, Watson, W.E.J.+, Nielsen, B.+, Dyer, J.A.+, Wong, L.S.+ and Johnson,

G.A.R.[+] Neurochemical studies on quinolone antibiotics: effects on glutamate, GABA and adenosine systems in mammalian CNS. Pharmacol. Toxicol.

Hardie, R.C.[+], Laughlin, S.B.[+], Osorio, D. Early visual processing in the compound eye: Physiology and pharmacology of the retina-lamina projection in the fly. Proc. 1st International Conference on Neurobiology of Sensory Systems. (eds. R.N. Singh and N.J. Strausfeld). Goa. India. Plenum Press, NY.

Horridge, G.A. Technical perspectives derived from insect vision. Proc. International Conference on Technology for the Blind. Melbourne.

Horridge, G.A. Primitive vision based on sensing change. Proc. 1st International Conference on Neurobiology of Sensory Systems. (eds. R.N. Singh and N.J. Strausfeld). Goa. India. Plenum Press, NY.

Laughlin, S.B.[+] and Osorio, D. Mechanism for neural signal enhancement in the blowfly compound eye. J. exp. Biol.

Li, Z.K., Buttery, R.[+] and Morgan, I.G. Cytochrome oxidase histochemistry reveals displaced ganglion cells in the chicken retina. Neuroscience Letters.

Li, Z.K. and Morgan, I.G. GABA and GAD-immunoreactive neurons in the chicken retina. Neuroscience Letters.

Morgan, I.G., Millar, T.J.*, Ishimoto, I.*, Boelen, M.*, Downton, M.* and Chubb, I.W.[+] Functional studies on enkephalin- and somatostatin-immunoreactive amacrine cells in the chicken retina. In: *Neurobiology of the Inner Plexiform Layer,* (eds. N.N. Osborne and R. Weiler). Springer-Verlag, Berlin.

Morgan, I.G. Diversity of retinal interneurons and retinal function. Neuroscience Letters.

Srinivasan, M.V. Visual motion processing in the invertebrate context. Proceedings, Conference of the Australian Physiological and Pharmacological Society, Canberra.

Srinivasan, M.V. Motion sensitivity in insect vision: roles and neural mechanisms. Proc. 1st International Conference on Neurobiology of Sensory Systems. (eds. R.N. Singh and N.J. Strausfeld). Goa. India. Plenum Press, NY.

Yang, G., Dvorak, D.R.* and Morgan, I.G. Electrophysiological properties of directionally selective cells in the nucleus of the basal optic root in the chicken. Neuroscience Letters.

MOLECULAR GENETICS

Published

Brajanovic-Urosevic, N.,[+] Naora, H., Mills, G.C.[+] and Holoubeck, V.[§] Nucleotide sequence of small chromatin-associated RNA (fr3 RNA). Eur. J. Biochem. 173, 375–376.

Clark-Walker, G.D., Hoeben, P.,* Plazinska, A., Smith, D.K.* and Wimmer, E.H. (1987). Application of mitochondrial DNA analysis to yeast systematics. In: *The Expanding Realm of Yeast-like Fungi.* pp 259–266. (eds. G.S. De Hoog, M. Th. Smith and A.C.M. Weijman). Elsevier Science Publishers, Amsterdam.

Sun, L-Q.* and Naora, H. A transcriptional unit neighbouring *c-myc*. Progress in Biochem. Biophys. 15, 214–215.

In Press

Clark-Walker, G.D. The genome of Bakers Yeast—the Benchmark for a Eukaryotic Cell. Yeast.

Naora, H. Gene-ecological aspects of non-coding DNA sequences and genome evolution. In: *Dynamic Structures in Biology.* (eds. B. Goodwin, A. Sibatani, and W.D. Webster.) Edinburgh University Press.

Naora, H., Gene ecology and origin of genomes. In: *Life, Structures and Recognition.* (ed. A. Sibatani) UPU Inc., Tokyo.

Naora, H., Miyahara, K. and Koishi, K. Concerted structures of extragenic sequences within a gene. Biology Forum.

Sun, L-Q.*, Naora, H. and Su, C-Z. Study on *c-myc* expression. Chinese J. Biochem.

Sun, L-Q.* and Naora, H. A novel regulatory mechanism for gene expression. Molecular Biology in Medical Science Review.

Sun, L-Q.* *c-myc* activation and amplification. J. Fourth Military Medical University, Xi'an, People's Republic of China.

POPULATION GENETICS

Published

Arnold, M.L., Contreras, N., and Shaw, D.D. 1988 Biased gene conversion and asymmetrical introgression between subspecies. Chromosoma 96, 368–371.

Boussy, I.* A latitudinal cline in P-M gonadal dysgenesis potential in Australian *Drosophila melanogaster* populations. Genet. Res. 49, 11–18.

Colgan, D.J. Hormonal effects of the developmental variation in the glucose-metabolizing enzymes of the grasshopper *Caledia captiva*. Entomologia Generalis.

Cooke, P.H., Richmond, R.C.[§] and Oakeshott, J.G.* High resolution electrophoretic variation at the esterase-6 locus in a natural population of *Drosophila melanogaster*. Heredity 59, 529–264.

Freeth, A.L., Gibson, J.B., and Wilks, A.V. Transcription analysis of alcohol dehydrogenase null alleles from natural populations of *Drosophila melanogaster*. Genome 30, 25–30.

Gibson, J.B. and Wilks, A.V. The alcohol dehydrogenase polymorphism of *Drosophila melanogaster* in relation to environmental ethanol, ethanol tolerance and alcohol dehydrogenase activity. Heredity 60, 403 414.

Jiang, C., Gibson, J.B., Wilks, A.V., and Freeth, A.L. Restriction endonuclease variation in the region of the alcohol dehydrogenase gene: a comparison of null and normal alleles from natural populations of *Drosophila melanogaster*. Heredity 60, 101–107.

John, B.* The Biology of Heterochromatin. In: *Molecular and Structural aspects of Heterochromatin*. (ed. R. Verma) C.U.P., New York.

John, B.* and Miklos, G.L.G. *The Eukaryote Genome in Development and Evolution*. Unwin Hyman, London.

John, B.*, Rentz, D.C.F.+ and Contreras, N. (1987) Extensive chromosome variation in the stick insect genus *Sipyloidea* Brunner von Wattenwyl (Phylliidae: Necrosciinae) within Australia, and descriptions of three new species. Invertebr. Taxon. 1, 603–30.

Kohlmann, B., Nix, H.,† and Shaw, D.D. 1988 Environmental predictions and distributional limits of chromosomal taxa in the Australian grasshopper *Caledia captiva* (F.). Oecologia 75, 483–493.

Macbeth, H.M.+, Harrison, G.A.+ and Gibson, J.B. Geographical mobility and I.Q. components. J. biosoc. Sci. 19, 379–394.

McIntyre, C.L. Evolutionary change in grasses from the Triticeae. VI. Variation at isozyme loci in Triticeae. Plant Syst. Evol. 160, 123–142.

McIntyre, C.L., Clarke, B.C.+ and Appels, R.# Evolutionary change in grasses from the Triticeae. I. Amplification and dispersion of repeated DNA sequences in the Triticeae. Plant Syst. Evol. 160, 39–59.

McIntyre, C.L. Clarke, B.C.+ and Appels, R.# Evolutionary change in grasses from the Triticeae. IV. DNA sequence analyses of the ribosomal spacer regions in the Triticeae. Plant Syst. Evol. 160, 91–104.

Marchant, A.D. Apparent introgression of mitochondrial DNA across a narrow hybrid zone in the *Caledia captiva* species-complex. Heredity 60, 39–46.

Rowell, D.M.* The chromosomal constitution of *Delena cancerides* Walck. (Araneae: Sparassidae) and its role in the maintenance of social behaviour. In: *Australian Arachnology*, pp 107–111. (eds. A.D. Austin and N.W. Heather). Miscell. Public. No. 5, Australian Entomological Society, Brisbane.

Scoles, G.J.+, Gill, B.S.+, Xin, Z-Y+, Clarke, B.C.+, McIntyre, C.L., Chapman, C.+ and Appels, R.# Evolutionary change in grasses from the Triticeae. V. Frequent duplication and deletion events in the 55 RNA genes and the associated spacer regions of the Triticeae. Plant Syst. Evol. 160, 105–122.

Shaw, D.D. The origins and development of adaptations: A review. Aust. J. Ecol. 13, 248–250.

Shaw, D.D., Coates, D.J., and Arnold, M.S. 1988 Complex patterns of chromosomal variation along a latitudinal cline in S.E. Australia. Genome 30 108–117.

Watson, E.M.§ C-banding patterns in the Australian *Bulbine* (Liliaceae): the perennial group, *B. Bulbosa* s.lat. Plant Syst. Evol. 157, 201–217.

Watson, E.M.§ C-banding patterns in the Australian *Bulbine* (Liliaceae): the annual group, *B. semibarbata* s. lat. Plant Syst. Evol. 159, 1–17

West, J.+, McIntyre, C.L. and Appels, R.# An overview of evolution and taxonomic relationships in the Triticeae. Plant Syst. Evol. 160, 1–28.

In Press

Colgan, D.J. and Christian, P.D. A neoviral genome contaminating a mitochondrial preparation from *Caledia captiva*. J. Invertebr. Pathol.

Colgan, D.J. Developmental variation in relation to the maintenance of allozymic polymorphism in the enzymes of glycolysis in grasshoppers. J. Env. Biol.

Colgan, D.J. The genetic structure of the *Enterobacter* population in a community of grasshoppers. Biol. J. Linn Soc.

Christidis, L. Chromosome evolution in finches and their allies (families Ploceidae, Fringillidae and Emberizidae.) Genome.

Jiang, C., Gibson, J.B. and Chen, H. Genetic differentiation in populations of *Drosophila melanogaster* from the People's Republic of China: comparison with patterns on other continents. Heredity.

Marchant, A.D., Arnold, M.L., and Wilkinson, P. Gene flow across a chromosomal tension zone. 1. Relicts of Ancient Hybridization. Heredity.

Shaw, D.D., Marchant, A.D., Arnold, M.L., Contreras, N. and Kohlmann, B. The control of gene flow across a narrow hybrid zone: a selective role for chromosomal rearrangement? In: *Evolutionary and Ecological Significance of Hybridisation and Introgression in Insects*. (eds. R.H. Gooding and J.R. Spence.). Can. J. Zool.

Shaw, D.D., Marchant, A.D., Arnold, M.L., and Contreras, N. Chromosomal rearrangements, ribosomal genes and mitochondrial DNA: contrasting patterns of introgression across a narrow hybrid zone. In: *Kew Chromosome Conference III*. (eds. P.E. Brandham and M.D. Bennett.) HMSO London.

PLANT CELL BIOLOGY

Published

Badenoch-Jones, J.[#], Parker, C.W. and Letham, D.S. Use of isopentenyladenosine and dihydrozeatin riboside antibodies for the quantification of cytokinins. J. Plant Growth Regul. 6, 159–182.

Busby, C. H. and Gunning, B. E. S. Establishment of plastid-based quadripolarity in spore mother cells of the moss *Funaria hygrometrica*. J. Cell Sci. 91, 127–138.

Busby, C. H. and Gunning, B.E.S. Development of the quadripolar meiotic cytoskeleton in spore mother cells of the moss *Funaria hygrometrica*. J. Cell Sci. 91, 139–144.

Cadrin, M.[+], Wasteneys, G.O., Jones-Villeneuve, E.M.V.[+], Brown, D.L.[+], Reuhl, K.R.[+] Effects of methylmercury on retinoic acid-induced neuroectodermal derivatives of embryonal carcinoma cells. Cell Biol. Toxicol. 4, 61–80.

Clements, M.A. Orchid mycorrhizal associations. Lindleyana 3, 73–86.

Grolig, F.[#], Williamson, R.E., Parke, J.[+], Miller, C.[+], Anderton, B.H.[+]. Myosin and Ca^{2+}-sensitive streaming in the alga *Chara*: detection of two polypeptides reacting with a monoclonal anti-myosin and their location in the streaming endoplasm. Eur. J. Cell Biol. 47, 22–31.

Gubler, F. and Hardham, A.R. Secretion of adhesive material during encystment of *Phytophthora cinnamomi* zoospores, characterised by immunogold labelling with antibodies to components of peripheral vesicles. J. Cell Sci. 90, 225–235.

Gubler, F., Ashford, A.E.[+] and Jacobsen, J.V.[+] The release of α-amylase through gibberellin-treated barley aleurone cell walls. Planta 172, 155–161.

Hocart, C.H.*, Badenoch-Jones, J.[#], Parker, C.W., D.S. Letham and R.E. Summons.* Cytokinins of dry *Zea mays* seed: quantification by radioimmunoassay and gas chromatography-mass spectrometry. J. Plant Growth Regul. 7, 179–196.

Jameson, P.E.[§] Letham, D.S. Zhang, R.*, Parker, C.W. and Badenoch-Jones, J.[#]. Cytokinin translocation and metabolism in lupin species. I. Zeatin riboside introduced into the xylem at the base of *Lupinus angustifolius* stems. Aust. J. Plant Physiol. 14, 695–718.

Marc, J.*, Gunning, B.E.S., Hardham, A.R., Perkin, J.L.* and Wick, S.M.* Monoclonal antibodies to surface and cytoskeletal components of the spermatozoid of *Pteridium aquilinum*. Protoplasma 142, 5–14.

Marc, J.* and Gunning, B.E.S. Monoclonal antibodies to a fern spermatozoid detect novel components of the mitotic and cytokinetic apparatus in higher plant cells. Protoplasma 142, 15–24.

Mineyuki, Y.[§] and Gunning, B.E.S. Streak time-lapse video microscopy: analysis of protoplasmic motility and cell division in *Tradescantia* stamen hair cells. J. Microscopy 150, 41–55.

Mineyuki, Y.[§], Wick, S.M.[*] and Gunning, B.E.S. Preprophase bands of microtubules and the cell cycle: kinetics and experimental uncoupling of their formation from the nuclear cycle in onion root-tip cells. Planta 174, 518–526.

Nicholl, D.S.T.[+], Schloss, J.A.[+] and John, P.C.L. Tubulin gene expression in the *Chlamydomonas reinhardtii* cell cycle: elimination of environmentally-induced artifacts and the measurement of tubulin mRNA levels. J. Cell Sci. 89, 397–403.

Palni, L.M.S., Burch, L.[+] and Horgan, R.[+] The effect of auxin concentration on cytokinin stability and metabolism. Planta 174, 231–234.

Plazinski, J., Franche, C.[§], Liu, C-C.[+], Lin, T.[+], Shaw, W.[§] Gunning, B.E.S. and Rolfe, B. Taxonomic status of *Anabaena azollae*, an overview. Symposium on the Contribution of Biological Nitrogen Fixation to Plant Production. Plant and Soil 108, 185–190.

Wampler, J.E.[+], Chen, J.[+], De Mendoza, L.G.[+], Furukawa, R.H.[+], McCurdy, D.W., Pruett, L.[+], White, R.A.[+] and Fechheimer, M.[+] Strategies for spatially resolved microspectrofluorometric analysis. In: *Time-Resolved Laser Spectroscopy in Biochemistry*, Vol. 909, pp 319–327, (ed. J.R. Lakowicz). Proceedings of SPIE-The International Society for Optical Engineering.

Warren Wilson, J.[†], Walker, E.S.[†], Warren Wilson, P.M.[#] and Hall, P.J.* Morphogenetic, inductive and inhibitory effects of IAA conjugates on abscission in stem explants of *Impatiens sultani*. Ann. Bot. 60, 687–691.

Warren Wilson, P.M.[#], Warren Wilson, J.[†] and Walker, E.S.[†] Abscission sites in nodal explants of *Impatiens sultani*. Ann. Bot. 60, 693–704.

Wasteneys, G.O, Cadrin, M.[+], Reuhl, K.R.[+] and Brown, D.L.[+] The effects of methylmercury on the cytoskeleton of murine embryonal carcinoma cells. Cell Biol. Toxicol. 4, 41–60.

Webb, M.C. and Williams, E.G.[+] Effects of temperature, light, nutrients and carbon dioxide on the strength of the self-incompatibility response in detached flowers of *Lycopersicon peruvianum*. Ann. Bot. 61, 395–404.

Webb, M.C. and Williams, E.G.[+] The pollen tube pathway in the pistil of *Lycopersicon peruvianum*. Ann. Bot. 61, 415–423.

Williams, E.G.[+] and Webb, M.C. Enclosure of pollinated flowers weakens the gametophytic self-incompatibility response in *Lycopersicon peruvianum*. J. Exp. Bot., 38, 1756–1764.

Wong, O.C., Hocart, C.H.* and Letham, D.S. Mass-spectrometry of t-butyldimethylsilyl derivatives of cytokinins. In: *Mass spectrometry and allied topics*, pp 337–338 (ed. C.M. McEwen). American Society for Mass Spectrometry, Cincinnati, USA.

Wong, O.C., Zhang, R.[#] and Letham, D.S. Mass spectrometric studies of cytokinin metabolites in

relation to retardation of leaf senescence. In: *Mass spectrometry and allied topics*, pp 339–340 (ed. C.M. McEwen). American Society for Mass Spectrometry, Cincinnati, USA.

Zhang, R.[#], Letham, D.S. and Noodén, L.D.[§] Cytokinin conjugation in relation to soybean leaf senescence. In: *Conjugated plant hormones—structure, metabolism and function*, pp 128–137 (eds. K. Schreiber, H.R. Schutte and G. Sembnder). VEB Deutscher Verlag der Wissenschaften, Berlin, FRG.

In Press

Bittisnich, D.F.[†], and Williamson, R.E. Application of the acid-growth theory to a tip growing plant system. Planta.

Cleary, A.L. and Hardham, A.R. Depolymerization of microtubule arrays in root tip cells by oryzalin, and their recovery with modified nucleation patterns. Can. J. Bot.

Davis, A.R. Nectaries: secretory structures important to beekeepers. In: Proceedings of the Second Australian and International Bee Congress, Surfers Paradise (ed. J. Rhodes).

Davis, A.R. Contamination of honeybee larval food by insecticide: some possible pathways. In: Proceedings of the Second Australian and International Bee Congress, Surfers Paradise (ed. J. Rhodes).

Gubler, F. Immunofluorescence localization of microtubules in plant root tips embedded in butyl-methyl methacrylate. Cell Biol. Int. Reports.

Gubler, F., Hardham, A.R. and Duniec J. Characterising adhesiveness of *Phytophthora cinnamomi* zoospores during encystment. Protoplasma.

Gunning, B.E.S. Video enhancement and image processing in light microscopy. Part III. Image processing and presentation. American Laboratory.

Hardham, A.R. Lectin and antibody labelling of surface components of spores of the dieback fungus *Phytophthora cinnamomi*. Aust. J. Plant Physiol.

Hardham, A.R. Plant Growth and Morphogenesis. In: *Plant Physiology* (eds. L. Taiz and E. Zeiger). Benjamin/Cummings Pub. Co. California, USA.

Horgan, R.[+], Burch, L.R.[+] and Palni, L.M.S.[#] The degradative metabolism of cytokinins. In: *Plant Growth Substances 1988*. (eds. R.P. Pharis and S.B. Rood). Springer-Verlag, New York.

Letham, D.S. and Singh, S. Quantification of cytokinin O-glucosides by negative ion mass spectrometry. Plant Physiol.

Letham, D.S. Parker, C.W., Zhang, R.[#], Singh, S., Upadhyaya, M.N.[⋆], Dart, P.J.[⋆] and Palni, L.M.S.[#] Xylem translocated cytokinin: metabolism and function. In: *Plant Growth Substances 1988*. (eds. R.P. Pharis and S.B. Rood). Springer-Verlag, New York.

Lin, Q., Grolig, F.[#], Jablonsky, P.P. and Williamson, R.E. Myosin heavy chains: detection by immunoblotting in higher plants and localization by immunofluorescence in the alga *Chara*. Cell Biol. Int. Rep.

McCurdy, D.W., Sammut, M. and Gunning, B.E.S. Immunofluorescent visualisation of arrays of transverse cortical actin microfilaments in wheat root-tip cells. Protoplasma.

Mineyuki, Y.[#], Letham, D.S. and Hocart, C.H.[⋆] New 3-substituted xanthines: potent inhibitors of cell plate formation. Cell Biol. Int. Rep.

Nandi, S.K., Letham, D.S., Palni, L.M.S.[#], Wong O.C. and Summons, R.E.[⋆] 6-Benzylaminopurine and its glycosides as naturally occurring cytokinins. Plant Sci.

Nandi, S.K., Palni, L.M.S.[#], Letham, D.S. and Knypl, J.S.[§] The biosynthesis of cytokinins in germinating lupin seeds. J. Exp. Bot.

Nandi, S.K., Palni, L.M.S.[#] and Letham, D.S. Axial control of cotyledon expansion and chlorophyll formation in germinating lupin seeds. Plant Sci.

Nandi, S.K., Palni, L.M.S.[#], Letham, D.S. and Wong, O.C. Identification of cytokinins in primary crown-gall tumours of tomato. Plant Cell Environ.

Noodén, L.D.[§], Guianet, J.[+], Singh, S., Letham, D.S. Tsuji, J.[+] and Schneider, M.J.[+] Hormonal control of senescence. In: *Plant Growth Substances 1988*. (eds. R.P. Pharis and S.B. Rood). Springer-Verlag, New York).

Palni, L.M.S.[#] and Nandi, S.K. The biochemistry and molecular biology of cytokinin production and metabolism. In: Proceedings of the First International Plant Physiology Congress, New Delhi (ed. S.K. Sinha).

Palni, L.M.S.[#], Nandi, S.K. and Singh, S. Physiology and biochemistry of cytokinins. In: *Hormonal Regulation of Plant Growth and Development*, Vol. 5 (ed. S.S. Purohit). Martinus Mijhoff/Junk, The Netherlands.

Palni, L.M.S.[#], Nandi, S.K., Singh, S. and Letham, D.S. An overview of cytokinin biosynthesis. In: *Plant Growth Substances 1988*. (eds. R.P. Pharis and S.B. Rood). Springer-Verlag, New York.

Parker, C.W., Badenoch-Jones, J.[#] and Letham, D.S. A radioimmunoassay for quantifying the cytokinins, *cis*-zeatin and *cis*-zeatin riboside and its application to xylem sap samples. J. Plant Growth Regul. 7.

Plazinski, J. and Gunning, B.E.S. *Azolla-Anabaena* symbiosis. In: *Molecular Biology of Symbiotic Nitrogen Fixation*. (ed. P.R. Gresshoff), CRC Press.

Singh, S., Letham, D.S., Jameson, P.E.[§], Zhang, R.[#], Parker, C.W., Badenoch-Jones, J.[#] and Noodén, L.D.[§] Cytokinin biochemistry in relation to leaf senescence. IV. Cytokinin metabolism in soybean explants. Plant Physiol. 88.

Warren Wilson, J.[†], Warren Wilson, P.M.[#] and Walker, E.S.[†] Effects of applied IAA on the position of abscission sites induced in wounded explants from *Impatiens sultani* internodes. Ann. Bot.

Warren Wilson, J.[†], Walker, E.S.[†], and Warren Wilson, P.M.[#] The role of basipetal auxin transport in the positional control of abscission sites induced in *Impatiens sultani* stem explants. Ann. Bot.

Webb, M.C. and Gunning, B.E.S. The microtubular cytoskeleton during embryo sac development in *Arabidopsis thaliana*. In: *Pollination 88*, (ed. R.B. Knox). University of Melbourne Press.
White, R.A.[+], McCurdy, D.W., Harmon, A.C.[+], Pruett, P.L.[+], Pratt, L.H.[+], Fechheimer, M.[+] and Wampler, J.E.[+] The use of fluorescein dyes for pH measurements in living plant cells. Plant Physiology.
Williamson, R.E., McCurdy, D.W., Grolig, F.[#], Hurley, U.A., Jablonsky, P.P., Wasteneys, G.O. Methods for studying the plant cytoskeleton. In: *Plant Fibres*. (eds. H.-F. Linskens and J.F. Jackson). Modern Methods of Plant Analysis, New Series. Vol. 10. Springer-Verlag, Berlin.
Zhang, R.[#] and Letham, D.S. Cytokinin biochemistry in relation to leaf senescence. III. The senescence-retarding activity and metabolism of 9 substituted 6-benzylaminopurines. J. Plant Growth Regul.

PLANT MOLECULAR BIOLOGY

Published

Andrews, T.J. Catalysis by cyanobacterial ribulosebisphosphate carboxylase large subunits in the complete absence of small subunits. J. Biol. Chem. 263, 12213–12220.
Bassam, B.J.*, Djordjevic, M.A., Redmond, J.W.[+], Batley, M.[+] and Rolfe, B.G. Identification of a *nodD*-dependent promoter in the *Rhizobium* strain NGR234 which is activated by phenolic factors secreted by soybeans and other legumes. Molec. Plant-Microbe Inter. 1, 161–168.
Björkman, O.[+], Demmig, B.[+], and Andrews, T.J. Mangrove photosynthesis: response to high-irradiance stress. Aust. J. Plant Physiol. 1, 43–61.
Bruhl, J.J., Stone, N.E.* and Hattersley, P.W.* C_4 acid decarboxylation enzymes and anatomy in sedges (Cyperaceae): first record of an NAD-malic enzyme species. Aust. J. Plant Physiol. 14, 719–728.
Buchen-Osmond, C., Crabtree, K., Gibbs, A. and McLean, G. (eds) *Viruses of Plants in Australia*. R.S.B.S., A.N.U.
Canter Cremers, H.C.J.[§], Wijffelman, C.A.[+], Pees, E.[+], Rolfe, B.G., Djordjevic, M.A. and Lugtenberg, B.J.J.[+] Host specific nodulation of plants of the pea cross-inoculation group is influenced by genes in fast-growing rhizobia downstream to *nodC*. J. Plant Physiol. 132, 398–404.
Chen, H.C.*, Gray, J.X., Nayudu, M., Djordjevic, M.A., Batley, M.[+], Redmond, J.W.[+] and Rolfe, B.G. Five genetic loci involved in the synthesis of acidic exopolysaccharides are closely linked in the genome of *Rhizobium* sp. strain NGR234. Mol. Gen. Genet. 212, 310–318.
Chen, H.C.* and Rolfe, B.G. *Rhizobium* infection of *Leucaena leucocephala* via the formation of infection threads in curled root hairs. J. Plant Physiol. 332, 379–382.
Creaser, E.H., Gibbs, A.J., and Pares, R.D.[+] The amino acid composition of a tobamovirus from an Australian Capsicum crop. Aust. J. Plant Pathology 16, 85–87
Creaser, E.H. and Murali, C. Redesigning yeast alcohol dehydrogenase by protein engineering. Proceedings 14th International Congress of Biochemistry, Prague, p 250.
Dazzo, F.B.[+], Hollingsworth, R.[+], Philip-Hollingsworth, S.[+], Robeles, M.[+], Olen, T.[+], Salzwedel, J.[+], Djordjevic, M. and Rolfe, B.G. Recognition process in the *Rhizobium trifolii*-white clover symbiosis, In: *Nitrogen Fixation: Hundred years after*. Proc. 7th International Congress on Nitrogen Fixation, pp 431–435 (eds. H. Bothe, F.J. de Bruijn and W.E. Newton), Gustav Fischer, N.Y., 1988.
Djordjevic, S.P., Ridge, R.W.*, Redmond, J.W.[+], Batley, M.[+], Chen, H.C.* and Rolfe, B.G. Induction of pathogenic-like responses in the legume *Macroptilium atropurpureum* by a transposon-induced mutant of the fast-growing, broad host range *Rhizobium* NGR234. J. Bacteriol. 170, 1848–1857.
Edwards, G.E.[+], Jenkins, C.L.D.[+], Andrews, T.J. CO_2 assimilation and activities of photosynthetic enzymes in high chlorophyll fluorescence mutants of maize having low ribulose 1,5-bisphosphate carboxylase. Plant Physiol. 86, 533–539.
Fenner, F.[†] and Gibbs, A. (eds) *Portraits of Viruses; a History of Virology*. 344pp. Karger, Basel.
Hattersley, P.W.* Variations in photosynthetic pathway. In: *Grass Systematics and Evolutions*, pp 49–64. (eds. C.S. Campbell et al.). Smithsonian Institution, Washington.
Huang, S.Z.[§], Djordjevic, M.A. and Rolfe, B.G. Characterization of aberrant infection events induced on *Trifolium subterraneum* by *Rhizobium trifolii* region II mutants. J. Plant Physiol. 133, 16–25.
Morell, M.K. and Andrews, T.J. The role of a carboxylterminal sequence of ribulosebiphosphate carboxylase from *Rhodospirillum rubrum* studied by site-directed mutagenesis. Proc. Aust. Biochem. Soc. 20, 107.
Morell, M.K., Price, G.D., Woo, K.C., Hubick, K.T. and Wellington, A.B. Science Policy in Australia. Nature 336, 10.
Piskur, J. A 5kb intergenic region containing *oril* in the mitochondrial DNA of *Saccharomyces cerevisiae* is dispensable for expression of the repiratory phenotype. FEBS Letts. 29, 145–149.
Piskur, J. Sensitivity of intergenic regions of yeast mictochondrial DNA to single-strand-specific nucleases. FEBS Letts. 238, 435–440.
Plazinski, J., Franche, C.[§], Liu, C.-C.[+], Lin, T.[+], Shaw, W.[§], Gunning, B.E.S. and Rolfe, B.G. Taxonomic status of *Anabaena azollae*: An overview. Plant and Soil 108, 185–190.

Prendergast, H.D.V.* and Hattersley, P.W.* Leaf blade structure and C_4 acid decarboxylation enzymes in X *Cynochloris* spp. (Poaceae), intergeneric hybrids between parents of different C_4 types. Bot. J. Linn. Soc. 96, 381–389.

Richardson, A.E.*, Simpson, R.+, Djordjevic, M.A. and Rolfe, B.G. Expression and induction of nodulation genes in *Rhizobium trifolii* at low pH and in the presence of Ca and Al. Appl. Environ. Microbiology. 54, 2541–2548.

Richardson, A.E.*, Djordjevic, M.A., Simpson, R.J.+ and Rolfe, B.G. Effects of pH, Ca and Al on the exudation from clover seedlings of compounds that induce the expression of nodulation genes in *Rhizobium trifolii*. Plant and Soil. 109, 37–47, 1988.

Rolfe, B.G. Flavones and isoflavones as inducing substances of legume nodulation. Biofactors 1, 3–10.

Rolfe, B.G. and Gresshoff, P.M. Genetic analysis of legume nodule initiation. Ann. Rev. Plant Physiol. & Plant Mol. Biol. 39, 297–319.

Rolfe, B.G., Weinman, J.J. and Djordjevic, M.A. The genetics of nodulation and nitrogen fixation by rhizobia. In: *Microbiology in Action: A tribute to James M. Vincent on his 75th Year*, pp 157–175. (eds. I. Kennedy and W.G. Murrell) CRC Press, Inc.

Rolfe, B.G., Batley, M.+, Redmond, J.W.+, Richardson, A.E.*, Simpson, R.J.+, Bassam, B.J.*, Sargent, C.L., Weinman, J.J., Djordjevic, M.A. and Dazzo, F.B.+ Phenolic compounds secreted by legumes, In: *Nitrogen Fixation: Hundred Years After*. Proc. 7th International Congress on Nitrogen Fixation, pp 405–409. (eds. H. Bothe, F.J. de Bruijn and W.E. Newton), Gustav Fischer, NY.

Watson, L. Automated descriptions of grass genera. In: *Grass Systematics and Evolution*, pp 343–351. (eds. C.S. Campbell et al.). Smithsonian Institution, Washington.

Watson, L., Dallwitz+, M.J., Gibbs, A.J. and Pankhurst, R.J.# Automated taxonomic descriptions. In: *Prospects in Systematics*, pp 292–304. (eds. D.L. Hawksworth et al.) Publ. for Systematics Association, London. Clarendon Press, Oxford.

Watson, L., and Dallwitz, M.J.+ *Grass Genera of the World: illustrations of characters, descriptions, classification, interactive identification and information retrieval*. Research School of Biological Sciences, ANU, Canberra (with 4 microfiches and two floppy disks for use with MS-DOS microcomputers).

Watson, L., Damanakis, M.# and Dallwitz, M.J.+ *The Grass Genera of Greece: morphology, anatomy, keys, classification*. 230pp (in Greek) University of Crete, Iraklion.

Yeoh, H.H.* and Watson, L. Taxonomic patterns in protein amino acid profiles of grass leaves and caryopses. In: *Grass Systematics and Evolution*, pp 88–96. (eds. C.S. Campbell et al.). Smithsonian Institution, Washington.

In Press

Amarasinghe, V. and Watson, L. Comparative ultrastructure of microhairs in grasses. Bot. J. Linn. Soc.

Anderson, D.L. and Gibbs, A.J. Inapparent virus infections and their interactions in pupae of the honey bee (*Apis mellifera* L.) in Australia. Ann. appl. Biol.

Anderson, D.L. and Gibbs, A.J. Transpuparial transmission of Kashmir bee virus and sacbrood virus in the honey bee (*Apis mellifera* L.). Ann. appl. Biol.

Bender, G.L., Le Strange, K.K., Nayudu, M. and Rolfe, B.G. *Rhizobium nodD* gene is a key element in the host-specific interaction between non-legumes and *Rhizobium*. Molec. Plant-Microbe Inter.

Bruhl, J.J. and Quinn, C.J.+ Cypsela anatomy in the 'Cotuleae' (Asteraceae, Anthemidae). Bot. J. Linn. Soc. Lond.

Ding, S.-W., Keese, P. and Gibbs, A. Nucleotide sequence of the genome of onion yellow mosaic tymovirus. Virology.

Gadek, P.+, Bruhl, J. and Quinn, C.+ Exine structure in the 'Cotuleae' (Anthemideae: Asteraceae). Grana.

Keese, P., Mackenzie, A., and Gibbs, A.J. Nucleotide sequence of the genome of an Australian isolate of turnip yellow mosaic virus. Virology.

Morell, M.K., Price, G.D., Woo, K.C., Hubick, K.T. and Wellington, A.B. and Tanner, G.T.+ Australian Science: Problems at the coalface, In: *The Role of Innovation in the Economy*. National Science and Technology Analysis Group Forum. Academy of Science, Canberra.

Osorio-Keese, M., Keese, P. and Gibbs, A. Nucleotide sequence of the genome of eggplant mosaic tymovirus. Virology.

Piskur, J. Transmission of yeast mitochondrial loci to progeny is reduced when nearby intergenic regions containing *ori* sequences are deleted. Mol. Gen. Genet. 213.

Prendergast, H.D.V.*, Hattersley, P.W.* and Stone, N.E. Whole leaf blade chlorophyll A:B ratios in grasses. Can. J. Bot.

Prendergast, H.D.V.# Geographical distribution of C_4 acid decarboxylation types and associated structural variants in Australian grasses (Poaceae) Aust. J. Bot.

PLANT ENVIRONMENTAL BIOLOGY

Published

Adams, W.W. III*. Photosynthetic acclimation and photoinhibition of terrestrial and epiphytic CAM tissues growing in full sunlight and deep shade. Aust. J. Plant Physiol. 15, 123–34.

Adams, W.W. III*, Terashima, I.*, Brugnoli, E.§ and Demmig, B.+ Comparisons of photosynthesis and photoinhibition in the CAM vine *Hoya australis* and several C_3 vines growing on the coast of eastern Australia. Plant, Cell and Env. 11, 173–181.

Adams, W.W. III* and Osmond, C.B.* Internal CO_2 supply during photosynthesis of sun and shade grown CAM plants in relation to photoinhibition. Plant Physiol. 86, 117–123.

Ball, M.C.†, Cowan, I.R. and Farquhar, G.D. Maintenance of leaf temperature and the optimisation of carbon gain in relation to water loss in a tropical rain forest. Aust. J. Plant Physiol. 15, 263–276.

Boag, S.*, Tassie, L.+ and Hubick, K. The greenhouse effect: Implications for the Australian grape and wine industry. Australian and New Zealand Wine Industry Journal, 3(2) 30–36.

Brooks, A.*, Woo, K.C. and Wong, S.C. Effects of phosphorous nutrition on the response of photosynthesis to CO_2 and O_2, activation of ribulose bisphosphate carboxylase and amounts of ribulose bisphosphate and 3 phosphoglycerate in spinach leaves. Photosynth. Res. 15, 133–141.

Brugnoli, E.§, Hubick, K.T., von Caemmerer, S., Wong, S.C. and Farquhar, G.D. Correlation between the carbon isotope discrimination in leaf starch and sugars of C_3 plants and the ratio of intercellular and atmospheric partial pressures of carbon dioxide. Plant Physiol. 86, 10–13.

Condon, A.G.*, Richards, R.A.+ and Farquhar, G.D. (1987) Carbon isotope discrimination is positively correlated with grain yield and dry matter production in field-grown wheat. Crop Science 27, 996–1001.

Cowan, I.R. Stomatal Physiology and Gas Exchange in the Field. In: *Flow and Transport in the Natural Environment: Advances and Applications*, pp 160–172. (eds. W.L. Stefan and O.T. Denmead), Springer-Verlag.

Day, D.A.*, Price, G.D., Schuller, K.A.† and Gresshoff, P.M.† (1987) Nodule physiology of a supernodulating soybean (*Glycine max*) mutant. Aust. J. Plant Physiol. 14: 527–38.

Edmondson, D.L.*, Andrews, T.J. and Badger, M.R. Slow inhibition of ribulosebisphosphate carboxylase during catalysis, unrelated to decarbamylation. Proc. Aust. Biochem. Soc. 20, p.110.

Evans, J.R. Acclimation by the thylakoid membranes to growth irradiance and the partitioning of nitrogen between soluble and thylakoid proteins. In: *Ecology of Photosynthesis in Sun and Shade*, pp 93–106. (eds. J.R. Evans, S. von Caemmerer and W.E. Adams III). CSIRO, Melbourne.

Evans, J.R., Caemmerer, S. von and Adams, W.W. III* (eds.) *Ecology of Photosynthesis in Sun and Shade*. 358 pp. CSIRO, Melbourne.

Evans, J.R. and Terashima, I*. Photosynthetic characteristics of spinach leaves grown with different nitrogen treatments. Plant Cell Physiol. 29(1): 157–165.

Farquhar, G.D., Masle, J., Hubick, K.T., von Caemmerer, S. and Terashima, I*. Effects of drought, salinity and high soil strength on photosynthesis, transpiration and carbon isotope composition of plants. Current Topics in Plant Biochem. Physiol. 6: 147–155.

Farquhar, G.D., Hubick, K.T., Condon, A.G.* and Richards, R.A.+ Carbon isotope fractionation and plant water-use efficiency. In: *Applications of Stable Isotope Ratios to Ecological Research*, pp 21–40. (eds. P.W. Rundel, J.R. Ehleringer and K.A. Nagy). Springer-Verlag, New York.

Flugge, I.U.+, Woo, K.C. and Heldt, H.W.§. Characteristics of 2-oxoglutarate and glutamate transport in spinach chloroplasts. Studies with a double silicone-layer centrifugation technique and in liposomes. Planta 174, 534–541.

Francey, R.J.+ and Hubick, K.T. Tree-ring carbon-isotope ratios re-examined. Nature 333: 712.

Hubick, K.T. and Farquhar, G.D. (1987). Carbon isotope discrimination—selecting for water-use efficiency. Australian Cotton Grower 8(3): 66–68.

Hubick, K.T. and Farquhar, G.D. Carbon isotope discrimination—a selection criterion for improving cotton yield. Proc. Fourth Australian Cotton Conference. pp 311–317.

Hubick, K.T. and Reid, D.M.+ Effect of drought on transport and metabolism of abscisic acid in aeroponically-grown *Helianthus annuus* L. Physiologia Plantarum 74: 317–325.

Körner, Ch.§, Farquhar, G.D. and Roksandic, Z*. A global survey of carbon isotope discrimination in plants from high altitude. Oecologia. 74: 623–632.

Leegood, R.C.§ and von Caemmerer, S. The relationship between contents of photosynthetic metabolites and the rate of photosynthetic carbon assimilation in the leaves of *Amaranthus edulis* L. Planta 174: 253–265.

Masle, J. and Farquhar, G.D. Effects of soil strength on the relation of water-use efficiency and growth to carbon isotope discrimination in wheat seedlings. Plant Physiol. 86, 32–38.

Osmond, C.B.* (1987) An overview of plant ecophysiology. In: International Conference on Tropical Plant Ecophysiology, pp. 1–10 BIOTROP Special Publ. 31, Biotrop, Bogor, Indonesia.

Osmond, C.B.*, Ben, G-Y., Huang, L-K. and Sharkey, T.D.§ (1987) Defining the role of light in stress effects on photosynthesis. In: *Current Topics in Plant Biochemistry and Physiology*, Vol. 6, pp. 134–136. University of Missouri Press.

Osmond, C.B.* and Chow, W.S.+ Ecology of photosynthesis in the sun and shade: summary and prognostications. Aust. J. Plant Physiol. 15: 1–9.

Osmond, C.B.*, Oja, V.+ and Laisk, A.§ Regulation of carboxylation and photosynthetic oscillations during sun-shade acclimation in *Helianthis annus* measured with a rapid-response gas exchange system. Aust. J. Plant Physiol. 15: 239–251.

Osmond, C.B.*, Holtum, J.A.M.§, O'Leary, M.H.§, Roeske, C.+, Wong, O.C., Summons, R.E.* and Avadhani, P.N.+ Regulation of malic acid metabolism in CAM plants in the dark and light: *in-vivo* evidence from ^{13}C labeling patterns after $^{13}CO_2$ fixation. Planta 175: 184–185.

Parkhurst, D.F.§, Wong, S.C., Farquhar, G.D. and Cowan, I.R. Gradients of intercellular CO_2 levels across the leaf mesophyll. Plant Physiol. 86, 1032–1037.

Pate, J.S.+ and Farquhar, G.D. Role of the crop plant in cycling of nitrogen. In: *Advances in Nitrogen Cycling in Agricultural Ecosystems*, pp 23–45. (ed. J. Wilson), C.A.B. International, Oxford, UK.

Price, G.D., Day, D.A.† and Gresshoff, P.M.† (1987) Rapid isolation of intact peribacteroid envelopes from soybean nodules and demonstration of selective permeability to metabolites. J. Plant Physiol. 130: 157–64.

Terashima, I.*, Wong, S.C., Osmond, C.B.* and Farquhar, G.D. Characterisation of non-uniform photosynthesis induced by abscisic acid in leaves having different mesophyll anatomies. Plant Cell Physiol. 29(3), 385–394.

Terashima, I*. and Evans, J.R. Effects of light and nitrogen nutrition on the organization of the photosynthetic apparatus in spinach. Plant Cell Physiol. 29(1): 143–155.

Udvardi, M.K.+, Price, G.D., Gresshoff, P.M.† and Day, D.A.† A dicarboxylate transporter on the peribacteroid membrane of soybean nodules. FEBS Letts. 231, 121–129.

Wong, S.C. and Dunin, F.X.+ (1987) Photosynthesis and transpiration of trees in a eucalypt forest stand: CO_2, light and humidity responses. Aust. J. Plant Physiol. 14, 619–632.

Woo, K.C., Boyle, F.A.§, Flugge, I.U.+ and Heldt, H.W.§ (1987) ^{15}N Ammonia assimilation, 2-oxoglutarate transport, and glutamate export in spinach chloroplasts in the presence of dicarboxylates in the light. Plant Physiol. 85: 621–625.

In Press

Badger, M.R. and Price, G.D. Carbonic anhydrase activity associated with the cyanobacterium *Synechococcus* PCC7942. Plant Physiol.

Bagnall, D., King, R.W.+ and Farquhar, G.D. Temperature-dependent feedback inhibition of photosynthesis in peanut. Planta.

Blechschmidt-Schneider, S.§, Ferrar, P.J. and Osmond, C.B.* Control of photosynthesis by the carbohydrate level in source leaves of the C_4 plant *Amananthus edulis*. Planta.

Chow, W.S.+, Osmond, C.B.* and Huang, L-K. Photosystem II function and herbicide binding sites during photoinhibition of spinach chloroplasts *in-vivo* and *in-vitro*. Photosynthesis Res.

Day, D.A.†, Price, G.D. and Udvardi, M.K.+ The membrane interface of the *Bradyrhizobium japonicum—Glycine max* symbiosis: peribacteroid units from soybean nodules. Aust. J. Plant Physiol.

Ehleringer, J.R.+ and Osmond, C.B.* Stable isotopes. In: *Methods in Physiological Ecology*. (eds. J.R. Ehleringer, H.A. Mooney, R.W. Pearcy and P.W. Rundel). Chapman and Hall, London.

Evans, J.R. Photosynthesis and nitrogen relationships in leaves of C_3 plants. Oecologia.

Evans, J.R. and Seemann, J.R.§ The allocation of protein nitrogen in the photosynthetic apparatus: costs, consequences and control. In: *Towards a broad understanding of photosynthesis: multiple approaches to a common goal*. Alan R. Liss, New York.

Farquhar, G.D. Models of integrated photosynthesis of cells and leaves. Phil. Trans. Roy. Soc. London (Ser.B). 'New Vistas in Measurement of Photosynthesis'.

Farquhar, G.D. Atmosphere—land plant interactions. Proceedings of the Elizabeth and Frederick White Symposium on Global Change. Australian Academy of Science, Canberra.

Farquhar, G.D. Models relating subcellular effects of temperature to whole plant responses. In: *Plants and Temperature* (eds. S.P. Long and F.I. Woodward). Soc. Exp. Biol. Symp. 42.

Farquhar, G.D. and Sharkey, T.D.* Citation Classic. Commentary on Ann. Rev. Plant Physiol. 33, 317–345. 1982. Current Contents ISI Press, Philadelphia.

Farquhar, G.D., Wong, S.C., Evans, J.R. and Hubick, K.T. Photosynthesis and gas exchange. In: *Plants under stress: Physiology and ecology and their application to plant improvement* (eds. H.H. Jones, T.J. Flowers, and M.B. Jones). Cambridge University Press.

Hubick, K.T. and Farquhar, G.D. Genetic variation in carbon isotope discrimination and the ratio of carbon gained to water lost in barley. Plant, Cell & Environ.

Hubick, K.T., Shorter, R.+ and Farquhar, G.D. Isotopic composition of plant carbon correlates with water-use efficiency in field-grown peanut cultivars. Aust. J. Plant Physiol.

Leegood, R.C.§ and Osmond, C.B.* The flux of metabolites in C_4 and CAM plants. In: *Advanced Plant Biochemistry and Molecular Biology*, (eds. D.H. Turpin, D.T. Dennis). Longmans, Harlow.

Masle, J., Doussinault, G.+, Farquhar, G.D. and Sun, B.+ Foliar stage in wheat correlates better to photothermal time than to thermal time. Plant, Cell and Environ.

Masle, J. and Doussinault, G.+, Sun, B.+ Response of wheat genotypes (*Triticum aestivum* L) to temperature and photoperiod in natural conditions. Crop Science.

Osmond, C.B.* Photosynthesis from the molecule to the biosphere: a challenge for integration. In: *Understanding Photosynthesis*, (ed. W.R. Briggs). Liss, New York.

Osmond, C.B.* and Adams, W.W. III.*, Smith, S.D.§ Crassulacean acid metabolism. In: *Methods in Physiological Ecology* , (eds. J.R. Ehleringer, H.A. Mooney, R.W. Pearcy and P. Rundel). Chapman and Hall, London.

Price, G.D. and Badger, M.R. Ethoxyzolamide inhibition of CO_2-dependent photosynthesis in the cyanobacterium *Synechococcus* PCC7942. Plant Physiol.

Price, G.D. and Badger, M.R. Ethoxyzolamide inhibition of CO_2 uptake in the cyanobacterium *Synechococcus* PCC7942 without apparent inhibition of internal carbonic anhydrase activity. Plant Physiol.

Price, G.D., Badger, M.R. and Whitecross, M.I.† Photosynthetic utilization of bicarbonate in two species of *Elodea*. Proc. 7th Int. Workshop on Plant Membrane Transport. Australian Academy of Science, Canberra.

Terashima, I.* Productive structure of a leaf. In: *Understanding Photosynthesis* . (ed. W. Briggs). Alan R. Liss, New York.

Wright, G.C.+, Hubick, K.T. and Farquhar, G.D. Heritability and genotype x environment interactions of carbon isotope discrimination and transpiration efficiency of peanut (*Arachis hypogaea* L.). Aust. J. Plant Physiol.

Yu, J. and Woo, K.C. Glutamine transport and the role of glutamine translocator in chloroplasts. Plant Physiol.

Yu, J. and Woo, K.C. Photosynthesis in chloroplasts rapidly isolated from primary leaves of oat *Avena sativa* L. Effects of orthophosphate, metal ions and chelators. Photosynth. Res.

ECOSYSTEM DYNAMICS

Published

Comins, H.N.* and Fletcher, B.S.+ The simulation of fruit-fly population dynamics, with particular reference to the olive fruit-fly, *Dacus oleae*. Ecol. Model. 40, 213–232.

Fletcher, B.S.+ and Comins, H.N.* The development and use of computer simulation models to study the population dynamics of *Dacus oleae* and other fruit flies. Proc. 14th Int. Congress Entomol., Italy, pp 561–575.

Green, D.G. Modelling forest mosaics. In: *System Modelling and Optimization*. pp 584–593. (eds. M.Iri and K.Yajima), Springer-Verlag, Berlin.

Green, D.G., Bradbury, R.H.+, and Bainbridge, S.+ Embodiment of formal languages. Math. Comput. Simul. 30, 39–44.

Green, D.G. and Dolman, G.S.† Fine resolution pollen analysis. J. Biogeog. 15, 685–701.

Green, D.G., Reichelt, R.E.+, and Bradbury, R.H.+ Statistical behaviour of the GMDH algorithm. Biometrics 44, 49–69.

Green, D.G., Reichelt, R.E.+ and Buck, R.G.+ Self-adaptive modelling algorithms. Math. Comput. Simul. 30, 33–38.

Green, D.G., Singh, G.†, Polach, H.†, Moss, D.†, Banks, J.C.G.†, and Geissler, E.† A fine resolution palaeoecology and palaeoclimatology from south-eastern Australia. J. Ecol. 76, 790–806.

Landsberg, J.J.# Dieback of rural eucalypts: tree phenology and damage caused by leaf feeding insects. Aust. J. Ecol. 13, 251–267.

Landsberg, J.J.# Feeding preferences of common Brushtail Possums, *Trichosurus vulpecula*, on seedlings of a woodland eucalypt. Aust. Wildl. Res. 14, 361–369.

Noble, I.R. Attributes of plant invaders and the invading process: Terrestrial and vascular plants. In: *Biological Invasions*. pp 301 313. (ed. J.A Drake). SCOPE-Wiley Monograph, Chichester, UK.

Reichelt, R.E.+, Bainbridge, S.+ and Green, D.G. Crown-of-Thorns dispersal in the Great Barrier Reef—a simulation study. Math. Comput. Simul. 30, 145–150.

Robertson, D.R.+, Green, D.G. and Victor, B.C.+ Temporal coupling of larval production and recruitment by a Caribbean reef fish. Ecol. 69, 370–381.

Smith, T.M. and Urban, D.L.+ Scale and resolution of forest structural pattern. Vegetatio 74, 143–150.

Zammit, C. Dynamics of resprouting in the lignotuberous shrub *Banksia oblongifolia*. Aust. J. Ecol. 13, 311–320.

Zammit, C. and Zedler, P.H.+ The influence of dominant shrubs, fire and time since fire on soil seed banks in mixed chaparral. Vegetatio 75, 175–187.

In press

Austin, M.P.# Species association in the herbaceous layer of eucalypt forest in south-eastern Australia. In: *Vegetation Structure*. SPB Publishing, The Hague, The Netherlands. Utrecht, July 1987.

Belcher, J.W.+ and Wilson, S.D. Leafy spurge (*Euphorbia esula* L.) and the species composition of mixed-grass prairie. J. Range Manage.

Green, D.G. Cellular automata models of Crown-of-thorn ourbreaks. In: *The Acanthaster phenomenon—a modelling approach*. (eds. R.H. Bradbury and R.G. Buck) Springer-Verlag, Berlin.

Landsberg, J.J.# A comparison of methods of assessing insect damage to foliage of eucalypt trees. Aust. J. Ecol.

Landsberg, J.J.# and Wylie, F.R.+ Dieback of rural trees in Australia. GeoJournal.

Moore, A.D. On the growth equation used in forest gap simulation models. Ecol. Modelling.

Noble, I.R. and Weiss, P.W.* Movement and modelling of buried seed of the invasive perennial *Chrysanthomoides monilifera* in coastal dunes, and biological control. Aust. J. Ecol. 14(1).

Noble I.R., Moore A.D. and Strasser M.J. Stand structure and the prediction of vegetation dynamics. In: *Vegetation Structure*. SPB Publishing, The Hague, The Netherlands. Utrecht, July 1987.

Smith, T.M. and Taylor, S.+ The effects of shading on the establishment and growth of *Acacia tortilis* seedlings. S.African J. Bot.

Smith, T.M. and Urban, D.L.+ ZELIG: A spatially interactive forest gap simulator. Ecol. Modelling.

Urban, D.L.+ and Smith, T.M. Microhabitat pattern and the structure of forest bird communities. American Naturalist.

Wellington, A.B. Seedling regeneration and the population dynamics of mallee eucalypts. In: *Mediterranean landscapes in Australia: Mallee ecosystems and their management*. (eds. J.C. Noble and R. Bradstock). CSIRO.

Wilson, S.D. The suppression of native prairie by alien species introduced for revegetation. Landscape and Urban Planning.

Wilson, S.D. and Belcher, J.W.+ Plant and bird communities of native prairie and introduced Eurasian vegetation in Manitoba, Canada. Conservation Biology.

Wylie, F.R.+ and Landsberg, J.J.# Rural dieback. In: *Growing Trees on Australian Farms*. (ed K.W. Cremer) CSIRO, Canberra.

Zedler, P.H.+ and Zammit, C.A. A population-based critique of concepts of change in the chaparral. In: *The California chaparral: paradigms reexamined*. (ed. S.C. Keeley) Natural History Museum of Los Angeles County, Los Angeles, California.

STAFF

Director
Professor R.O. Slatyer, AO, DSc(Agric), HonDSc(W.Aust), HonDSc(Duke), FAA,FRS

Director's Unit
Director's Secretary
Deidre Whitelaw
Research Officer
Pamela Ferrar, MSc

School Secretary
Christopher Buller, BSc(Lond),BA
Secretary
Megan Apps

The School expresses regret at the loss of its longest serving honorary staff member, with the death of Mrs Maisie Carr in September. Mrs Carr joined the School as a Visiting Fellow in 1968 and continued active research until shortly before her death.

DEVELOPMENT NEUROBIOLOGY

Senior Fellow and Group Leader
Andrew David Blest, BSc(Sp.)(Lond), DPhil(Oxf)

Professor
Richard Freeman Mark, MMedSC,MB,ChB(NZ), CES Dr3rdCy(Aix-Marseille),FAA

Fellow
Kenneth George Hill, BSc,PhD(Melb).

Senior Research Fellow
Ian Stuart McLennan MSc(Auck),PhD (until May)

Research Fellows
Anthony William Gummer, BEng,PhD(WA)
Shin Ho Chung, BSc(Stanford),BSc(London), PhD(Harvard) (from September)
Sally Jane Stowe, MSc(Hons)(Auckland), PhD (from April)

Post-Doctoral Fellows
Stephen Charles Trowell, MA(Camb), MSc(Manc)
Judy Wye-Dvorak, BSc(USC), PhD (until January)

Visiting Fellows
Dr Stuart M. Armstrong, LaTrobe University (from December)
Dr Shin-Ho Chung (until September)
Dr P. Harrison, Mitchell College of Advanced Education
Dr Lidia Mayner, Northern Rivers College of Advanced Education
Professor Baruch Minke, Hadassah Medical School, Jerusalem
Dr Sally Jane Stowe, ANU Transmission Electron Microscope Unit (until April)

Research Officers
Lauren Marotte, MSc(Monash), PhD
Gert Stange, Dr rer nat(Göttingen) (from August)

Research Students
Jianwu Mo, BSc(Beijing)
Xiao-Ming Sheng, BSc(Shanghai)

Head Technical Officer
Margaret Canney (jointly with Mol. Neurobiology and Visual Sciences) (from August)

Senior Technical Officers
Margaret Canney (until August)
Gert Stange, Dr rer nat(Göttingen) (until August)

Technical aOfficer
Margrit Carter, BSc(Hons)Adelaide

Laboratory Technicians
Bridget Hilton
Margaret Porter, BSc

Animal Technician
Amanda Devlin

Secretary
Margaret Donohue

MOLECULAR NEUROBIOLOGY

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

Post-Doctoral Fellows
Camilla Margaret Myers, BSc(St.Andrews),PhD(Camb)(until December)
Stephen John Delaney, BSc(Leeds), PhD(London)
David Charles Hayward, BSc, PhD(London)

Visiting Fellows
Heinz Gert de Couet, DipBiol, Dr rer nat(TH Darmstadt)
Kevin Michael O'Hare, BA(Cantab) PhD(Edinburgh)
Ian Andrew Mark Mitchelson, BA(Oxon), PhD(London)
Alan Hugh David Watson, BSc(Edinburgh), PhD(St Andrews)
Paul Whitington, BSc(Adelaide), PhD
John Leslie Davidson Williams, BSc(Cardiff), PhD(Southhampton)

Research Students
Matthias Hennig, DipBiol(Erlangen-Nurnberg)
Ute Schuppler, Dip.Biol(Karlsruhe)

Head Technical Officer
Margaret Canney (jointly with Devel. Neurobiology and Visual Sciences) (from August)

Technical Officers
Jane Olsen, BSc
Julie Higginbotham, BSc

Laboratory Technicians
James Cotsell
Fiona Hall

Secretary
Lilian Chan

VISUAL SCIENCES

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
Peter Eric Coombe, BAg.Sci., PhD(Adelaide)

Postdoctoral Fellows
Robin Findlay, BSc,PhD(Aberdeen) (until June)
Thomas Millar, MSc(Melb), PhD(Flinders) (until February)
Daniel Osorio, MA(Camb), PhD(ANU)
David Neil Reye, BSc(Qld), PhD(Alberta) (until February)

Visiting Fellows
Dr Les Philip Davies, Dept of Community Services & Health, ACT
Prof Bob Pinter, University of Washington, USA (until March)
Dr Miriam Lehrer, University Zurich, Switzerland
Dr Willi Ribi, Max-Planck-Institut für Biologische Kybernetik, Tübingen, FRG.
Mr Wang, X. Institute of Biophysics, Academia Sinica, People's Republic of China
Prof Zhang, S.W., Institute of Biophysics, Academia Sinica, People's Republic of China
Dr Zhu, H., Institute of Biophysics, Academia Sinica, People's Republic of China

Research Students
Zoran Aleksic, MSc(Belgrade)
Jan Dalczynski, MSc(Tech Univ Warsaw)
Marc Golcich, BSc(Adel) Grad. Dip.Sci.
Andrew Charles James, BSc(Adel)
Zhe Fei Jin, BSc(Univ Sci & Tech, Heifei, People's Republic of China)
Roman Poznanski, BAppSc (RMIT), MSc(Monash)
Jian Shi, BSc(Univ Sci & Tech, People's Republic of China)
Qi Jian Sun, BSc(Inst Biophysics, Beijing, People's Republic of China)
Julie Lorraine Thacker, BSc(WA) (until June)
Eric James Warrant, BSc(NSW)
Guang Yang, BSc(Univ Sci & Tech, Hefei, People's Republic of China)

Research Assistant
Ljerka Marcelja, BSc(Zagreb)

Head Technical Officers
Michael Savage, E & C (until April)
Margaret Canney (from September)

Senior Technical Officers
Paul Gibbon, BA(CCAE), E & C
Patricia Miethke, BSc(Adel)
Martin Nagel, BSc(UCD), Grad.Dip.Elec.(NIHE)
Mark Snowball, E & C

Technical Officer
Ron Dencio (until May)

Laboratory Technicians
Geno Ewyk (temp)
Charlene Dwyer (temp)

Clerk
Jane Vickers

Secretary
Lilian Chan

MOLECULAR GENETICS

Senior Fellow and Group Leader
George Desmond Clark-Walker, MSc (WAust), DPhil (Oxf)

Professor
John Arthur Pateman, BSc, PhD (London), MA (Camb), FRSE, FRS (until May)

Professorial Fellow
Hiroto Naora, BSc (Tokyo Univ. of Literature and Science), DSc (Tokyo)

Research Fellow
Antony Wharton Braithwaite, MSc (Auck) PhD (on leave to July)

Postdoctoral Fellows
Ryzard Maleszka, MSc, PhD (Warsaw)
Anne Mathews, BSc(Agric), MSc(Agric) Bangalore, PhD.
Kaoru Miyahara, BSc, MSc (Kyushu), PhD.
Onn Choon Wong, BSc, MSc (Waikato), PhD. (W'gong)(until December)
Patrick Skelly, BSc, MSc (Dublin), PhD

Visiting Fellows
Dr Lun-Quan Sun (The Fourth Military Medical University) PRC (from June)
Prof. Jean-Claude Mounolou, Docteur d'Etat (Paris), (until May)

Research Students
Felice Driver, BSc
Chris Hardy, BSc
Kyoko Koishi, B.Pharm. Sc., M.Pharm. Sc. (Karnazawa)(until December)

Research Assistants
David Willoughby Buckle, BSc (Melb), MSc (Auck)
Ursula Norris, BSc (until March)

Senior Technical Officer
Patricia Wilkinson, BAppSc (CCAE)

Technical Officer
Erika Wimmer

Laboratory Technicians
Helen Roma Liszczynsky, BSc (Adel)
Alexandra Plazinska, MSc (Cracov)
Robin Myfanwy Chapple, BSc.

Secretary
Elizabeth Robertson (until August)
Catherine Condon (temp) (from October)

POPULATION GENETICS

Professorial Fellow and Group Leader
John Bryan Gibson, BSc, PhD(Sheff), MA(Camb)

Fellow
David Dobson Shaw, BSc(Durh), MSc(Birm), PhD(S'ton),M.I.Biol

Research Fellow
Donald James Colgan, PhD(Melb), BSc, BEc (until April)

Postdoctoral Fellows
Allan Lindsay Freeth, BSc(Cant),PhD (until June)
Adam Douglas Marchant, BSc (from May) M.I.Biol.

Visiting Fellows
Dr Rudi Appels, CSIRO Divison of Plant Industry, Canberra
Dr R. Callow, Biological Sciences, Manchester University

Research Students
Peter Daniel Christian, BA(Oxf) (jointly with Plant Molecular Biology) (until January)
Peter Cooke, BSc(UNE) (until June)
Bert Kohlmann, BSc(NPI,Mex)
Anne Game, BSc(Melb)
Chengshan Jiang, MSc(Fudan)
Lynne McIntyre, BScAgr(Syd) (until June)
Adam Douglas Marchant, BSc (until April) M.I.Biol.
Julia Playford, BSc(UWA) (from March)
Jane Elizabeth Symonds, BSc(N'castle,UK)

Research Assistants
Barbara Austin, BSc(Aberd),MPhil(Lond) (until February)
Susan Maynes, DipAnimal Care (NSWIT)
Darryl Read, BSc (from March)

Senior Technical Officers
Patricia Wilkinson, BAppSc(CCAE)
Ann Verona Wilks, MSc(Melb)

Technical Officer
Nelida Contreras, BSc(Chile)

Laboratory Technicians
Thi Huiynh Anh Cao, BLet(Saigon)
Prudence Gaffey, BA(Hons)(jointly with Prehistory, RSPacS)

Laboratory Assistant
Elizabeth Cipe

Secretary
Catherine Condon (from October)
Elizabeth Robertson (until August)

PLANT CELL BIOLOGY

Professor
Brian Edgar Scourse Gunning, MSc, PhD (Belf), DSc, FAA, FRS

Professorial Fellow and Group Leader
David Stuart Letham, MSc (NZ), PhD (Birm), FAA

Senior Fellow
Peter Crook Lloyd John, BSc, PhD (Lond)

Fellow
Richard Edward Williamson, MA, PhD (Camb)

Senior Research Fellow
Adrienne Ruth Hardham, BSc (Monash), PhD

Research Fellows
Rosslyn Muriel Hoggart, BSc, PhD (Melb) (from February)
Peter Paul Jablonsky, BSc, PhD (La Trobe)
Jacek Plazinski, MSc, PhD (Krakow)

Postdoctoral Fellows
Janet Gorst, BScAg, MSc (NE), PhD (from March)
Frank Gubler, BSc, PhD (NSW)
John Harper, BSc, PhD (Belfast)
David McCurdy, BSc, PhD (La Trobe)
Geoffrey Wasteneys, BSc (Car) PhD (from November)

Visiting Fellows
Dr Jane Badenoch-Jones (until January)
Professor Liu Chung-chu, Fujian Academy of Agricultural Research (July)
Dr Rosali Fabricius (from June)
Dr Franz Grolig, Justus Liebig Universitat, Giessen (until April)
Dr Lok Man Singh Palni (from April)
Dr Pamela Warren Wilson
Dr Ren Zhang, Academia Sinica, Beijing (March–September)

Research Students
Jeremy Carmichael, BSc (Belfast)
Ann Cleary, BSc (Monash)
Mark Clements, BSc, MSc (from March)
Arthur Davis, BSc, MSc (Guelph)
Moira Galway, BSc (Car) (until May)
Geoffrey Hyde, BSc (Syd) (from March)
Qiao Lin, BSc (Shichuan) (from March)
Shyamal Nandi, BSc (VB), MSc (GBP) (until May)
Suchirat Sakuanrungsirikul, BSc (Bangkok)
Santokh Singh, BSc (Puchan), MSc (PAU) (until September)
Geoffrey Wasteneys, BSc (Car) (until November)
Jian Wang, BS (Hebei) (from August)
Mary Webb, BSc (Melb)
Xue-Dong Zhang, BSc (Nankai)

Research Assistant
Janet Elliott, BAppSc (QIT)

Senior Technical Officers
Patricia Wilkinson, BAppSc (CCAE) (jointly with Population Genetics and Molecular Genetics Groups)
Charles W. Parker, MSc, ARACI
John Wicks BRTC (jointly with Plant Environmental Biology Group) (until May)

Technical Officers
Cathy Busby, BSc (Monash), MSc
Jadwiga Duniec, MSc (Warsaw)
Ursula Hurley, BSc (Natal)
Frank Sek, BApSc (CCAE)
David Willcocks, DipAppSci(Biol) (CCAE)

Laboratory Technicians
Kim Ballantyne (from February)
Lynn Croft, BSc (Glasgow) (until October)
Jacinta Kelly, BSc (from October)
Susan McKinney, Assoc Dip Tech Path (Bruce TAFE) (from February)
Margaret Sammut
Rona Taylor, BSc (until September)

Secretary
Brenda Ballantyne (until November)

PLANT MOLECULAR BIOLOGY

Senior Fellow and Group Leader
Adrian John Gibbs, ARCS, PhD (Lond)

Professor
Barry Rolfe, BAgrSc, PhD (Melb)

Senior Fellows
John T. Andrews, BSc, PhD (Qld) (from February)
Leslie Watson, MSc (Manch)

Research Fellows
Jacek Plazinski, MSc. PhD, (Krakow)
Kieran F. Scott, BSc(Massey), PhD (until January)
Brett Tyler, BSc (Monash), PhD (Melb)(until August)

Postdoctoral Fellows
Cornelia Buchen-Osmond, Dipl. Biol., PhD (Frankfurt)
Michael Djordjevic, BSc (Old), PhD
Steven Djordjevic, BSc (Qld), PhD (from July)
Murray Henwood, BSc (Vic. Uni. Wellington, NZ), PhD (from August)
Layne Huiet, BSc (Duke) PhD (Georgia) (until August)
Paul Konrad Keese, PhD (Adel)
Andrew David Jeffrey Meek, BSc (Hons), PhD
Mathew Kennedy Morell, BSc, PhD (Syd) (National Research Fellow)
Murali Nayudu, BSc, PhD (Monash)
Wendy Thompson BSc (Exeter) PhD (Bath)(from June)
Jeremy Weinman, BSc, PhD

Visiting Fellows
Bernard Baum, Agriculture Canada, Ottawa, (from October)
Christine Kabuye, National Museum of Kenya, (February–March)
Elizabeth A. Kellogg, Harvard University Herbarium, (November)
Kieran F. Scott, BSc (Massey), PhD (from January)

Visitor
Petra Gross, MSc (Göttingen) (from November)

Research Students
Vindhya Amarasinghe BSc (Colombo)
Jeremy Bruhl, BSc (NSW)
Hancai Chen
Shou-wei Ding, BSc, MSc (People's Republic of China)
James Gray, BSc (Syd)
M.L. Areelak Kashemsanta, BSc, MSc (Mahidol) (until August)
Yuxin Mao, BSc (Zhejiany Agricultural University) (until August)
Jure Piskur BSc (Ljubljana) (from June)
Lucy Sargent, BSc (Qld)
Yuguang Shi, BSc (People's Republic of China) MSc (UNE)(until August)
Kate Le Strange, BSc (NSW)

Honours Students
Tony Arioli, BSc
Wendy Lewis, BSc

Research Assistants
Karen Jane Crabtree, BSc (Loughborough)
Janette Rosemarie Lenz, BA (from June)

Head Technical Officer
Neal Gowen, BRTC.

Senior Technical Officer
Anne Maree Mackenzie, BSc (Melbourne)

Technical Officers
Karin Harrison, Dip. Appl. Sci. (CCAE)
Heather Kane, BSc, PhD (from August)
Jan McIver, BSc (Melb)
Marie Oakes, BSc
Veronica Ross, BA, LittB (until August)
Marjolein Torronen
Elena Gartner

Laboratory Technicians
Jennifer Bolton-Gibbs
Tanya Brown
Jennifer Howe, BSc (from September)
Anne Moten, BSc (Adel) BA
Susan Perry, Dip AppCs (CCAE)

Secretaries
Louise Booth
Val Rawlings

PLANT ENVIRONMENTAL BIOLOGY

Professor and Group Leader
Graham Douglas Farquhar, BSc (Qld), BSc, PhD, FAA

Professor
Ian Roy Cowan, MSc (Lond), PhD (Nott), FAA

Fellow
Murray Ronald Badger, BScAgr (Syd), PhD

Senior Research Fellow
Kam Chau Woo, BSc (Adel), PhD

Research Fellows
Susanne von Caemmerer, BA, PhD
Kerry Trent Hubick, BSc, PhD (Calgary)
Josette Masle, Dr Ing (INA Paris) (from June)
Suan Chin Wong, MSc (Nanyang), PhD

Postdoctoral Fellows
John Richard Evans, BSc, PhD (QEII Fellow) (from February)
Graeme Dean Price, BSc, PhD (National Research Fellow)
Jeong Sheop Shin, MS (Korea), PhD (Mont. St.) (National Research Fellow) (from December)
Ichiro Terashima, BSc, DSc (Tokyo) (until August)

Visiting Fellows
William Dexter Bowman, Duke University, USA (until March)
Emeritus Professor Denis J. Carr
Mrs S.G. Maisie Carr (dec.)
Ms. Robyn Elizabeth Cleland (until February)
Professor H.W. Heldt, University of Göttingen, FRG (July–September)
Dr. Agu Laisk, Estonian Academy of Science, USSR (from November)
Professor Charles Barry Osmond, Duke University, USA (February–March, August–October)
Dr. Vello H-M. Oja, Estonian Academy of Science, USSR (from November)
Dr. R.C. Nageswara Rao, International Crops Research Institute, India (October–November)
Professor David Walker, University of Sheffield, U.K. (until May)

Research Students
David Bagnall, BSc (UNSW), MA
Daryl Edmondson, MSc (Auck) (until May)
Sally Henderson BScAgr (Melb)
Lin-Ke Huang
M.S. Candido Lopez-Castaneda, BScAgr, MScAgr (Chapingo)(from June)
James Virgona, MSc (Macquarie)
Jian-Wei Yu, MSc (Guangzhou)

Research Assistant
Andy Mower BSc (Adel) (from June)

Head Technical Officer
Robert Jackson (from January)

Senior Technical Officers
Win S. Coupland
Anne Gallagher, BRTC
Derek Millar
John Wicks, BRTC (until May)

Technical Officers
Peter Groeneveld, BSc (For)
Prue Kell, BRTC
Sue K. Wood

Laboratory Technicians
Frank Fox, BSc (until March)
Wesley Keys
Sue Kirby (until October)
Ross Rowe, BSc (casual—March–October)
Edwina Walsh (February to September)
Tony Condon, MSc (Syd) (until November)

Laboratory Attendant
Jean E. Hardy (part-time)

Secretaries
Leonie Hoorweg (casual—to May) (from August)
Michelle Hynson (casual—from May to June)
Catherine Condon (casual—from June to September)
Elaine Napper (casual—from June to August)

ECOSYSTEM DYNAMICS

Senior Fellow and Group Leader
Ian Roy Noble, BSc, PhD (Adel)

Professor
Ralph Owen Slatyer, AO, DSc(Agric) (WAust), HonDSc (WAust & Duke), FAA, FRS

Senior Research Fellow
David Geoffrey Green, MSc (Monash), PhD (Dal) (from May)

Research Fellows
Thomas M. Smith, BSc (WVa), PhD (Tennessee) (until June)
Alan Bruce Wellington, BSc (Monash), PhD
Scott Douglas Wilson, BSc (Trent), PhD (Ottawa) (from October)
Charles Anthony Zammit, BSc (Murd), PhD (Macq) (from September)

Post-Doctoral Fellow
Susan Margaret House, MSc (Lond), PhD (from November)

Visiting Fellows
Dr Michael Phillip Austin, CSIRO Div Wildlife and Ecology
Professor Joseph Hurd Connell, University of California, Santa Barbara (from September)
Dr Alan Pennock Newton House (from November)
Dr Jill Jennifer Landsberg, CSIRO Div Forestry and Forest Products

Research Students
Michael Hodda, MSc
Heather Keith, BSc (NSW)
Andrew Douglas Moore, BSc (Adel)
Suzanne Mary Prober, BSc Agr (Syd)
Jann Elizabeth Williams, BSc (Melb)

Research Officer
Pamela Ferrar, MSc

Head Technical Officer
Peter Michael Cochrane, BSc

Assistant Programmer
Michael James Strasser, BSc (Monash) (until March)
Richard William Fitzgerald, BA (NSW), Grad Dip Appl Stats (CCAE) (March to September)

Laboratory Technicians
Penny A. Butcher, BNatRes (UNE) (until August)
Graham von Schill
Sandra Lee Berry, Assoc Dip Lab Tech (Darling Downs), BSc (Macquarie) (from November)

CENTRAL SERVICES

SCHOOL SERVICE STAFF

Administration Business and Technical Manager
Peter Firth

Assistant Business Manager
Alexander McDonald

Assistant to Business Manager
Stephen King

Clerks
Danielle Anderson (from October)
Carol Barmin
Tania Hoffmann
Tania Felton (until May)
Christine Kelson (until October—secondment)
Margaret Mitchell
Heather Morgan
Diane Price (until May)
Sue Hearder (Trainee) (from February)

Tea Assistant
Audrey Coupland

Computer
Programmer
David Sandilands
Assistant Programmer
Steven Ball

Gas Chromatograph/Mass Spectrometer
Research Officer
Onn Choon Wong, PhD (W'gong)

Laboratory Preparation
Laboratory Attendants
Jeane Atkinson (until February)
Elizabeth Cipe
Jean Hardy

Photography and Illustration
Senior Technical Officer
Maureen Whittaker
Technical Officer
Garry Stephen Hanson
Illustrator
Garry Brown
Laboratory Technicians
James Whitehead
Maocan Cai (Temp) (until January)

Plant and Animal Culture
Senior Technical Officer
Paul Thomas Puttifoot
Technical Officers
Ronald Colin Dencio (until May)
Peter Hank Fokker
Laboratory Technicians
Russell Cameron
David Jones Ferguson (until January)
Labourers
Mark Allon (from January)
Debra Kay Rankin (until March)
Paul Smider (casual) (until July)

Security and Cleaning
Head Watchman/Janitor
Terence James Durrant
Watchmen/Janitors
Stanley Kelly
Alexander King Kyle
William Kyle
John Nelson
Robert Payne
Cleaners
M. Bencic (from August)
V. Bencic (from July)
Cveta Bodrozic
David O'Rourke
Marica Peric
Diane Petrovic
Liza Robregado
Maria Santosousso
Slavica Skrobot
Eva Versegi (until April)

Store
Chief Storeman
Werner Gunther Friedrich (until December)
Senior Storeman
Robin George Mark Hassall
Clerk
Annemarie Thaller
Storeman Driver
George Roussidis (until February)
David Williamson (from March)

Workshop
Head Technical Officer
Walter Pfluger (until August)
Douglas Crawford (from August)
Senior Technical Officers
Douglas Crawford (until August)
Reginald Dwyer (until March)
Kerry Richens
Technical Officers
Mark Buckley (until April)
Doug Turnbull
Senior Laboratory Craftsmen
Godfried Aschenberger
Gian Franko Foppoli
Michael Gerstenbuehler
Greg Jackson
Malcolm Andrew Lamond
Paul Larsen
Alfred Lee
Daniel Lloyd (from April)
Peter Maselos (from November)
Leonard Palmer (until January)
Jan Reyn
Tad Rudzcuk
Michael Tobin (from November)
Steve Fulham (Temp)
Craig Korn (Temp) (from February)
Labourer
John New (from August)
Senior Adult Storeman
Graham Edwards
Apprentices
Daniel John Clayton
Dan Brian Grant
Paul Melis (until September)
Laboratory Technician
Andrew Cooper (from February)

ELECTRON MICROSCOPE UNIT

The School houses a University facility, the Transmission Electron Microscopy (TEM) Unit. Members of the Unit are University employees but are shown in this Report because of their physical location in RSBS. The service provided by the Unit is heavily used and is much appreciated by RSBS researchers. In 1989 the TEM and Scanning Electron Microscopy (SEM) units will be incorporated into one ANU Electron Microscopy Unit, which will continue to be located in RSBS.

Head Technical Officer
George Hunter Weston (until August)

Senior Technical Officers
Sally Stowe (until March)
David James Llewellyn

Technical Officer
Katherine Lorna Asmussen
Ian Andrew Duff

Laboratory Technicians
Diane Davis (from July)
Alison Margaret McLean (until June)

STUDENTS' THESES SUBMITTED AND EXAMINED DURING 1988

VISUAL SCIENCES

Doctor of Philosophy

Thacker, J.
Thesis: Optics in the developing Scarab Beetle.

Van der Valk, J.
Thesis: The functional organisation of the retina of the Axolotl.

MOLECULAR GENETICS

Doctor of Philosophy

Baker, A.R.
Thesis: Molecular genetics of steroid hormone receptors.

Mitchell, L.E.
The Molecular cloning and characterisation of the wheat ADH-1A gene.

Murali, C.
Thesis: Protein engineering of the Yeast alcohol dehydrogenase 27334.

POPULATION GENETICS

Doctor of Philosophy

Christian, P.D.
Thesis: Studies of *Drosophila* C and A viruses in Australian populations of *Drosophila melanogaster*.

Cooke, P.H.
Thesis: Electrophoretic and nucleotide polymorphism at the Esterase-6 locus of *Drosophila melanogaster*.

Marchant, A.D.
Thesis: Mitochondrial DNA variation in the *Caledia* species complex: Implication for evolutionary history.

PLANT CELL BIOLOGY

Doctor of Philosophy

Galway, M.E.
Thesis: The cytoskeleton and cell morphogenesis in the alga *Mougeotia*

Nandi, S.K.
Thesis: Studies of cytokinin biosynthesis, metabolism and function.

Singh, S.
Thesis: Cytokinin metabolism in relation to leaf senescence.

PLANT MOLECULAR BIOLOGY

Doctor of Philosophy

Amarasinghe, V.
Thesis: Comparative ultrastructure, function and taxonomic significance of microhairs in grasses.

Bender, G.L.
Thesis: The genetic basis of *Rhizobium* host range extension to the non-legume *Parasponia*.

Bassam, B.J.
Thesis: A genetic analysis of host specificity in the broad-host-range *Rhizobium* strain NGR234.

Iismaa, S.E.
Thesis: A molecular and genetic analysis of symbiotic nitrogen fixation genes in *Rhizobium trifolii*.

Upadhyaya, N.M.
Thesis: The biology and genetics of the Rhizobium-induced leaf curl syndrome of Pigeonpea (*Cajanus cajan* (Miller sp.))

Cell Biology Honours

Lewis, W.R.
The role of the *Rhizobium* NGR2343 *nodD* gene in determining host specific nodulation.

Howles, P.
Molecular characterization of genes involved in the acid tolerance phenotype of *R. trifolii*.

PLANT ENVIRONMENTAL BIOLOGY

Doctor of Philosophy

Edmondson, D.L.
Thesis: *In vivo* and *in vitro* regulation of ribulose-1,5-bisphosphate carboxylase/oxygenase activity.

Condon, A.G.
Thesis: The use of carbon isotope discrimination in screening wheat genotypes for efficient use of water.

ECOSYSTEM DYNAMICS

Doctor of Philosophy

Helen Margaret Armstrong
Thesis: Effects of rabbits on the vegetation of an arid zone National Park.

ERRATUM

The following names were omitted from the staff list for the Plant Molecular Biology Group

Senior Fellow
Ernest Creaser, MA, PhD (Camb)

Postdoctoral Fellow
Greg Bender, BSc, PhD

Research Students
Tracey Cross, BSc Hons (Melb)
Sue Moody, BSc Hons (Melb)
Chandra Murali, MSc H1 (Kotambsi Sci Inst), MSc (Karn)

Honours Student
Sarah Wilson BSc

Senior Technical Officer
Kathy Britt, AAIMLT (Melb), BSc

Laboratory Technician
Kate Clark