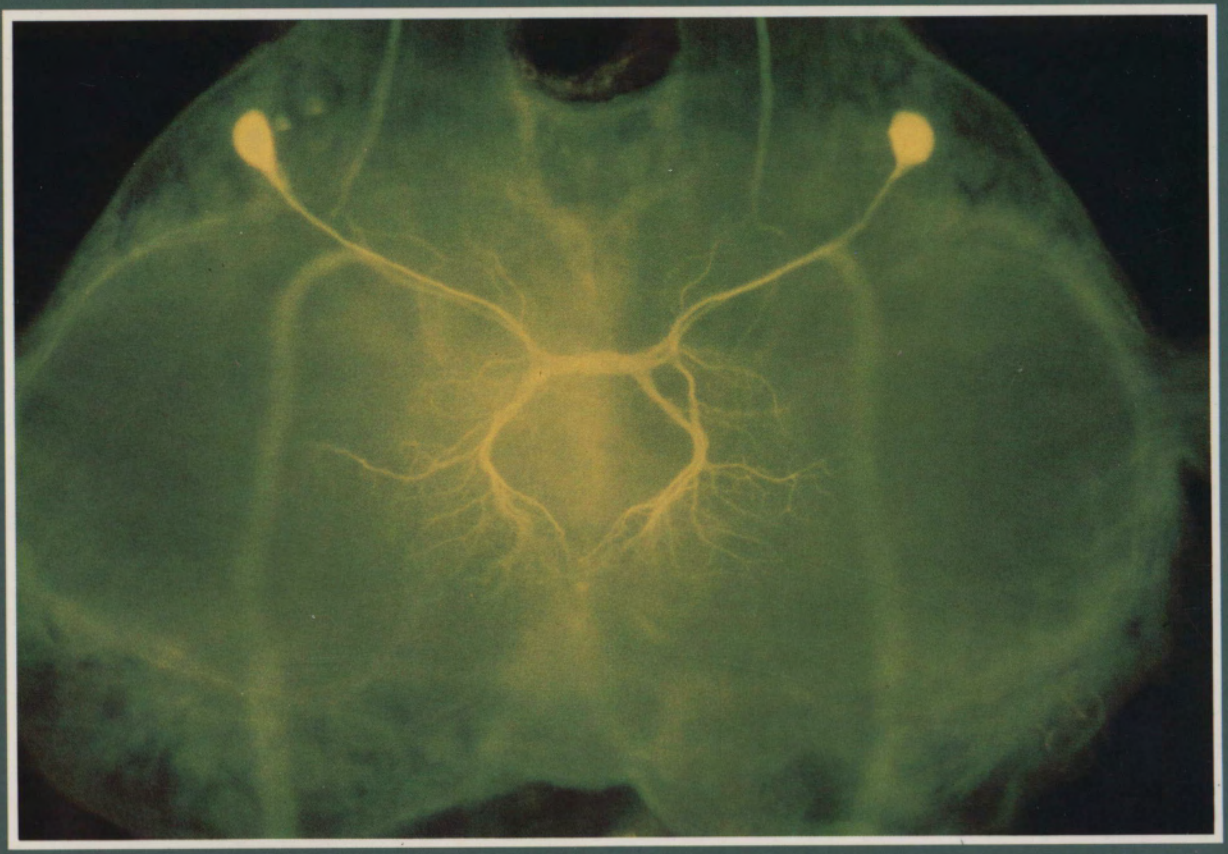
RESEARCH SCHOOL OF BIOLOGICAL SCIENCES



ANNUAL REPORT 1987

THE AUSTRALIAN NATIONAL UNIVERSITY

Cover photograph

A MODEL SYSTEM FOR NEUROBIOLOGICAL RESEARCH

Discovering how nervous systems are 'wired-up' and function is simplified by studying model neuronal networks in lower animals, such as the G neurone subsystem.

This photograph shows the cell body and major arborizations (magnified 200 times) of the two G neurones in the mesothoracic ganglion of a locust, revealed by the ultraviolet illumination of the cells following intracellular injection of a fluorescent dye. The bright yellow spots are the cell bodies of two G neurones; the cell bodies are connected to the major branches of the cells by thin fibres (the thin descending lines) which end in extensive arborisations—these connect with other nerves.

The G neurone has been studied by researchers with widely differing interests:

- **Neurobiologists** (including Drs Boyan and Ball in RSBS) are interested in the G neurone because it processes information from a wide range of sense organs such as the compound eyes, ears and wind-sensitive cerci, and sends its output to one of the motoneurones that controls the jump. Being large and easily recordable, and extending throughout the central nervous system, the G neurone is proving very valuable as a model for studies of cell circuitry and information processing.
- **Developmental biologists** (including Dr Boyan) have determined the complete lineage of the G neurone—that is, we know all of the cell divisions in the embryo that lead to the final neurone in the adult. We also know the serially equivalent cells to the G neurone in several other segments of the animal.
- **Geneticists** are interested in G neurone because the equivalent cell has been found in other animals such as the crayfish and, more importantly, *Drosophila*. This opens the way for genetic manipulation to test how various gene products affect the form and function of the G neurone.

(PHOTOGRAPH: G. Boyan)

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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
- + not a member of the University
- * former member
- † member of another part of the University
- § former visiting research worker

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DIRECTOR'S INTRODUCTION

R.O. Slatyer
Director

1987 has been a significant year in the School's development. During the year the School's sectional strategic plan for the 1988–92 quinquennium was prepared and subsequently endorsed by the University Council, providing a sound basis for the further evolution and development of our major research activities.

In addition, this year saw the introduction of the School's new organizational structure, based on flexibly constituted research groups, which replaced the previous departmental structure.

With the new strategic plan and organizational structure we now recognize eight major areas of research activity. They are:

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

The establishment of the new groups is enabling us to consolidate the strengths of the existing research areas and also to relocate researchers and general staff into new associations. In the process the following important developments in the School are taking place:

- the rapid dispersion of the concepts and techniques of molecular biology through most areas of the School. In the process the better understanding of the molecular basis of cellular communication constitutes a major challenge and provides an underlying theme;
- the establishment of a major thrust in plant molecular biology, which capitalizes on existing strengths in both molecular biology and plant science. It involves the development of a new research theme on the molecular analysis of plant performance which has the potential to position the School in the forefront of international research in this field. During 1987 we have been able to appoint Dr T.J. Andrews, a senior research scientist with the Australian Institute of Marine Sciences to a new tenured post in this area;
- the expansion of the Ecosystem Dynamics Group, based on existing strengths, and focussed on developing an underlying body of ecological theory on which the conservation and management of areas of natural or semi-natural vegetation can be based. Discussions are under way which will hopefully link this activity with other ecological groups in the University, notably in CRES, RSPacS and The Faculties, and with the new Centre for Information Sciences. We are very pleased that the University has provided strategic funding for the development of this Group. The funds will permit us to build an

outstanding programme in this area, and advertisements have already been placed for new appointments;

- restructuring of our neuroscience research into two major areas—developmental neurobiology and vision research. The latter is associated with the establishment of a cross-campus Centre for Visual Sciences, which links the vision research interests of RSBS with those of JCSMR and RSPhysS and which will interact closely with the new Centre for Information Sciences. The University has provided support from its strategic initiatives fund to assist with the development of the Centre. These funds, together with the new facilities which will be constructed during 1988 will ensure that both the RSBS neuroscience groups and other participants in the Centre have adequate resources for research of the highest quality.

The research associated with these developments is outlined in the body of the Report.

In 1987 the School's academic staff totalled 65, of whom 43% were tenured. Another 12 non-tenured academic staff were supported from outside funds. The total value of external support was in the region of $1.0 m.

Members of the School competed strongly for National Research Fellowships during 1987. Of the eight Fellowships obtained by the University, five (plus one Queen Elizabeth II Fellowship) were obtained by RSBS.

An honours course in cell biology was offered, in association with the Faculty of Science. This was the first year the course had been offered and was highly successful. All four of the students who completed the course gained first class honours (or the equivalent Graduate Diploma). Two of the graduates have enrolled in PhD's in the School.

Professor Barry Osmond (left) left the School in December to accept a chair at Duke University. Professor Bernard (Barney) John (centre) left in the latter part of the year, Dr John Andrews (right) joined the staff as a Senior Fellow; he was previously a Senior Research Scientist at the Australian Institute of Marine Science. He will play a leading role in one of the School's major developments—the Molecular Analysis of Plant Performance.

It is a pleasure to note that 1987 was also the first year in which a Robertson Symposium was held. The Symposia recognises the major contributions Professor Sir Rutherford Robertson has made to the School, the University and to science in general and will be held at about yearly intervals. They will be focussed on areas in which the School is in the forefront of international research activity. The first Symposium, which was opened by Professor Robertson, and in which he participated actively, was on the Ecology of Photosynthesis in Sun and Shade.

The School lost two senior staff, Professor B.John who took leave prior to retirement and Professor C.B. Osmond, who accepted a Chair at Duke University. Both had made major contributions to the School's scientific development, extending, in Professor John's case, to the key role he played as Director of the School from 1979 to 1984.

RESEARCH SUBJECT AREAS

In the following pages research projects are generally included in the Group in which the researchers were located. Those Groups are:

DEVELOPMENTAL NEUROBIOLOGY
VISUAL SCIENCES
MOLECULAR GENETICS
POPULATION GENETICS
PLANT CELL BIOLOGY
PLANT MOLECULAR BIOLOGY
PLANT ENVIRONMENTAL BIOLOGY and
ECOSYSTEM DYNAMICS

DEVELOPMENTAL NEUROBIOLOGY

Introduction

Developmental Neurobiology spans a broad spectrum of research, from the molecular analysis of development processes at one end to the ways in which complex mammalian brains grow in early development and establish accurate and functionally 'correct' connections between their millions of individual nerve cells.

The Developmental Neurobiology Group conducts studies of the Molecular Neurogenetics of *Drosophila* at one end of the spectrum, and experimental analyses of the development of sensory pathways in marsupial embryos at the other. Between these extremes of scale, we also examine the regulation of the shape of the unstable cell surface of arthropod photoreceptors in relation to the functional demands that they satisfy; the ways in which growing nerves in locust embryos are addressed to their targets; the basic biophysics of audition, particularly as it is consolidated during development of birds in the egg; and the regulation of muscle growth and nerve-muscle relationships in chicken embryos by prostaglandins.

These various approaches to the development of the nervous systems all relate to the basic enigmas in our current understanding of how complex nervous systems function in mature animals. Each relates to fundamental problems whose elucidation will be important in a variety of contexts. The following are descriptions of these research projects.

The Neural Basis of Behaviour: the Flight System of Orthopteroid Insects

Investigators: George Boyan, Matthias Hennig, Eldon Ball

Insects have nerve cells that can be identified individually, offering an enormous advantage over vertebrates for the analysis of simple behaviours. We study the initiation of flight in the locust by wind-sensitive hairs on the cerci—two sensory structures at the tip of the abdomen. On the basis of studies by ourselves and others it is now possible to analyse the entire pathway from receipt of a stimulus to a movement made in response to it. This is one of the few systems in which this has been achieved.

A locust must discriminate between external wind currents and its own movements, because both activate the wind-sensitive cercal hairs. To make this distinction, it employs a mechanism well-known in vertebrates—presynaptic inhibition—in a novel way. Information about its own movements, derived from receptors at the base of the cerci, is used to filter input from wind-sensitive hairs that are situated more distally.

We are now beginning to investigate the developmental histories of selected identified neurons in the locust cercal system so that we can understand how the adult patterns of connectivity arise.

The insect flight system also allows us to analyse another fundamental question: how are two small sets of nerves and muscles co-ordinated to produce two quite different behaviours. To attack this problem, we are examining the production of flight and song in the locust.

Neuromuscular Development in the Locust Embryo

Investigators: Camilla Myers, Paul Whitington#, Michael Bastiani#, H. Gert de Couet, Eldon Ball

Because in insects we can identify individual neurons, we can ask questions about neuromuscular development that are intractable in vertebrates, but which are of great theoretical and practical significance.

We have already established that there are two fundamentally different mechanisms of muscle formation in the locust. In one, a giant primordial syncytium containing many nuclei is formed, which then breaks up into a series of smaller syncytia which we term 'muscle pioneers', each of which acts as a scaffold for an adult muscle. In the second, muscle pioneers are formed directly in a temporal sequence, without an initial giant syncytium. Differences between the musculature of the three pairs of legs of a locust result either because a given pioneer does not form, or because a pioneer first forms, then dies.

In conjunction with these studies of muscle development, we are mapping the normal development of muscle innervation by specific identified neurons. In a particular case, a developing neuron makes several 'mistakes' before contacting its appropriate neuron. Why these 'mistakes' are made and how they are routinely corrected are fundamental questions for our understanding of normal neuromuscular development. Using the locust, with its large individually identifiable neurons, we are examining how these cells interact with each other as they grow, and also with the nascent muscle fibres with which they are destined to make contact.

These studies are paralleled by some of the questions that Ian McLennan is asking about the development of chick embryonic muscle, which he describes below. Both studies are of potential important to our understanding of clinically important human muscular dystrophies.

The Development of Chick Embryonic Muscles

Investigators: Ian S. McLennan, Margaret Porter, Hiroto Naora, Kyoko Kyoshi, Tom Millar, Joe Ho+, Kerry Bartlett+, Zenia Dennett+, John Rostas#, Sue Shanin+

Several organs, including the brain and skeletal muscle obtain their mature numbers of cells early in embryogenesis; their subsequent growth results solely from the enlargement of these cells. We are interested in determining how the number of cells within a muscle is regulated, because the mechanisms have implications for agricultural meat production, and for our capacity to induce the regeneration of diseased human muscle. To this end, we examine the formation of the neuromuscular system in chick embryos. We have already shown that motoneurons influence the production of a sub-population of muscle precursor cells (myoblasts). This year, we have concentrated on the influence of prostaglandins on myoblast proliferation. Prostaglandins are a family of compounds that are involved in local cell-to-cell communication, and some members have profound effects on the developing embryo. Prostaglandin E1 (PGE1) and PGE2 inhibit myoblast proliferation, whereas PG12 stimulates it. F series prostaglandins antagonise the action of the E series, but are unable to induce muscle formation beyond normal levels by themselves.

It is important to study the acute effects of prostaglandins on muscle production if we are to understand how they work. We are examining the influence of prostaglandins on oncogene m-RNA production, and have indications that developing muscles produce several oncogenes, including c-fos, c-myc, c-sis, c-Hi-ras and c-ki-ras.

In association with Drs Rostas and Bartlett and Ms Shanin (University of Newcastle), we have localised the binding sites of various monoclonal antibodies to muscle. One, PA20, binds to the M-band of myofibrils and appears to recognise a hitherto undescribed protein associated with the contractile apparatus. Another, AA21, binds to the internal membranes of slow, but not fast, fibres, and also appears to be recognising a novel protein.

In collaboration with Dr Ho (Sydney University) we have developed a technique that will enable the embryological origin of muscle fibres to be identified in mature animals. The technique will permit us to study the ways in which the embryological origin of muscle fibres influences their responses to a variety of pathological and physiological stimuli.

Cell Biology of Photoreceptors: Transduction Enzymes

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

The photoreceptor cells of vertebrate eyes contain a transductive amplification cascade which is now better understood than any other intracellular signalling pathway. Insects and crustaceans have photoreceptors which do just as good a job as ours, but much less is known about their biochemical mechanisms. By largely neglecting the study of invertebrate photoreceptor biochemistry, researchers may have overlooked a source of accessible new information about the ways in which all cells regulate their internal milieus.

We are investigating two phosphatase enzymes that are major proteins of the transduction site in retinae of invertebrate animals—the photoreceptor microvillus.

The most interesting enzyme, a novel phosphoprotein phosphatase, is a major protein within microvilli. Similar activity is only feebly present in photoreceptors of vertebrates, where over the last decade its study has proved intractable. Perturbations of its activity are believed to accompany some inherited retinal degenerations in laboratory animals. We have localised active enzyme to rhabdomeral microvilli in *Limulus* and crabs, and have characterised the polypeptide for the first time from any preparation in crab and squid. We believe from several lines of evidence that the enzyme will prove to participate in regulation of the receptive state of the photopigment rhodopsin.

The second enzyme is a cytosolic inositol polyphosphatase which inactivates 1,4,5 inositol trisphosphate (InsP3) by hydrolysis. InsP3 is an important intracellular signal for the release of stored calcium in many cells, and calcium fluxes are known to play significant roles in the regulation of phototransduction cascades.

We believe that the local compartmentalisation of enzymes in relation to their substrates is a key problem in transduction biochemistry. Characterisation of enzymes is a preliminary to localising them during the development and maintenance of these complex cells.

Embryology, Physiological Optics and Evolution of Jumping Spider Eyes

Investigators: A. David Blest, Peter McIntyre#, Margrit Carter.

Jumping spiders depend on acute vision to discriminate between prey, mates and territorial rivals. Their visual acuities are only slightly inferior to our own. Discriminations are mediated through large principal ocelli with a unique tiered retina and telephoto optics. We have investigated the post-embryological development of the tiered retina with a view to determining how it might have evolved. The retina starts as a conventional hemispherical monolayer of receptive segments, and is converted to its mature, boomerang-shaped form by lateral compression, receptive segments migrating to overlie each other, generating four tiers. The first tier of receptors is organised as long light guides. Light guiding properties are only achieved on the 14th to 15th days of development, and we argue that the course of morphogenesis approximates to that of the evolution of these sophisticated eyes.

The phylogeny and systematics of the Salticidae have represented a major arachnological enigma for the last century. From our recent field work in the Panamanian rain forest, we are able to infer much about the phylogeny of the Family from the diverse functional architectures of their retinae taken in conjunction with their behaviours, and our data on retinal development.

Function of the Avian Cochlea

Investigators: Ken Hill, Tony Gummer, Gert Stange, Bridget Hilton

During 1987, for the first time, we were able to measure auditory responses in conditions of effective isolation from extraneous noise. We discovered that in the adult pigeon, suppression and excitation of primary nerve fibres are antagonistic factors underlying responses, even to single tones presented in a quiet background. Thus, suppression of spontaneous firing occurs in a proportion of fibres in bands bordering the response area. We have demonstrated that the presence of extraneous noise (or a second tone) increases overt suppression of spike responses, apparently by altering the relative sensitivity of the spiking mechanism to these antagonistic factors. The bandwidth of the suppression appears wider than the bandwidth of excitation. Moreover, our results suggest that the suppression factor acts proximal to the receptor cell-primary fibre synapse. When compared with the properties of the factor responsible for phase locking in the responses of the primary fibres, the bandwidth over which a fibre is either suppressed or excited by tonal stimuli corresponds with the bandwidth over which phase locking occurs, subject to the roll off in phase locking with increasing frequency. We have previously shown that phase locking appears to be independent of the excitatory factor associated with the spike responses. These further results strongly support our unified hypothesis of avian cochlear function, involving a dualistic mechanism for sensory coding in terms of spike rate and spike synchronicity, in which spike responses depend on both synaptic and extracellular electrical processes.

Functional Development in the Avian Auditory System

Investigators: Jianwu Mo, Ken Hill, Tony Gummer and Gert Stange

We have developed a technique for measuring the auditory responses of single nerve cells in the developing chick embryo at 2–5 days prior to hatching. In common with concurrent work in the USA, we find that neurons in the medulla (most likely as yet non-functional auditory neurons) show highly-characteristic, rhythmic bursting activity. This activity suggests some form of underdamped oscillation in factors affecting neural firing. Of great significance is our discovery that functional neurons show phase-locked responses as early as at 16–17 days of embryonic development. Such early functional competence is in marked contrast with the late (10-day post-birth) development of phase locking in mammals. The avian system clearly is of great comparative significance for understanding auditory development.

Development of the Visual System in the Tammar Wallaby

Investigators: Richard Mark, Judy Wye-Dvorak, Lauren Marotte, Xiao-Ming Sheng

The main aim is to study factors involved in the development of specific neuronal connections in mammals. The visual system of the marsupial wallaby is used firstly because of its highly ordered topographical connections and secondly because these animals have the unique feature of birth at a very early stage of neuronal development prior to the innervation of the brain by the nerve cells from the eye. During the protracted development in the marsupial pouch they are available for experimental manipulations which are not feasible in placental mammals.

Projections from the eye to the brain have been mapped after rotation of the eye in the orbit (a torsional squint) on the day of birth. Nerve fibres from the eye find their way unerringly to their correct destinations in the brain even if they enter it by an abnormal route such as via the nerves innervating the extraocular muscles, indicating that specific recognition between nerves and their targets and not simple pathway guidance is operating. A study of the development of retinal topographical

connections to the lateral geniculate and superior colliculus has shown that topographical precision is refined during development and is complete prior to eye opening. The development of these centres after removal of one eye on the day of birth has shown that many features previously thought to depend on binocular competition between functioning eyes can develop and make connections with the visual cortex in the complete absence of visual input.

The development of visual cortical connections with subcortical visual centres has also been investigated. The ascending connections to the cortex form within a few days of the innervation of subcortical structures by the retinal ganglion cells but the descending connections do not develop until months later when the differentiation of the cerebral cortex takes place.

The foregoing anatomical studies are being complemented by an electrophysiological approach. Retinotopy of the adult lateral geniculate nucleus determined electrophysiologically has corroborated the anatomical findings and shown that the response properties of single geniculate neurons are similar to those in other mammals. Unit recording from the cerebral cortex revealed the map of the visual field to be laid out rather like that of a monkey with projection on the lateral surface of the occipital cortex, and with the area centralis represented rostroventrally. Cells are strongly directionally sensitive. These normative data will be used to analyse the development of nerve connections after induction of a torsional squint prior to optic innervation of the brain.

The wallaby, which we introduced some years ago as a result of a New Initiative grant from the University, clearly has a future as a standard laboratory animal in developmental neurobiology. If it is to serve as a basic model of mammalian, and ultimately human, development it must be ascertained that its brain shows no major deviations from the general mammalian pattern. Further detailed neuroanatomical studies have shown that there is no trouble in establishing homologies between areas of the cerebral cortex and the nuclei of the thalamus and those of major advanced eutherian mammals. A major difference is the inexplicable course of the corpus callosum: taking the form of the fasciculus aberrans it crosses dorsal to the anterior commissure rather than running straight across between the cortices.

Molecular Neurobiology: Neurogenetics and Developmental Gene Circuits

Investigators: George L. Gabor Miklos, H. Gert de Couet, Jane Davies and Masa-Toshi Yamamoto

A major problem in neurobiology is to understand the mechanisms by which nerve cells form specific connections. In order to build a nervous sytem, the genome must encode and utilize certain protein molecules to sequentially coordinate the construction of a network of neurons which determines the behavioural repertoires of the organism. 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 techniques, genetics and deployment of monoclonal antibodies. We utilize the 100,000 neuron nervous system of the fly *Drosophila melanogaster* because of the pragmatic technical advantages this organism offers over nearly all other animals. It has extensive data bases in genetics and molecular biology as well as sophisticated genomic re-entry vectors which are routinely available for gene re-introduction and mutagenesis programmes. In mammals on the other hand, these systems are still unreliable and poorly developed. Furthermore, it is already known that nearly 40% of the monoclonal antibodies so far made to the fly nervous system cross-react to the human brain and so it is very likely that many of our findings can be evaluated in the mammalian context.

We have located and are characterizing specific 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 a large international and local network (see Joint Research Projects) wherein we are melding our genetic and molecular biological expertise with the neuroanatomical, neurophysiological and embryological expertise of overseas laboratories.

By microdissecting and microcloning the 19-20 region of the X chromosome of *Drosophila* (with Vincenzo Pirrotta, Baylor College of Medicine, Houston, Texas, USA) we have isolated cloned entry points in and around neurological genes such as *Passover, small optic lobes, sluggish, uncoordinated and stoned (stress sensitive).*

Jane Davies has extensively characterized the DNA landscape surrounding the *Passover* locus whose gene product is needed for specifying several connections between identified neurons of the giant fiber pathway as well as between specific neurons in the antennal regions of the brain. She has also initiated overseas collaboration with laboratories utilizing neurophysiological, neuroanatomical and genetic approaches to this gene complex (see Joint Research Projects).

This year has heralded two major achievements. Gert de Couet and Jane Ada have completely sequenced a cDNA clone which we believe to be a product of the neuromuscular *flightless* locus. This is the first complete nucleotide sequence of an invertebrate neurological gene generated from this school. The predicted amino acid sequence derived from the analysis of this gene indicates that its protein product is novel and exhibits only minor homologies with known protein sequences. The gene is single copy and gives rise to several developmentally regulated transcripts. We will now utilize the power of the *Drosophila* genomic delivery vectors to not only rescue the mutant phenotype, but to reintroduce *in vitro* mutagenized gene copies into the genome. Knowing our *flightless* gene sequence, we are also now in the position to produce specific deletion derivatives, re-enter the genome and systematically evaluate the functional domains of our protein. Having secured the cloned bridgeheads around the *flightless* locus, we have now extended our chromosomal walks into the adjacent DNA landscapes of *small optic lobes* and *sluggish*.

Our second major achievement has come from our microdissection and microcloning experiments and has revealed some unsuspected properties of chromosome structure. We (George Miklos, Toshi Yamamoto and Julie Higginbotham) have found that the small chromosome 4 of *D. melanogaster* is a pastiche of many different repetitive DNA sequences interspersed with unique DNA sequences. This finding may provide clues to some important aspects of gene regulation for those genes sequestered in beta-heterochromatin.

Gert de Couet and Tai-ischi Tanimura have opened up new research avenues as a result of their development of monoclonal antibodies to *Drosophila* rhodopsin. Other groups have been unsuccessful in making these antibodies and we have therefore supplied the laboratories of C. Zuker, J. O'Tousa, W. Stark and G. Rubin (see Joint Research Projects) with these monoclonals so that these overseas groups can now monitor rhodopsin gene expression in genetically engineered transformed flies. (ii) DNA microclones containing repetitive sequences. Our microdissection and microcloning experiments have unearthed a plethora of repetitive DNA sequences that are predominantly domiciled in beta-heterochromatin. A number of overseas laboratories working on DNA binding proteins and DNA divergence studies have realised that our microclones are indispensable for their studies and we are collaborating with them (see Joint Research Projects).

VISUAL SCIENCES

Introduction

The aim of this research group is to understand the mechanisms by which the visual information from the outside world is caught and analysed by the nervous system behind the eye. Of all physiological research in the world, much is on the nervous system; and of this most is on the visual system because the stimulus is easy to manipulate and the results illustrate the principles of integration in all nervous systems. There is already a substantial body of knowledge, with many laboratories worldwide engaged on the vertebrate and especially the mammalian visual system. The general principle that emerges is that natural visual processing systems operate in a massively parallel fashion akin to the new parallel-processing architecture which is about to be introduced in computers. It is already apparent that if we could make computers with the architecture of the nervous system, especially in the area of pattern recognition, the computing power and speed would be greatly increased. Almost anything we can learn about the principles of visual mechanisms is therefore of potential significance to forthcoming technology.

Modern interdisciplinary work at the interface between artificial pattern recognition and natural visual processing systems has relied so far upon the psychophysics of man and the electrophysiology of the first stages in the mammalian (cat) visual system. The problem here is that the mammal system is too complex, too indeterminate, and it relies on memory to function.

In RSBS the Visual Sciences Group takes a different line by analysing visual processing mechanisms in insects and lower vertebrates. It concentrates on insects for 3 reasons; they are at the appropriate level of complexity to copy into artificial seeing systems, they have identifiable components (neurons) and not too many kinds of them, and they are cheap, convenient and fascinating in their own right as behaving organisms. As the following projects illustrate, the Group covers the whole spectrum from visual behaviour, to anatomy and electrophysiology of the component neurons, to the performance of models which work by the same principles that we find in the natural systems. It is one of the very few places in the world with such a program.

A New Theory Of Evolution of Visual Processing

Investigator: Adrian Horridge

From data on visual processing in vertebrates, insects, and invertebrates, from insects down to lowly animals like jellyfish, worms and protozoans, it became apparent that eyes with complicated retinas and very large arrays of photoreceptors can have a survival value although they have no complex brain behind them, and they can not "see" the visual world as a picture as we do. Eyes can be diffraction-limited but not see the pictures that the optics and receptors would allow. This apparent contradiction has been solved in a new theory, based on motion perception, which has produced several new areas of investigation, some of which immediately follow this item.

How Do Insects See Objects in 3-Dimentional Spaces

Investigator: Adrian Horridge

In a very easily evoked response, insects reach out for a nearby twig with one anterior leg when they reach the end of the twig they are walking on. They use their eyes and identify objects around them in 3-dimensions, picking out the nearest. The Praying Mantis uses as visual cues the relative motion of nearby objects caused by the insect's own motion. The key measurement made by the eye is the angular motion at each region of the eye. The better this is resolved, the more exact is the vision. The general background motion caused by head rotation must be subtracted from local motion in each small region of the eye. An important question is how general is this mechanism, and what other visual processing mechanisms are active at the same time.

Motion Perception as the Basis of Vision

Investigators: Adrian Horridge, Mandyam Srinivasan

The visual processing group is off to a flying start with a new theory of object vision by insects, based on relative motion caused by the insects' own motion. This theme is generating new experiments on discrimination of objects by bees, and the properties of neurons in the optic lobe are being tested with moving patterns. The decision to move from retina and photoreception into optic lobe and visual processing had been taken in 1984. One tenured position (Dr Srinivasan) and four non-tenured posts in the new topic (Drs Reye, Findlay, Guy, and Maddess) were filled in 1985. The Group is therefore set on a very positive path to a new burst of neurobiological research activity that yields insights into artificial visual systems.

Lamina Ganglion Cells

Investigators: Adrian Horridge, Ljerka Marcelja, Peter Coombe, Richard Guy and Andrew James

The second neurons on the visual pathway in insects have large monopolar cell bodies just beneath the primary photoreceptors from which they receive numerous synapses. Earlier work by Laughlin showed that these cells reject signals that are redundant to the seeing of contrast i.e. they adapt to constant light intensity but see changes in intensity in time and in space. In further characterization of these large cells we look for their participation in behaviour and their place as components feeding into deeper neurons on the visual processing pathways.

Retinal Circuitry, Neuro-transmitters and Visual Processing

Investigators: Ian Morgan, David Dvorak, Tom Millar, Jan van der Valk, Marc Golcich, Guang Yang and Les Davies[#]

The aim of this project is to explain how the vertebrate retina turns the visual inputs which are enregistered in the eye by the photoreceptors as a rather stereotyped response, into subtle, coded, meaningful messages which are transmitted by the retinal ganglion cells to the brain. The research is multidisciplinary, bringing neuroanatomical, neurochemical and neurophysiological techniques to bear on the same questions. Key features of our approach are the use of immunohistochemical techniques for the ultrastructural characterization of specific retinal cells, the use of pharmacological manipulation of the inputs to cells, and intracellular electrophysiological techniques. A unique feature of our work is the systematic use of neurotoxins to specifically and permanently eliminate groups of neurons from retinal circuits, enabling analysis of their synaptic connections, and physiological and even behavioural functions.

This year there has been a particular focus on the role of the amacrine cells in controlling the response properties of retinal ganglion cells, making use of the techniques we have developed for the specific elimination of amacrine cells as a class using N-methyl-D-aspartic acid as a neurotoxin; and for the selective elimination of the cholinergic amacrine cells using ethylcholine mustard aziridinium ions. Elimination of amacrine cells as a class does not change the basic properties of the receptive field centres of ganglion cells in that the units remain predominantly ON-OFF, and their sensitivities to light are not significantly affected. Centre responses remained transient, which is of particular interest since inhibitory amacrine cells are generally believed to generate transience by feed-back inhibition. It therefore seems likely that the site of transience generation is in the bipolar cell terminal, or in the ganglion cell itself. Elimination of the amacrine cells as a class markedly disrupted both the silent and the responsive surrounds of the ganglion cells, in contrast to the generally accepted belief that the horizontal cells are the major determinants of centre-surround organization. Motion and direction sensitivities also seemed to be eliminated. After elimination of the cholinergic amacrine cells, the basic centre and surround properties of the ganglion cells were unaffected. This refutes the suggestion that the cholinergic amacrine cells are responsible for response transience at the ganglion cell level. Motion and directional sensitivities seemed however to be eliminated. This result will be followed up by detailed investigation of the response properties of directionally selective ganglion cells, recording from a specific brain nucleus which they project to.

The directionally selective ganglion cells have been identified by back-labelling with fast blue or rhodamine-labelled beads. The cells have then been filled under visual control with Lucifer Yellow, allowing the complete morphology of the cells to be reconstructed. The cells bodies are located on the boundary between the inner nuclear and inner plexiform layers, and a prominent axon descends through the inner plexiform layer and ganglion cell into the topic fibre layer. The cells have 5-6 prominent dendrites which branch repeatedly, but without showing the convoluted dendritic branching postulated in mathematical models of directional selectivity. Now that the cells have been identified, their synaptic relationships with the cholinergic amacrine cells, and other cells, including the GABAergic amacrine cells can be explored.

The morphological description of the cholinergic amacrine cells has brought forward two observations, neither of which is consistent with the current models of how directional selectivity is generated. There seems to be no non-cholinergic amacrine cell input to the cholinergic amacrine cells, thus leaving no room for the GABAergic input postulated by the pre-synaptic models. Nor does there appear to be overlap of GABAergic and cholinergic processes, as is required by both the pre-synaptic and post-synaptic models.

The DCMD Neuron

Investigators: David Reye, Richard Guy, Sun Qijian and Bob Pinter#

This locust neuron, known for 40 years, detects motion of any small target in the whole visual field but is inhibited in a pattern-dependent way by large disrupted patterns. Detailed investigation of its response profiles (done by this group) and its outputs to numerous motor units in the ventral cord (done by others) formerly failed to elucidate its special function as an output of the visual system, but now we have a new theory that is related to vision by the animal's own motion.

Honeybee Visual Behaviour, and the use of Colour and Motion Cues

Investigators: Mandyam Srinivasan, Miriam Lehrer#, Wolfgang Kirchner# and Shao Wu Zhang*

The new theories on motion perception have initiated a series of different experiments on discrimination of objects by flying bees. A whole new area of visual discrimination behaviour was opened up in collaboration with these three Visiting Fellows. Honeybees can be trained to come for sugar at a place where they have been given visual cues. Therefore a great deal can be learnt by careful manipulation of the cues presented to them in later tests.

It now appears that, although bees have excellent trichromatic colour vision, they use a colour-blind, green-sensitive channel to

(i) detect motion
(ii) resolve high-spatial-frequency gratings, and
(iii) use the angular velocity of images moving across the eye as the main cue for the range and existence of separate objects.

A large proportion of visual processing in the honeybee appears to be carried out by a high-resolution, colour-blind, fast-acting moment-to-moment system measuring angular velocity. In robotic vision, mechanisms of this kind would provide one solution to the problem of distinguishing objects and measuring their range.

Motion-detecting Neurons

Investigators: Jian Shi, Richard Guy and Robin Findlay

Higher order neurons on the insect visual pathway have very large visual fields that detect movement over a large angle. It is a puzzle why many of the largest and most easily recorded outputs of the visual mechanism are clearly unsuited for signalling the *direction* of movements relative to the eye. It is also a puzzle what aspects of the visual world they measure in a way that is independent of other variables, for example we are faced with the paradox that measurement of stimulus velocity is influenced by the pattern, the contrast, and the orientation, whereas the whole insect *behaves* as if it

does not confuse these features. One of the recent findings is that the H1 neuron of the fly (an identified visual processing neuron) measures the modulation of motion irrespective of pattern or modulation frequency, and therefore it will be sensitive to a change in the range of surrounding objects. Slowly, as analysis proceeds, these properties of the component neurons are discovered so that their role in the visual processing can be copied into simulation models and artificial seeing systems.

Simulation of Visual Processing

Investigators: Mandyam Srinivasan, Jin Zhefei, Bob Pinter#, Andrew James and Zoran Aleksic

It is always tempting to take what knowledge we have of the component neurons, aim to mimic the visual behaviour, introduce a few guesses, then simulate a model of the system, using principles like local adaptation and lateral inhibition that have been inferred from the natural visual systems. The results are of interest for the construction of artificial seeing systems and are useful in guiding new experiments on the natural mechanisms. There is also a large area here for the investigation of how natural systems have the optimum configuration for particular visual tasks.

MOLECULAR GENETICS

Introduction

Central to studies undertaken by the Molecular Genetics Group is the need to understand how genes function. Consequences of altering a gene's environment to its expression are being examined in oncogenic cells and in mitochondrial and nuclear genomes of yeasts. These studies will help to clarify effects of both short-range and long range structural changes in DNA to alteration of gene regulation. As part of these investigations mechanisms of genome rearrangements and evolution are being examined.

Cancer Cell Biology

Investigators: Hiroto Naora, Kaoru Miyahara, Exmond Decruz, Felice Driver, Kyoko Koishi, Sun Lun Quan, David Buckle, Ursula Norris, Helen Liszczynsky

Malignant alteration of cell function is a complex process and requires multiple and co-operative events induced by carcinogenic stimuli. Activation of cellular oncogenes (*c-onc*) is involved in these events. *C-oncs* are expressed in normal cells at tightly regulated levels, often in a tissue or developmental stage-specific manner. On the other hand, enhanced or constitutive expression of various *c-oncs* is often, but not necessarily always, observed in tumor cells. The aim of this work is to investigate a regulatory network for oncogene expression.

Our attention is particularly devoted to the following projects:

a studies on the molecular mechanisms underlying the cis-acting gene-to-gene interaction and an examination of higher-order chromatin structures;

b structural and functional characterization of the novel gene, *nbl*, abundantly expressed in Burkitt lymphomas with emphasis on the chromosomal organization of the gene and also the intracellular localization of gene products;

c studies on malignant alteration of cell function with particular emphasis on territorial effects of genes including manipulation of tumor growth;

d characterization of the gene expression network system in which *c-myc* and *c-mos* are involved. This study includes the investigation of the genes which suppress *c-onc* expression in normal cells;

e studies on genome evolution and the origin of contemporary gene structures.

Protein Engineering

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

The object of protein engineering is to change the structure of proteins in a predictable manner by altering the sequence of nucleotides in their genes. This is a technique of fundamental importance, both in the elucidation of structural and functional 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 three dimensional structure of one of them, that from horse liver has been determined by X-ray crystallography and it is possible to deduce the structures of ADH enzymes from other species by homology. Several ADH structural and regulatory genes have been cloned and sequenced and some are available on vectors suitable for laboratory manipulation.

The major research thrust this year has been on the yeast ADH-1 enzyme. We engaged in changing the active site of this enzyme to enable it to oxidise larger substrate molecules and we have previously shown that two amino changes did have the desired effect ,although the magnitude was not large. This year we have made the two changes singly and were surprised to find that the effect of the double change was not that of simple additive effects of two single changes. Thus , making the change at position 48 from threonine to serine—substituting a smaller amino acid—had a very marked effect in enhancing the rate of catalysis of alcohols of carbon numbers 3-5 whereas changing tryptophan 93 to phenylalanine had little effect on the smaller alcohols but had a strong influence on the catalysis of hexanol,heptanol and octanol. We interpret this finding as follows; amino acids at position 48 are part of the active site at the bottom of the substrate pocket and expansion of the pocket in this area allows enhanced oxidation of alcohols of 3-5 carbons. Above this range access to the active site is impeded by the bulky side chain of tryptophan at position 93 ,this being further from the bottom of the pocket and closer to the environment. Replacement of trp with phe (smaller side chain) enables alcohols with 6-8 carbons to be more effectively metabolised.Following this line of reasoning we are changing the amino acid at position 57, which is even further away from the bottom of the pocket. In yeast this is again tryptophan and we think it is a further constrictor of the active site cleft. We are changing 57 to either leucine or alanine to enlarge the substrate pocket and also making other changes at the entrance to the substrate pocket. We are in collaboration with Professor Bryan Jones who will test our engineered enzymes to see if they are of value in preparative organic syntheses. This year we have investigated a novel procedure for oligonucleotide synthesis using paper discs. This method will produce large numbers of oligonucleotides at low cost.

We have further collaborative protein engineering investigations , firstly to alter the expression of the NodD gene of Rhizobium and secondly to modify the substrate activity of p-hydroxybenzoate hydroxylase.

Genes and Enzymes of Alcohol Metabolism in Aspergillus

Investigators: E.H.Creaser,Tracey Cross and K.Britt

Investigations in this area are moving from studying the enzymes themselves, to trying to elucidate the systems which control their formation. In Aspergillus formation of alcohol dehydrogenase and aldehyde dehydrogenase is under the control of the gene AlcR. This gene was partially sequenced by John Pateman last year and we are working to clone the complete gene and to study the properties of the regulatory protein produced by it . Initial studies indicate that the gene is not similar to the corresponding regulatory gene from yeast. However, our observations on the various molecules which induce formation of alcohol and aldehyde dehydrogenases indicate that there could be more than one regulatory gene operating in the system. This makes study of the system more interesting but more complex. Essential methodology for this project, notably protoplast transformation, has been established.

A short visit by Professor McKinley-McKee of Oslo University enabled us to make a detailed kinetic study of the Alcohol Dehydrogenase of Aspergillus; the study continues in collaboration.

Mitochondrial Biogenesis and Mitochondrial Genome Evolution in Yeasts

Investigators: Des Clark-Walker, Ryzard Maleszka, Patrick Skelly, Chris Hardy, Alexandra Plazinska, Erika Wimmer

Mitochondrial genomes in yeasts are model systems to study the evolution of DNA and the regulation of gene expression. By sequence comparisons of mitochondrial DNAs from seven species in the *Dekkera/Brettanomyces/Eeniella* complex we have discovered that small genomes with conserved gene order are more distantly related than larger molecules with rearrangements. This surprising result provides circumstantial support for the proposal that rearrangements in mtDNAs are produced from an intermediate molecule having non-tandem direct repeats. Formation of these intermediates is postulated to be facilitated by increasing the length of intergenic 'spacer' segments, while decreasing these regions would reduce the formation of these intermediates. A direct demonstration of this pathway for rearrangement has been provided by studies with *Saccharomyces cerevisiae* mitochondrial DNA. Various rearrangements of the mitochondrial genome have been produced via molecules with

Dr Des Clark-Walker (centre) signing a contract for a $250,000 (approx.) grant from Burns Philp and Company to undertake development research into genetically marking strains of yeast. With him are Professor Ian Ross, the Deputy Vice Chancellor (left) and a representative of ANUTECH (Dr John Turner) who are agents for the grant.

Fundamental research into aspects of yeast molecular genetics, conducted at RSBS, have potential application to the food industry. Studies are now underway to adapt the findings of Dr Clark-Walker's research to the specific needs of the commercial interest.

Yeasts have wide, and increasing, uses in the biotechnology and food industries and there is scope for further development of collaboration of this kind.

(Photograph by Bob Cooper)

non-tandem direct repeats. Consequences of rearrangements and deletions of intergenic sequences for mitochondrial gene expression are under study. Investigations are proceeding on:

a Phenotypic consequences of deleting intergenic sequences and rearranging gene order of mitochondrial DNA from bakers yeast *Saccharomyces cerevisiae*.

b Sequences involved in recombinogenic 'hot spots' of mitochondrial DNA in bakers yeast.

c Nuclear-mitochondrial genome interactions during catabolite repression and derepression in bakers yeast.

d Characterization of deletions and rearrangements in mitochondrial DNA of *Kluyveromyces lactis*.

e Factors involved in the conversion of the petite-negative yeast *Kluyveromyces lactis* to a petite-positive strain following fusion with *Saccharomyces cerevisiae*.

f Phylogenetic relationships between seven mitochondrial DNAs (size range 28-101kb) in the *Dekkera/Brettanomyces* and *Eeniella* species complex of yeasts.

Intergenic Sequences of Yeast Mitochondria

Investigators: Jure Piskur, G.D. Clark-Walker and B. Tyler

Intergenic sequences of the yeast mitochondrial genome have been shown to be dispensable for expressions of the respiratory phenotype. Deletion mutants have been used to study the possible reasons that these 'unnecessary' intergenic sequences are conserved in the genome.

It has been shown that particular intergenic sequences enhance transmission of linked loci to the progeny.

POPULATION GENETICS

Introduction

The Population Genetics Group investigates both micro- and macroevolutionary processes in the flora and fauna from Australia and the Pacific region.

Using modern molecular and biochemical techniques, the Group analyses structural variations at the DNA level and assesses its functional significance in the evolution of the population and the species. Current research is focused on two complementary aspects of DNA organisation: the gene and the chromosome.

At the genic level, the main focus of the work involves two enzyme systems in *Drosophila* species; the aim of the research is to define the selective constraints in populations on enzyme structure and function.

At the chromosomal level, the Group is investigating the fine structure of those chromosomal regions involved in cell division. In particular, the structure of the centromere is under investigation to determine its molecular organisation and how changes in its chromosomal location alter cellular and developmental processes.

Population and Molecular Genetics of Drosophila

Investigators: John Gibson, Allan Freeth, Peter Christian, Chengshan Jiang, Jane Symonds, Ann Wilks, Anh Cao

Null alleles at the alcohol dehydrogenase and sn-glycerol-3-phosphate dehydrogenase loci were discovered at frequencies up to 4% in some Australian populations of *Drosophila melanogaster*. The presence of these alleles raises interesting questions about their origins and the mechanisms by which they are maintained over years in populations that experience severe annual bottlenecks. To answer these questions null alleles at both loci have been extracted from a number of geographically separate populations and their properties and molecular structures are being studied.

A northern blot analysis of nineteen naturally occurring *Adh* null alleles has shown that they all produce a transcript about 100 bases longer than that produced by the normal allele and they accumulate a precursor of 1800 bases. The amount of transcript produced by the null alleles is about 10% of that produced by normal alleles.

Restriction endonuclease variation in the 12kb region surrounding twelve *Adh* null alleles has been compared with normal alleles from the same populations. Each of the null alleles had the same haplotype as revealed by digestions with eight hexanucleotide restriction enzymes. This haplotype also occurred in 4 of the 46 chromosomes bearing normal alleles; these four chromosomes with the null allele haplotype carried the Adh^s allele. The data suggest that the *Adh* null alleles from geographically separate populations share a common ancestry and are derived from the same mutation in an Adh^s allele.

In order to identify the mutation responsible for the loss of alcohol dehydrogenase activity the null allele mRNA has been investigated by S1 nuclease digestion. These experiments have shown that there is a defect in the splicing of two of the three introns present in the *Adh* gene. The aberrant splicing patterns appear to result from the utilisation of alternative or novel 5′ donor and 3′ acceptor splice sites.

Studies of a number of *Gpdh* variants from widely separated populations along the east coast of Australia has shown that they all produce some GPDH activity and that, in contrast to the *Adh* nulls, none of them are true null activity alleles. The *Gpdh* low activity variants so far investigated are heterogeneous in the level of GPDH and in the transcripts produced.

Previous evidence for latitudinal variation in electrophoretically detectable variants at the *Adh* and *Gpdh* loci has been substantiated in new surveys. To explain these phenomena it is necessary to know much more about *Drosophila* population structure and the effects of migration. Laboratory populations of *D. melanogaster* have been used to investigate relationships between the amount of migration and the strength of selection on phenotypic divergence between two subpopulations in different environments. The results show that quite weak selection, coupled with partial isolation resulting from microgeographic separation, can have very marked effects on the genetic structure of populations.

On the basis of the population differentiation known to exist in Australia a study has been made of the distribution of two *Drosophila* viruses DAV and DCV using a specially developed cDNA hybridization assay. Infected flies were found in 8 of 34 populations screened, with infection frequencies ranging from 0.6% to 12.9%. Within infected populations there were similar frequencies of DAV in *D. melanogaster* and *D. simulans*. The highest frequencies of DAV infection were found in the populations in ecologically stable environments.

Genome Evolution and Chromosome Organisation in the Genus Caledia

Investigators: D.D. Shaw, D. Colgan, M.L. Arnold, A.D. Marchant, B. Kohlmann, N. Contreras, and D. Willcocks

The Australian grasshopper, *Caledia captiva* is a species complex which exhibits one of the best cases of divergent chromosome evolution among the higher eukaryotes. Consequently, this species has been chosen as a model system to investigate (a) the molecular structure of the eukaryote chromosome, (b) the influence of chromosome change upon developmental processes during adaptation to seasonally fluctuating environments and (c) the genetic structure of populations as revealed by comparative molecular analyses.

During the past year, our investigations into the significance of genome reorganisation during evolution have been substantially improved by the inclusion of molecular techniques into our analyses. A series of diagnostic molecular and biochemical markers, which include mitochondrial, ribosomal and highly repeated DNA, enzyme variants and chromosomal rearrangements, have allowed us to effectively characterise most of the nuclear and mitochondrial genomes of two chromosomally divergent taxa.

Comparative analysis of the distribution of these markers across a very narrow zone of hybridisation has revealed that allozymes, ribosomal and mitochondrial DNA variations penetrate the zone up to 400 kms while its chromosomal profile is less than 1 km wide. Biogeographical analysis of the same region indicates that the hybrid zone has moved southward leaving behind the molecular and biochemical markers while retaining its very narrow chromosomal profile, despite persistent and prolonged hybridisation.

Using the enzymes and DNA restriction fragment length variants, we have obtained two biogeographically independent data sets which provide the clearest evidence yet that the structure of the genome, and its variability, performs a fundamental adaptive role during evolution which is probably independent of its gene content. In this case, the movement of the centromere on every member of the genome from distal to more medial locations, or vice versa, appears to provide the organism with an adaptive strategy for survival in unpredictable environments. The evidence we have obtained from both populational and laboratory analysis indicates that the concerted alterations to chromosome structure, by rearranging the position of the centromere, modify the rate of development during early embryogenesis. An acrocentric genome is thought to slow down the rate of cell division during early development and is adaptively superior to a metacentric genome in those geographic regions which are restricted to a single generation a year. Chromosomal polymorphisms exist as a consequence of the seasonal unpredictability of those environmental factors which govern the number of generations a year. These data suggest an independence between genic and chromosomal evolutionary processes and have important implications for the interpretation of chromosome evolution in other organisms. The analysis of restriction fragment length polymorphisms in the ribosomal DNA derived from hybrid populations has provided direct evidence of biased gene conversion events with the incorporation of donor DNA into the recipient genome at very high frequencies. Restriction enzyme analysis has shown that the conversion event within this multigene family is restricted to only a part of the spacer region between the 18S and 28S ribosomal genes. Whether or not this spacer DNA improves the transcriptional efficiency of the recipient is currently under investigation.

Movement of the centromere is a consistent feature of genome evolution, in addition to its essential role in chromosome segregation during cell division. Despite this, its molecular structure in higher eukaryotes remains unknown. We have initiated a series

this, its molecular structure in higher eukaryotes remains unknown. We have initiated a series of experiments to isolate, clone and sequence the DNA from the centromeric regions of *Caledia* chromosomes. One of the taxa within this species possesses chromosomes which are not flanked by the highly repeated sequences that characterise most other eukaryotes. We have adapted the techniques used in mammalian cell culture to obtain large numbers of isolated, intact metaphase chromosomes from rapidly dividing whole embryo cultures. By digesting the chromosomes with micrococcal nuclease, to remove nucleosomal arrays, we are now attempting to isolate and purify centromeric DNA with its associated kinetochore proteins and initiate an analysis of its molecular structure and pattern of organisation and distribution within the chromosome.

During these analyses, Dr Colgan has developed methods for cloning homologous sequences from target genomes after selection by probes bound to filter membranes. These novel techniques mean that, for the first time, it is feasible to clone low copy number sequences from multiple individual samples belonging to one or more species. The techniques are highly flexible and will have a major impact on DNA studies in population genetics and evolution and in medical and veterinary nosology. They will also be extremely useful in the cloning of protein-encoding sequences into expression vectors.

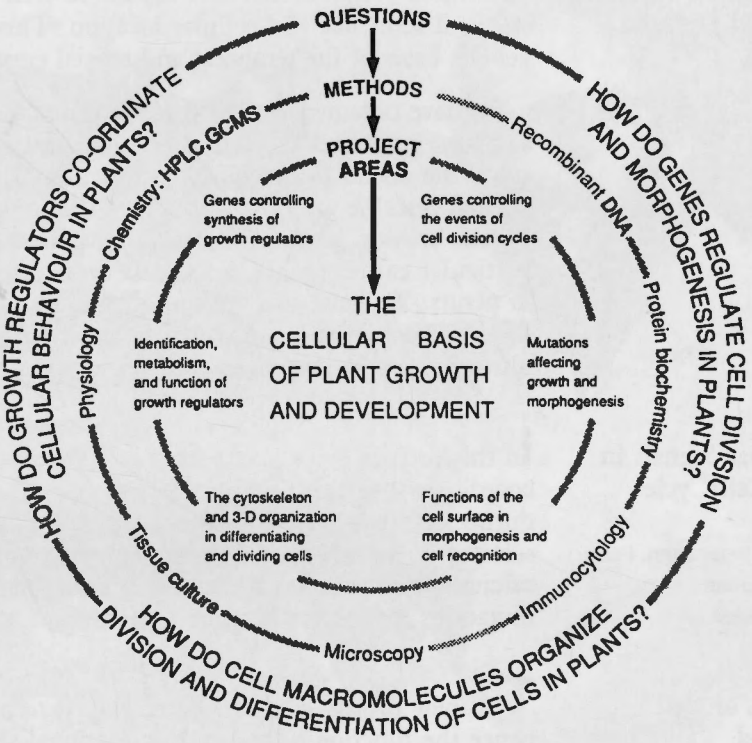
A project designed to investigate the coevolutionary interactions between the bacterial gut fauna and the various taxa of *C. captiva* has been completed. Surveys have revealed unprecedented amounts of genetic variation in the gut *Enterobacteria* and in the plasmids they harbour. These plasmids have potential to act as vectors of components of a pathogenic ds RNA virus of *C. captiva* for the control of *Locusta migratoria*.

PLANT CELL BIOLOGY

Introduction

The work of the Plant Cell Biology Group focuses on the cellular processes by which plants grow. These cellular phenomena are important because they underlie the development of the entire plant world. They are the basic means of generating all plant structures. The fundamental events are that new cells are added to a growing plant by cell division. The new cells enlarge and develop specific shapes and functions which, in aggregate, produce stems, roots, and leaves.

The Plant Cell Biology Group is structured so that staff members with complementary areas of expertise are able to interact and collaborate. Our common goal is to study the cellular basis of plant growth and development (see diagram). We co-ordinate our research programmes at three levels of enquiry, collaborating in each of these in a series of projects, described below. The key areas are at the level of genetic controls, the level of sub-cellular mechanisms of development, and the level of supra-cellular co-ordination in the plant.



Genetics and Molecular Control of Plant Cell Development

We first describe projects concerned with the genetic and molecular control of cellular development. Which genes are specifically concerned with development, what are their gene products, and how do they function? We exploit a unicellular plant, *Chlamydomonas*, because its cell division control genes can be mutated and because its cycle of cell division can be manipulated in the laboratory. A minute flowering plant, *Arabidopsis*, is increasingly being used because it presents opportunities for studying genes that regulate morphogenetic features of more complex plants. In both cases the main techniques are those of recombinant DNA research, protein biochemistry and immunology.

i Characterization of Plant Cell Cycle Genes

Investigators: Peter John, David McCurdy, Lok Palni, Jeremy Carmichael, Frank Sek, Janet Elliott

This project concerns the identification of genes that regulate cell division and the localization and functional analysis of their protein products.

A major development in the present year has been our detection, in plants from all taxonomic groups, of a "start division" protein, previously detected in yeasts only. The protein operates the major control point of the cell division cycle and commits a cell to DNA replication, mitosis and cytokinesis. The operation of a control in higher plants equivalent to "start division" was predicted from our earlier work on *Chlamydomonas*. It is remarkable that cell division control may use effectively the same "start" protein in all plant groups. The start protein is now seen to have been so strongly conserved that it shares the same antigenic determinants and retains the same molecular weight.

We are investigating the function of this important protein and the extent to which its presence correlates with the proliferation of plant cells. Its presence is being investigated in synchronously dividing cells, in tissues in which proliferation is regulated as part of a developmental program, and in tissues in which cell division can be regulated by added hormones. This broad approach is possible because of the diversity of complementary interests in the Group.

ii Co-ordination of Events in Plant Cell Division

Investigators: Peter John, John Harper, Frank Sek, John Wicks

Individual events of cell division are so well co-ordinated that they always occur in a standard sequence and cellular location. This investigation is aimed at elucidating the genetic basis of the temporal and spatial control systems.

We have obtained temperature conditional cell division mutants in *Chlamydomonas*, and have now back-crossed these to at least an F6 generation. We are thus able to study the effects of blocking the function of a single gene in an otherwise entirely normal cell. We are now identifying the functions of individual genes and, by making genetic crosses, are studying which events are normally triggered by the completion of particular earlier events. Such data on temporal sequencing are otherwise not available in plants. We have also optimized procedures for immunofluorescence microscopy of *Chlamydomonas* and can study the location of individual proteins as well as cell ultrastructure in normal and genetically blocked divisions.

iii Molecular Signals in the Plant Cell Cycle

Investigators: Peter John, Peter Jablonski, Suchirat Sakuanrungsirikul

In this project we examine the mode of action of molecules which we have found to coordinate initiation and termination of at least some of the many processes that occur during cell division. We concentrate on calcium ions and cyclic AMP, and use a selected set of cell division mutants in *Chlamydomonas* possessing altered responses to calcium and cyclic nucleotides. Selection methods have been developed to obtain mutations in calcium binding proteins and in the control of cyclic AMP.

iv Genetics of Cell Division and Morphogenesis in Roots

Investigators: Richard Williamson, Peter John, Peter Jablonski, Jacek Plazinski, Brian Gunning, Ursula Hurley, Lynn Croft

This new project concerns genes that determine the structural configuration and hence the function of roots. We are screening mutants of *Arabidopsis* that have been obtained in homozygous form by selfing. Particular attention is being paid to genes that influence the progress of cells through division, the orientation and limitation of cell division to establish multicellular tissues of precise shape and size, and the shaping and differentiation of cells. As well as identifying previously unknown genes that have been revealed by mutation we plan to introduce genes coding for proteins that are part of, or influence, the cell cytoskeleton, so that we can test for their functions in cell morphogenesis. In preliminary work we have determined the number and tissue expression patterns of isoforms of actin and tubulin in *Arabidopsis*.

v Calcium-binding Proteins in the Growth and Development of Higher Plants

Investigators: Peter Jablonski, Franz Grolig[#], Jacek Plazinski, Richard Williamson

Calcium regulates many facets of plant development. We are working to identify calcium-binding proteins in higher plants and to clone their genes from *Arabidopsis*. Calmodulin purified from pea shoots was used to raise a series of monoclonal antibodies. These recognise calmodulin in all higher plants tested and some antibodies recognise a protein of higher molecular weight in *Arabidopsis* and some other species. *Arabidopsis* will be exploited for gene cloning and mutational analysis to clarify the role of calcium in regulating higher plant development.

Intracellular Mechanisms of Development

At the next level of enquiry we look inside cells to examine structures that organize the processes of division and growth. Every cell has a "cytoskeleton", functioning as a microscopic framework that allows developmental events to be placed correctly in three dimensions, rather like a scaffolding for a building operation. The surface of the cell is also a key site in plant (just as in animal) cells. We investigate the components of the cytoskeleton and cell surface and study how they are used as subcellular tools in division, shaping, and differentiation of cells. The main techniques are sophisticated types of microscopy, protein biochemistry, and the use of specific antibodies with which particular proteins—notably the building blocks of the cytoskeleton—can be identified and located with precision inside cells.

PLANT CELL STUDIES
Dr Richard Williamson and colleagues in the Plant Cell Biology Group study plant morphogenesis and motility using the two unusual organisms pictured. Growing in the pots are mutants of the flowering plant *Arabidopsis thaliana* whose genetic alterations cause their roots to develop abnormally. Genetic and molecular analysis of the mutants, helped by the organism's unusually small genome, aims at understanding the process shaping the roots of this and other plants. Growing in the tanks are algae which contribute to the same goal. Because a single cell of *Chara corralina* can be bigger than an *Arabidopsis* root with its myriad cells, experiments involving 'cell surgery' are relatively easy with *Chara*. The results have implications for how all plants grow since many of the processes shaping these giant cells operate on a much smaller scale in the microscopic cells of flowering plants.

i The Cytoskeleton in Mitosis, Cytokinesis, Meiosis and Cell Growth

Investigators: Brian Gunning, Adrienne Hardham, Moira Galway, Ann Cleary, Mary Webb, Yoshinobu Mineyuki, Cathy Busby, Margaret Sammut, Geoffrey Wasteneys, Richard Williamson

We examined the phenomena of plant cell morphogenesis in a wide range of systems, selected for their capacity to illuminate the general principles of cytoskeletal function.

The main components of cell division—mitosis and cytokinesis—have been studied in living cells of *Tradescantia* stamen hairs using video microscopy enhanced through the use of newly-developed computer programs which operate on digitized video images. Influences of the preprophase band site on the process of cell plate formation have been detected, and several of the compounds synthesized by Dr Letham and his colleagues in their work on cytokinin growth regulators (see later) have been found to be potent inhibitors of cell plate completion.

The role of the cytoskeleton in establishing the complex intracellular dispositions needed to organize the two sequential divisions of meiosis, and the subsequent formation of haploid spores, have been comprehensively documented in the moss *Funaria* using immunofluorescence microscopy with antibodies to tubulin and microtubule organizing centres. A new study of meiosis and embryo sac development in *Arabidopsis* has begun.

Relationships between the orientation of microtubules and the geometry of cell growth continue to feature in the work of the Group, and have been examined in detail in two algae-giant cells of *Nitella*, and protoplasts of *Mougeotia*.

ii Dynamics of Microtubule Arrays in Plant Cells

Investigators: Adrienne Hardham, Moira Galway, Ann Cleary, Margaret Sammut, Cathy Busby, Geoffrey Wasteneys, Richard Williamson

Previous work has shown that microtubule arrays regulate many aspects of cell morphogenesis. We have now conducted several investigations on the problem of how cells develop their microtubule systems, making use of the sensitivity of microtubules in root tip cells, giant internode cells of *Nitella*, protoplasts of *Mougeotia*, and spores of *Funaria*, to depolymerization by the herbicide oryzalin. The pattern of recovery after removal of the drug has proved to be most revealing. Nucleation of microtubules occurs at discrete sites in some systems and dispersed in the cell cortex in others. Alignment of microtubules into organized arrays is a separate process, probably regulated by interactions involving other proteins.

The giant cells of characean algae allow many experiments to be performed which are impossible with microscopic plant cells, yet concern ubiquitous processes. One of the most promising developments during 1987 has been the discovery that these cells will incorporate exogenously supplied labelled tubulin into their cortical arrays of microtubules.

iii Microtubule-associated Proteins in Plant Cells

Investigators: Peter Jablonski, Richard Williamson, Ursula Hurley

Microtubules form several different arrays that perform diverse functions in plant cells. It is suspected that this versatility may be achieved through the specialized properties of various proteins that associate with tubulin during or after its polymerization into microtubules. Very little is known about such proteins, and we have started a number of approaches to detect and characterize them by: purifying fractions which affect the rate of polymerization of tubulin *in vitro* and which co-polymerize with tubulin; analysing isolated cytoskeletal preparations, before and after selective removal of microtubules; using labelled tubulin as a probe with which tubulin-binding proteins can be recognized; and identifying proteins from higher plant cells which are immunologically related to known microtubule-associated proteins. We have evidence for the existence of a considerable family of these proteins, and expect this project to yield much fundamental new information as it proceeds.

iv Monoclonal Antibodies to Cytoskeletal and Cell Surface Antigens in Plant Cells

Investigators: Brian Gunning, Richard Williamson, Peter Jablonski, Adrienne Hardham, Frank Gubler, Jadwiga Duniec, David McCurdy, Franz Grolig[#], Jan Elliott, Moira Galway

We have continued to exploit monoclonal antibodies made in previous projects, and have raised new and valuable antibodies for use in biochemical and cytological work on the cytoskeleton and cell surface.

Monoclonal antibodies raised against cytoskeletal preparations of the spermatozoid of *Pteridium aquilinum* detect components of the mitotic and cytokinetic apparatus in higher plants. One of them recognizes a glycoprotein that is secreted into the developing cell plate of dividing cells as well as mature cell walls. This antibody therefore has allowed us to investigate, using immunogold electron microscopy techniques, the intracellular pathway of secretion of glycoproteins in higher plants. Our findings indicate that part of this pathway may involve extensive arrays of multilamellar or multivesicular membrane structures. We are currently investigating the nature of these structures using high-pressure, rapid freezing techniques for ultrastructural observations.

Among other monoclonal antibodies obtained in new investigations are sets elicited by preparations containing microtubule associated proteins—to be used in the work described above, and sets elicited by surface and peripheral components of regenerating protoplasts of the green alga *Mougeotia*—to be used as probes to help elucidate the relationship between the microtubule cytoskeleton and cell surface components during cell wall formation.

We have continued to analyse actin and myosin of giant cells of characean algae. Only one isoform of actin can be identified and, in contrast to pea chloroplasts, it is not detectable inside *Chara* chloroplasts. A cytoskeletal preparation is being analysed that contains stabilised f-actin and microtubules together with various other proteins.

These include a 130 kDa protein shown by antibodies to be exposed on the outer surface of the plasma membrane.

v The Role of Cell Surface Components in Infection of Plants by Pathogenic Fungi

Investigators: Adrienne Hardham, Frank Gubler, Jadwiga Duniec, Janet Elliott

Surface molecules are involved in a number of aspects of the infection of plants by pathogenic fungi. The aim of this project is to determine the types of molecules occurring on the surface of fungal cells, and to elucidate their involvement in the early stages of infection of host plants. Our studies focus on the properties of the surface of the dieback fungus *Phytophthora cinnamomi*, which is one of the most destructive plant pathogens in Australia.

Adhesion is an important aspect of infection because it means the fungal cells are not washed away before they have a chance to colonize the plant. Monoclonal antibodies raised against fungal surface components have been used to characterise the adhesive material, and for the first time in any fungal infection, to determine its sites of intracellular storage and the timing of its secretion. We have expanded our collection of monoclonal antibodies to surface and intracellular components of the fungal cells, and have continued our investigations of the diagnostic properties of monoclonal antibodies raised against *P. cinnamomi*. We have also begun a project on the soybean pathogen, *P. megasperma* in collaboration with Dr Brett Tyler in the Plant Molecular Biology Group. Our aim is to generate mutants defective in stages of infection which involve fungal surface components.

Growth Regulators in Plant Development

The third approach in the Group deals with integration of development in the plant by means of growth regulating molecules. Chemical signals move from cell to cell and organ to organ, phasing in and phasing out the successive steps in developmental sequences, from germination to senescence. Part of this work involves identification of biologically-active substances that are present in minute quantities in plant tissue, and characterization of their translocation and metabolism in relation to plant development. Our research concentrates on cytokinins, phytohormones implicated in control of cell division and many aspects of plant development, including leaf senescence. Studies of cytokinin biosynthesis, translocation and metabolism were continued in order to gain new insight into hormonal controls, using the following experimental systems:

a sequential leaf senescence in tobacco (Santokh Singh, Stuart Letham, Lok Palni, Bill Parker)

b monocarpic leaf senescence in soybean (Santokh Singh, Stuart Letham, Bill Parker)

c germination of lupin seeds (Shyamal Nandi, Lok Palni, Stuart Letham)

d cell division in cultured plant tumour tissues (Shyamal Nandi, Lok Palni)

e organ development in cultured tobacco stem pith (Lok Palni).

Five new projects commenced in 1987. These and two selected major projects are outlined below.

i Cytokinin Receptors in Plant Cells

Investigators: Stuart Letham, Zhang Xue-Dong

A major new project was commenced during the year. The objective is to identify the cytokinin receptor in plant cells, that is, the molecular species to which cytokinin binds to evoke a growth or physiological response. For this project radioactive cytokinin analogues suitable for photoaffinity labelling are required and much of the year was occupied by work on their chemical synthesis.

ii Transfer of Genes for Cytokinin Biosynthesis to Higher Plants

Investigators: Zhang Ren, Stuart Letham, T.J.V. Higgins +

Another new project concerns transfer of genes for cytokinin biosynthesis to higher plants and is a joint activity with Dr T.J. Higgins in the Division of Plant Industry in CSIRO. The aim is to genetically modify photosynthetic capacity, senescence characteristics and ability to undergo cell division. The *ipt* gene for cytokinin biosynthesis with its own promoter has been transferred from T-DNA of *Agrobacterium tumefaciens* to tobacco. This gene would be expected to be expressed in all tissues. Work is in progress to replace this endogenous promoter with promoters from other genes to give tissue-specific expression of the *ipt* gene.

iii Cytokinins and the Rhizobium—Legume Symbiosis

Investigators: Stuart Letham, Bill Parker, Narayana Upadhyaya, Kieran Scott, Peter Dart

When *Rhizobium* strain IC 3342 forms nodules on pigeon pea, it causes leaf curl (see 1986 Report pg 26). Workers in the Plant Molecular Biology Group have characterized the phenomenon genetically. Joint work with this Group has now shown that the xylem sap of plants bearing nodules formed by strain IC 3342 has greatly elevated cytokinin levels. Cytokinin supplied exogenously to the xylem of pigeon pea induces symptoms which resemble the curl phenomenon and thus this appears to be at least partly a consequence of cytokinin overproduction. In a major advance, a genetic locus has now been recognised (Upadhyaya, Scott and Dart) which results in the overproduction of cytokinin.

iv Enzymic Inactivation of Cytokinins

Investigators: Lok Palni, R. Horgan +, L. Burch +

Cytokinin oxidase is an important enzyme in cytokinin metabolism as it completely inactivates some natural cytokinins. In collaborative research with overseas workers it has now been shown that the activity of this enzyme *in vitro* is enhanced by another plant hormone (auxin). A similar *in vivo* effect of auxin on cytokinin stability and metabolism has previously been demonstrated. This is a significant finding because the two hormones have long been known to interact and are used in combination in culture media for plant tissue culture and micropropagation. Cytokinin oxidase may provide a biochemical site at which their joint effects are mediated.

v Growth Regulators in Humic Acids

Investigators: Lok Palni, J.K. MacLeod †

Previous work in the Group had a considerable commercial impact by showing that seaweed preparations used as fertilizer contain growth regulators. A new project concerns the identification of growth promoting substances in humic acid, a preparation widely used in agriculture, and available in large quantity as a by-product of the Victorian coal mining industry.

vi Translocation of Cytokinins in Lupin Species

Investigators: Stuart Letham, Zhang Ren, Paula Jameson, Bill Parker

The view that root-produced cytokinin moves in the xylem to the shoot where it regulates development and senescence is a widely accepted concept in developmental botany. Hence it is paradoxical that studies of the distribution and metabolic fate of cytokinins moving in the xylem are very few. Previous studies have little physiological significance for several reasons. In studies of cytokinin transport in the xylem, it is obviously important to first identify the endogenous xylem cytokinins and then to introduce radioactive analogues of these natural compounds in physiological concentrations directly into the xylem. During the year, such a study with lupin plants, commenced in 1980, was completed. Features of the study include: (1) the high proportion of the xylem cytokinin which was retained in the stem; (2) direct lateral movement of cytokinins from xylem to bark; (3) the lack of appreciable movement to the seed even over a prolonged period; (4) the disproportionate retention of cytokinin by the petioles, which increased with leaf maturity; (5) changes in metabolism in leaf laminae associated with senescence; (6) the conservation of a proportion of xylem cytokinin in leaf laminae as O-glucosides and alanine conjugates; (7) the detection of a new nucleotide metabolite of cytokinin in pod walls, bark and lateral shoots which has been partially identified; this is a transient metabolite with an intact zeatin riboside moiety and appears to be important in cytokinin uptake and transport. These studies of cytokinin translocation and metabolism are relevant to

sequential leaf senescience, lateral shoot development, the proposal that developing seeds accumulate xylem cytokinins, and the origin of phloem cytokinins.

vii Positional Control in Plant Development

Investigator: Pamela Warren Wilson#

One of the most baffling areas of research on growth regulators concerns "positional information" in plants. This project has successfully documented two systems in which the spatial patterns of differentiating tissue can be modified experimentally by growth regulator treatments, with predictable results.

Explants of lettuce pith will develop tracheary elements if given appropriate concentrations of auxin, but little attention has been paid to the positioning of this cell differentiation. Studies this year have shown that it occurs in strands whose direction is probably determined by the direction of auxin flow away from localized application sites. The second system concerns the position at which organs develop abscission sites. Previous work established the importance of auxin concentration in determining the site. New work underlines the importance of auxin in positional control, and shows that another regulator that is often implicated in induction of abscission—ethylene—lacks position determining properties, but merely affects the frequency of abscission.

PLANT MOLECULAR BIOLOGY

Introduction

The research of four of the five laboratories aims to increase our understanding of the ways that plants interact with microbes and either restrict or control infection by them. The other laboratory is developing computerized databanks of information about plants.

This research is not merely of theoretical interest but of considerable practical potential. For example, the plant-microbe studies are providing information that may be used to design strategies for controlling plant pathogens, and for fostering beneficial plant-microbe interactions. It is probable that there are only a limited number of ways in which plants react to invaders, thus by studying and comparing the responses induced by different microbes, it will be possible to distinguish between the basic pathways of plant response, and those factors which modulate responses to individual microbial pathogens and symbionts. The interactions of plants and

Mr Shouwei Ding a Ph.D student in the Plant Molecular Biology Group celebrates having determined the complete genomic nucleotide sequence (6221 nucleotides) of ononis yellow mosaic tymovirus. Mr Ding, who is in the 2nd year of his course comes from the Anhui Agricultural University, Hefei, People's Republic of China. Members of the Group have recently completed the genomic sequences of three tymoviruses as part of a project to understand the molecular basis of the host range preferences of different viruses of plants.

representatives of three groups of microbes are being studied; bacteria, fungi and viruses. Work with *Rhizobium* species, which nodulate legumes and some non leguminous plants, is rapidly unravelling the molecular signals and sensors that enable plant hosts and bacterial symbionts to establish mutually beneficial relationships. Work is progressing well on the molecular analysis of gene control and plant infection by the fungi, *Neurospora* and *Phytophthora*. Finally, work on viruses of the tymovirus group is establishing the genetic pathways by which this group speciated, and hence acquired distinct host ranges; knowledge that is a prerequisite for understanding the molecular basis of host range differences.

Molecular Evolution of Plant Viruses

Investigators: Adrian Gibbs, Shou-wei Ding, Jennifer Howe, Paul Keese, Anne Mackenzie, Drew Meek, Marlene Osorio-Keese, Marjo Torronen and Xue-juan You

The molecular evolution of the tymoviruses is being studied. Initially the genomes of several viruses of this group are being sequenced and compared. This information will provide clues on:

- the pattern and rate of evolution of this virus group, and the role of mutational drift and recombination in that evolution;
- the way in which some viruses with RNA genomes maintain genetically stable populations, given the poor fidelity of RNA replication;
- the molecular basis of the host ranges and virulence of viruses and how these traits may be manipulated.

In 1987 the genomic sequences of the Club Lake isolate of turnip yellow mosaic virus (TYMV), of eggplant mosaic virus and of ononis yellow mosaic were determined. The sequences of large parts of the genomes of a Blue Lake isolate and the European type strain of TYMV, of Andean potato latent virus, of three strains of Kennedya yellow mosaic virus were also obtained, and a significant start made on determining the genomic sequences of dulcamara mottle virus and the cauliflower isolate of TYMV.

Each genome consists of single-stranded RNA 6214-6331 nucleotides in length. All show significant similarities, both in nucleotide sequence and in the predicted encoded amino acid sequences. The predicted sequences confirm the results of *in vitro* translation studies showing that the genome of TYMV encodes a large polyprotein of about 1800 amino acid residues and a 3′ terminal coat protein gene. In addition, each genome has an unexpected overlapping open reading frame at its 5′ terminus, which encodes a protein of about 600 residues; the amino terminal portions of the non-coat proteins are similar, but the carboxy terminal portions are not. Sequence comparisons of the region of the polyprotein containing the "GDD" motif show that the tymoviruses are distant members of the virus supergroup that contains the tricornaviruses, tobamoviruses and tobraviruses of plants, and the alphaviruses of animals.

A comparison is being completed of the genomic sequences of two Australian TYMV isolates that produce distinct symptoms; one from Club Lake and the other from Blue Lake of the Kosciusko Alpine area. Biogeographical and ecological studies have indicated that TYMV probably spread to Australia from Europe more than 10–12 thousand years ago, and the Club and Blue Lake populations became separated approximately 8,000 years ago. There is an average difference between these isolates of 1.5% in their nucleotide sequences and of 1.1% in the predicted amino acid sequences. The two sequences have similar nucleotide homologies in their coat protein-coding and polyprotein-coding regions, however the predicted amino acid sequences of the polyproteins differ by only 1% whereas those of the coat proteins differ by 1.6%. In all, about one third of the genomic sequence of the European type strain TYMV is available, and differs, in comparable regions, from both Australian isolates by 5.3%, whereas they differ from one another in the same regions by only 1.2%. Thus the biogeographical conclusions outlined above are confirmed, and it is

likely that Australian TYMVs separated from the European population about 30 thousand years ago.

Field samples of *Kennedya rubicunda* plants showing virus symptoms were tested by a wide range of assay techniques including 'dot immuno-binding' and 'dot blot hybridization'. It was found that clear yellow mosaic symptoms were always associated with the presence of kennedya yellow mosaic tymovirus, whereas symptoms of mild marbling mosaic or general chlorosis were not. A combination of agarose electrophoresis and 'dot immuno-binding' assay made it possible, for the first time, to distinguish between electrophoretically distinct strains of KYMV directly in sap from field samples

Molecular Analysis of Rhizobium—Plant Interactions

Investigators: Barry Rolfe, Michael Djordjevic, Murali Nayudu, Jacek Plazinski, Greg Bender, Steven Djordjevic, Hancai Chen, Brant Bassam, Lucy Sargent, Jim Gray, Alan Richardson, Shizhen Huang, J.J. Weinman, J. McIver, J. Miller, A. Moten, K. Le Strange, J. Bolten-Gibbs, L. Currie, T. Brown, E. Gartner, M. Oakes, R. Taylor, T. Arioli, W. Lewis

Work has concentrated on the early events of colonization and infection of the roots of legumes and the non-legume *Parasponia* by *Rhizobium*, a soil bacterium.

Eleven genes have been identified as being involved in clover nodulation and these are clustered in a 14kb DNA portion of the Sym plasmid of the clover infecting *Rhizobium trifolii* strain ANU843. They are arranged in four separate operons (nod*ABCIJO, nodD, nodFEL* and *nodMN*), as judged by DNA sequence analysis, Tn5-induced mutagenesis and expression data using *nod* genes fused to the *E. coli lacZ* gene. The expression of these nodulation (*nod*) genes is activated by the product of the *nodD* gene in the presence of plant secreted flavonoids (phenolic compounds of low molecular weight). The expression of the *nodABCIJO, nodFEL* and *nodMN* genes is regulated by conserved DNA sequences which occur 5′ to these *nod* gene operons.

Extracts from white clover seedlings contained three active components which could induce *Rhizobium* containing *nod:lac* fusion genes. These stimulatory substances were identified as the flavones, 7,4′-dihydroxy flavone (DHF); 4′-hydroxy-7-methoxy flavone and 4′,7-dihydroxy-3′-methoxyflavone (geraldone)). In addition, two other substances were found to antagonise *nod* gene induction by stimulatory flavones when present at concentrations about 3 to 4 times the level of the active flavones. These compounds were identified as the isoflavone formononetin and 7-OH coumarin umbelliferone. Furthermore, these *in vitro* experiments showed that the activation of nod genes is determined by the ratio of stimulator to inhibitor (S:I). The inhibitory mechanism appears to be competition for the *nodD* product.

Three different types of mutants of *R. trifolii* with an altered pattern of regulation of their *nod* genes have been isolated in the last year. One mutant, NC8, shows an elevated response to various added flavone compounds. This mutation is not of the Sym plasmid but is elsewhere in the genome; it is possible that the phenotype may more easily take up stimulatory signals from plants.

Another group of mutants strongly and constitutively express the *nodABCIJO* operon and have been identified as being *nodD* mutants. All the *nodD* mutants obtained can still complement different *nodD* mutants of *R. trifolii* for clover nodulation. Some of these mutants are stimulated by compounds, such as coumarin, umbelliferone; isoflavones, biochanin A, daidzein and formononetin which inhibit the parental strain and are inhibited by the previous stimulatory compounds, 7,4′-dihydroxyflavone, chrysin, naringenin and luteolin.

Mutants of the third type weakly express the *nodABCIJ* operon and preferentially respond to specific flavones. Careful analysis of these mutants by DNA sequence analysis has shown that the ability of the *nodD* gene product to interact with plant secreted flavonoids is influenced by the amino acid sequence in several regions of it.

Split root assays also have been used to examine the initial events of subterranean clover infection. Mutants derived from *R. trifolii* strain ANU843 were used to

infective *Rhizobium* strains. The ability to invade root hairs was required to initiate the plant inhibitory response. Moreover, plants could discriminate between infections initiated by the parent strain or by mutants subtly impaired in their ability to nodulate. In addition, the split-root assay was successfully used to compare the competitiveness of various rhizobia.

Pre-exposure of some poorly-competitive strains to the flavone plant signal for 4 hours enabled them to out-compete a normally more successful strain. The findings support our earlier results which showed that the most competitive strains express their nodulation genes and initiate root hair invasions before their less competitive cousins. Furthermore, the studies using the split root assay, have indicated that *Rhizobium* has host range genes *(hsn)* which are important in the early steps of infection of the plant. These genes probably "pacify" the plant so that it does not reject the invading *Rhizobium* cells.

The *Rhizobium*-clover symbiosis is known to be sensitive to low pH and associated acid soil factors and this possibly contributes to the reduced productivity of clover-based pastures on acid soils. Currently we are investigating the effect of low pH on the early events in the formation of nodules on clover roots by "acid tolerant" and "acid sensitive" strains of *Rhizobium trifolii*.

SOYBEAN ROOTS SHOWING DIFFERING ABUNDANCE OF NITROGEN—FIXING NODULES INDUCED BY SYMBIOTIC ASSOCIATION WITH *RHIZOBIUM* BACTERIA

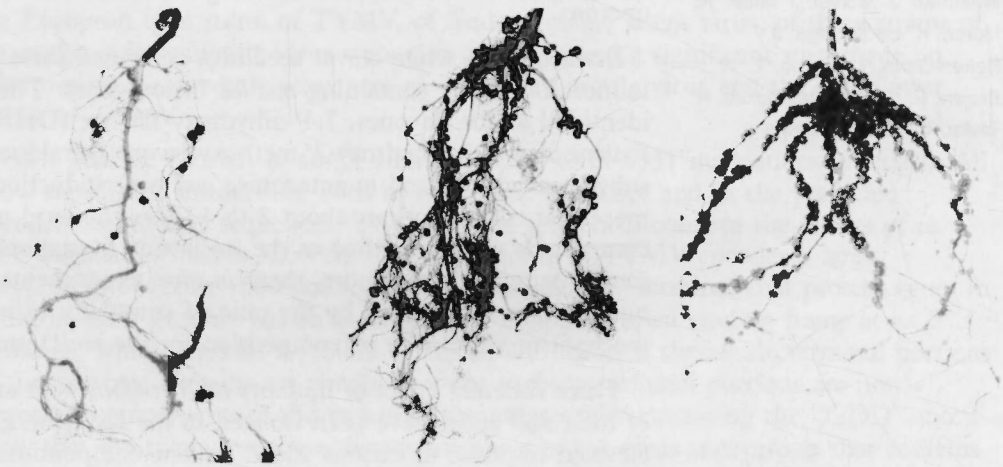
1. *Glycine max* (Soybean) wild type cultivar Bragg

2. Cultivar Bragg nts-1116. A plant mutation which has increased nodulation ability

3. Cultivar Bragg nts-1007. A super nodulating plant mutant

In each case the plants have been inoculated with competitive *Rhizobium* strains native to China identified at RSBS. This work is supported by an Australian Government Section 39 Public Interest grant. The Department of Botany, Faculty of Science, is collaborating on the project.

The project's objective is to develop a new variety of Soybean and an appropriate *Rhizobium* inoculum which will give a better yield.



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There are at least two reasons why acid sensitive rhizobia may be unable to form nodules in acidic environments.

Either:

1 the plant does not produce flavones under such conditions, or,
2 the bacterium is unable to respond to the presence of flavone at low pH.

Since flavones are present at the critical pH's for nodulation (pH 4.5), low levels of *nod* gene expression suggest that the inability to initiate nodules at these criitical pH's is largely a bacterial problem. Moreover, the observation that acid tolerant strains of *R. trifolii* can express nodulation genes at lower pH also supports this hypothesis.

We have mutated with the transposon Tn*5* an acid tolerant *R. trifolii* strain, recently isolated by Dr Rod Roughley, and have located 3 different loci involved in the acid tolerance phenotype. One of these genes is located in a plasmid and the other two loci are in the bacterial chromosome. The plasmid gene has now been cloned and characterized by restriction enzyme analysis. When this gene was transferred back to the mutant its acid tolerance was restored.

Molecular Genetics of Bradyrhizobium sp.Parasponia

Investigators: Kieran Scott, Layne Huiet, Heather Kane, N.M Upadhyaya, Sukrita Chakrabarti, Peter Thygesen, Phillip Williamson, Joanne Stanton

Highlights of our research this year have been to:

- identify six genes (*nodLMN* and *nodPQR*) in *Bradyrhizobium parasponia* that are potentially involved in legume and/or nonlegume host specific interactions;
- construct mutants in *B. parasponia* with accelerated nodulation and nitrogen fixation in *Macroptilium atropurpureum*;
- identify a locus in *Rhizobium* strain IC3342 which when transferred to a non-pathogenic *Rhizobium* strain enables it to cause systemic pathogenesis when nodulating *Macroptilium atropurpureum*. This locus contains a potential regulatory gene with homology to the *ompR* gene of *E.coli*;
- initiate a programme to identify determinants for the host-specific nodulation of Australian native *Casuarina* species determinants from the actinomycete *Frankia*.

The Molecular Studies of Gene Control and Plant Infection by Fungi

Investigators: Brett Tyler, Wendy Thompson, Yuguang Shi, Areelak Kashemsanta, Yuxin Mao, Karin Harrison and Barbara Austin

The first aim of this project is to understand how cells co-ordinate the activities of the genes encoding the protein synthesis machinery—the ribosomes. There are nearly 500 of these genes and their expression is complex, involving three different RNA polymerases. We have used the fungus *Neurospora crassa* to look for DNA sequences capable of co-ordinating the transcription of ribosomal genes from each of the three main groups—the large (40S) ribosomal RNA genes (transcribed by RNA polymerase I), the ribosomal protein genes (RNA polymerase II) and the 5S ribosomal RNA genes (RNA polymerase III). In 1987 we have:

i obtained definitive evidence that two specific DNA sequences, called the TATA-box and the D Box, are both required for the expression of two groups of the ribosomal genes, the large rRNA genes and the 5S rRNA genes;

ii cloned and sequenced a ribosomal protein gene to determine if the third group of ribosomal genes also requires a TATA box and D box;

iii initiated experiments looking for the regulatory proteins involved in the function of the TATA box and D box.

This year we have also started a project—with the assistance of Dr A. Hardham (Plant Cell Biology) and Dr B. Rolfe—to study the genes which determine how the fungal pathogen *Phytophthora megasperma* infects soybeans and how it evades detection by the plant's defence response. So far we have:

i developed a new drug resistance gene (against the antibiotic bleomycin) to help us introduce cloned DNA into *Neurospora* and *Phytophthora*;

ii produced *Phytophthora* protoplasts for genetic studies and transformation experiments;

iii developed a new rapid assay for determining *in vitro* whether different soybean cultivars are resistant to particular races of *Phytophthora megasperma*.

Computerised Data Banks for Grasses, Sedges, Legumes and Angiosperm Families

Investigators: L. Watson, M.J. Dallwitz+, J.B. Bruhl, C.R. Frylink and S. Perry

In a project commenced in 1970, we have developed a computerised data bank of morphological, anatomical, physiological and geographical information on grasses, which was extended in 1987 to incorporate data on over 400 characters, recorded for 750 genera. Significant additions this year included extensive original biochemical and associated anatomical data (Prendergast, Hattersley* and Stone) on variations in photosynthetic pathways, obtained in the Taxonomy Lab, and comprehensive information on floristic-regional distributions provided by B.K. Simon (Division of Primary Industries, Queensland). 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 in microcomputers. The data are being used for continuing studies of grass classification; in preparing an account of the grasses of Southern Africa, in collaboration with G.E. Russell which will be extended there to species level; and in producing a book on the grass genera of Greece (in collaboration with M. Damanakis[1]).

A complete, operational data base for the 177 genera of Leguminosae Caesalpinioideae is also maintained; another for the families of Angiosperms (which now contains a complete, automated classification) is being developed as time permits; and one for the genera of Cyperaceae is in preparation, as background for a study of the taxonomy of sedges with special reference to variation in photosynthetic pathways.

The Virus Identification Data Exchange (VIDE) Project: A Databank for Plant Viruses

Investigators: Alan Brunt#, Cornelia Buchen-Osmond#, Karen Crabtree, Michael Dallwitz+, Adrian Gibbs, George McLean+ and Les Watson

The VIDE project is assembling a database of information of value for virus identification for all the plant viruses of the world. This collated information is being distributed, as books and by computer methods, to aid plant virus identification, especially in developing countries. The data is handled by the DELTA taxonomic database system.

During the year work has concentrated on compiling information on plant viruses identified in Australia, on viruses of legumes, and viruses of tropical crop plants. The main database now contains detailed information of over 400 viruses, and its format was completely revised during the year.

Systematic Studies of Plant Structure and Function

Investigators: Hew Prendergast, Vindhya Amarasinghe, Jeremy Bruhl, Nancy Stone, Paul Hattersley* and Leslie Watson

A long term interest of the Taxonomy Lab is trying to enhance understanding of plant structure/function relationships, by application of taxonomic expertise; and conversely, to extend taxonomic knowledge by using the new insights obtained. Our newly discovered structural/biochemical associations in grass leaves, which are of fundamental interest in connection with variations in photosynthetic pathways were published in 1987. These have important implications for arid and semi-arid grassland research programs; and marked 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*.

Microhairs are minute structures of critical taxonomic interest, occuring in large numbers on the leaves of many grasses. Some of them are known to be salt glands and all of them may be important in water relations, but few have been studied in any detail. In a current project, ultrastructural studies have shown that some 'chloridoid type' microhairs have intricate systems of partitioning membranes in their basal cells, while others (for example, in *Eragrostis*) do not. The microhair forms well known to light microscopists are thus only partially informative about ultrastructural type, and hence may be misleading about functions.

PLANT ENVIRONMENTAL BIOLOGY

Introduction

The Plant Environmental Biology Group comprises three interacting themes. Two of them, Biochemistry and Physiology of Photosynthesis, and Plant Physiological Ecology, are long standing. They explore the nature of biochemical and physiological processes in plants adapted to diffeent environments. There is concentration on the process unique to green plants, photosynthetic carbon fixation. The third theme, Molecular Analysis of Plant Performance, also concentrates on this, but is a relatively new development employing the techniques of molecular biology to analyze and make use of the genetic basis of variation in photosynthesis in plants.

Biochemistry and Physiology of Photosynthetic Processes

Investigators: Barry Osmond, Ichiro Terashima, Kam Chau Woo, Jian Wei Yu, L.K. Huang, John Evans+ and W.S. Chow+

Study of the photosynthetic processes continue to proceed at levels ranging from the chloroplast to the response of the intact leaf. These have given great insight into the ways in which metabolic events are organised in the chloroplast, and how they respond to external environmental influences, such as light and temperature, that are so important in determining the ability of a plant to grow in different environments. Investigations may be grouped into the following topic areas:

a Metabolite Transport Across the Chloroplast Envelope

The communication between the chloroplast and the cytosol is of vital importance to the integration of chloroplast metabolism into the growth processes of the plant. Intact chloroplasts from oat leaves have been used to study the transport of a number of metabolites accross the chloroplast envelope (Yu and Woo). The results to date indicate the presence of three distinct translocators for dicarboxylate transport: (1) a general dicarboxylate carrier; (2) a 2-oxoglutarate carrier; and (3) a glutamine translocator. The role of the glutamine translocator during photorespiratory NH_3 reassimilation is being examined further.

b The effects of light, nitrogen and low temperatures on photosynthesis

The development of chloroplasts within a leaf is affected by both growth irradiance and the level of nitrogen nutrition. This has been studied with spinach plants (Terashima and Evans), where it has been found that the number of thylakoids per granum stack and the ratio of cross sectional area of granum to stroma increased with depth from the upper surface across single leaves and with a decrease in growth irradiance. However, the absolute number and the intra-leaf gradients of these parameters were not affected by nitrogen status. The cross sectional area of the chloroplast was constant among cell layers in the same leaves, but was larger the greater the nitrogen level and/or the lower the irradiance during growth. The leaves of such large chloroplasts tend to show a lower efficiency of *in vivo* rubisco activity, probably due to a larger liquid phase resistance to CO_2 transfer.

Low temperatures combined with excess light energy can combine to cause damage to the photosynthetic processes. The cause for this has been studied in spinach (Osmond, Chow, and Huang), where *in vitro* and *in vivo* studies at 25° and 10°C suggest that loss of the atrazine binding D1 protein of the PSII reaction centre complex is unlikely to be the primary cause of photoinhibition in thylakiods and leaves. Whereas the loss of photochemical reaction centre PSII function (flash yield of O_2–evolution) closely follows changes in 77°K fluorescence during photoinhibition, the loss of atrazine binding sites at 10° is much slower. During temperature dependent recovery in weak light, increases in 77°K fluorescence and O_2 flash yield are not accompanied by restoration of atrazine binding sites.

Rice cultivars differ significantly in their sensitivity to chilling temperatures and understanding the basis for these differences is of agronomic importance in extending the growing range of rice varieties. In an ACIAR sponsored project, in collaboration with CSIRO Food Research and Chinese Institutes, Huang and Osmond have established varietal differences in the sensitivity to chilling temperatures in rice leaves,by means of chlorophyll fluorescence (77°K) and the quantum yield of photosynthetic O_2–evolution. Chilling in the dark has no effect on these parameters, but depending on the variety, chilling temperatures exaggerate normal light dependent changes in fluorescence and quantum yield. However, chilling temperatures at night reduces the normal recovery of these light dependent changes.

NEW EQUIPMENT INCREASES OUTPUT

Members of the Plant Environmental Biology Group pictured with the School's new ratio mass spectrometer (l. to r. Suzanna von Caemmerer, Kerry Hubick, Wes Keys, Frank Fox, Chin Wong, Graham Farquhar, Derek Millar and Sue Wood)

The new instrument, a V.G. Isogas SIRA-24 is integrated with a CARLO ERBA elemental analyser. Under computer control, the system enables automatic analysis of organic materials up to five times faster than before.

Graham Farquhar's lab use the equipment to measure carbon isotope ratios in plants. This ratio, he has discovered, provides information about plant water use efficiency. His research program aims to define criteria relevant to competative success of particular species. Eventually it is hoped that this work will help plant breeders develop plant varieties which use water more efficiently.

Plant Physiological Ecology

Investigators: Graham Farquhar, Ian Cowan, Ralph Slatyer, Susanne von Caemmerer, Kerry Hubick, Chin Wong, Pam Ferrar, David Bagnall, Wesley Keys, Win Coupland, Frank Fox, Peter Groeneveld, Derek Millar, Sue Wood, Marilyn Ball +, Enrico Brugnoli +, Josette Masle +

This program is designed to understand the adaptations in plants which facilitate photosynthetic carbon fixation in various conditions of resource availability. It aims, thereby, to define criteria relevant to the competitive success of particular species in natural ecosystems, and the selection of crop varieties suitable for cultivation in particular agricultural environments.

a Water Use Efficiency

Of primary interest is the compromise made in terrestrial plants between carbon fixation and water use. In our studies of tropical mangroves, we find that the compromise is influenced by salinity, and temperature. Mangroves are increasingly conservative in water use the greater their tolerance to salinity, and this tends to engender leaf temperatures that are supraoptimal for photosynthesis. Characteristics of leaf size, orientation and thickness have been shown to contribute to maintenance of near optimal leaf temperatures with minimal evaporative cooling in a way which makes an instructive illustration of the accommodation of a number of conflicting selection pressures.

Much of our experimental work on carbon fixation and water use has centred on the use of a technique involving measurements of trace amounts of the naturally-occurring stable isotope ^{13}C in plant tissue. There is less ^{13}C in plant tissue than in the atmospheric carbon dioxide available for fixation. We have shown that this discrepancy, or discrimination, depends on the properties of both photosynthetic metabolism and of stomata, the pores in leaves that admit CO_2 while unavoidably allowing the loss of water. In plants with the common, C_3, pathway of photosynthesis, the discrimination is negatively correlated with the ratio of photosynthesis to stomatal conductance, and, therefore, with the ratio of accumulated dry matter to water consumption. This year, in collaboration with CSIRO, we extended previous observations with crop plants to include sunflower, a source of vegetable oil in Australia. As with the other species we have investigated (peanut, wheat, barley, cotton), we have demonstrated that there is considerable genetic variation in water-use efficiency. In cooperation with the Department of Forestry, ANU (A. Gibson and E. Bachelard) we also found that variation occurred among provenances of the river gum, *Eucalyptus camaldulensis*. Plants grown from seeds collected in different regions of the country had water-use efficiencies that differed and these efficiencies were negatively correlated with carbon isotope discrimination. This is of ecological and practical interest. The use of *Eucalyptus camaldulensis* and other species as fast-growing sources of pulp production is becoming widespread.

Water-use efficiency is influenced by growth conditions. Using sunflower and barley, we have confirmed our earlier observations with other species that water stress increases water-use efficiency. Reduced soil nitrogen availability reduces efficiency in *E. camaldulensis* and in peanuts. Mild salt stress and increased soil strength increase efficiency in barley. Whenever we have discovered variation in water-use efficiency, we have also found that it is negatively correlated with discrimination.

Measurement of carbon isotope discrimination can provide information about leaf gas exchange over quite short periods of time. With a visiting scientist from Italy (Brugnoli) we have demonstrated that gas exchange parameters integrated over a single day are correlated with the $^{13}C/^{12}C$ ratio of starch and sucrose produced in that day.

We hope that measurement of discrimination in freshly synthesized carbohydrate will enable workers in the field to determine how plants are responding on time scales that are shorter than those required for production of leaves, yet sufficiently long to average the effects of fluctuations in light and temperature that occur naturally during a day.

Determinations of carbon isotope discrimination also assist in our more fundamental studies of photosynthetic metabolism. We have improved our technique of measuring discrimination over periods of several minutes to hours, and have used it to investigate functioning in species which are intermediate between those having the C_3 pathway of photosynthesis only, and those having the C_4 pathway which, by virtue of its ability to operate at low intercellular concentrations of CO_2, is generally accompanied by greater water-use efficiency. The results are consistent with a biochemical model we have developed to account for the characteristics of photosynthesis in C_3–C_4 intermediates.

We have been concerned with spatial variation in stomatal characteristics and its influence on exchange of CO_2 and water vapour on two scales. It has been shown that stomatal closure in leaves supplied with abscisic acid (a hormone believed to modulate stomatal response to plant water stress) is "patchy", and that previous observations that abscisic acid affects leaf photosynthetic metabolism are probably artifacts arising from a consequential misinterpretation of gas exchange measurements. The finding suggests that many experiments on the influence of water deficiency and other stresses on leaf metabolism may need to be reassessed.

The second scale encompasses variation in land management. As air passes over crops having different surface properties relating to water loss, readjustments of humidity and temperature take place. Theoretical models of the processes are being developed in order to predict the potential improvement in water-use efficiency on an agricultural scale associated with the use of crop genotypes having tighter stomatal control of water loss.

While photosynthetic metabolism continues to be of fundamental interest, we are becoming increasingly concerned with the interrelationship of photosynthetic processes with plant carbon metabolism and plant growth as a whole. Conditions in which the capacities for carbon assimilation, carbohydrate translocation, and synthesis of compounds for growth appear to be mismatched are of especial interest. Our studies of the responses of crop plants to enhanced atmospheric concentration of CO_2 suggest that many species will not take full advantage of the potential for increased assimilation in the changing global environment. Increase in rate of assimilation is accompanied by a massive increase in the amount of tran-structural carbohydrate. We intend to investigate the limitations inhibiting the conversion of this pool of photosynthate into other plant compounds.

Other studies involving interactions between assimilation and growth have been to do with the functioning of seedlings in compacted soils carried out in collaboration with a visitor from France (J. Masle), and of fruit development in peanut as influenced by low temperature, carried out in collaboration with associates in CSIRO.

b Temperature acclimation of the photosynthetic response of *Eucalyptus* species from diverse habitats

The ability of *Eucalyptus* to acclimate to changes in growth temperature has been investigated and the results compared with *Nerium oleander*, a shrub adapted to grow over a wide range of environmental conditions and which experiences large seasonal variations in temperature at particular sites, during the growing season. The *Eucalyptus* species investigated were *E.pauciflora* (Perisher Valley treeline—Lat. 36.5°), *E.pauciflora* (Waste Point—Lat. 36.5°), *E.incrassata* (Vic—Lat. 35.65°), *E.camaldulensis* (Vic.—Lat. 37° and Qld.—Lat. 17.5°) and *E.miniata* (NT—Lat.

16.75°). All species were grown at two growth temperatures of 15/10°C and 35/30°C (day/night temperatures) under natural sunlight in the glasshouse, with a photoperiod of 14 hours. The assimilation (A) response to temperature (T) was measured, as well as the response of A to changing internal CO_2 concentrations (C_i) over a range of temperatures. Some insight into the mechanisms involved in acclimation to temperature has been gained.

The results for *N.oleander* were consistent with previously published data and indicated the ability of this species to acclimate to an increased growth temperature by a shift in the temperature optimum for photosynthesis and maintenance of the optimum rate of photosynthesis. Changes observed in the slope of the A/C_i curve (a measure of activity of Rubisco) and in the calculated regeneration capacity of RuBP (V_i) are also consistent with earlier data.

Results for *Eucalyptus* do not support the hypothesis that plants with growth restricted to certain times of the year would show a greater degree of acclimation than those not confined to a particular season. All species, except *E.miniata*, showed an 8°–9°C shift in the optimum temperature for photosynthesis with increased growth temperature. The shift for *E.miniata* was much smaller. The photosynthetic rate at the optimum temperature was lower for all high temperature grown plants. Stomata were important in influencing the photosynthtic response of all species only at temperatures above the optimum.

Elimination of effects of VPD and stomata on photosynthesis (diffusion processses) by plotting A/T at constant C_i indicated that the observed responses to temperature were under metabolic control. It is postulated that the decline in assimilation rate at high temperatures for low-temperature grown plants may be due to reversible inactivation of Rubisco. The level of inactivation varies with species. The photosynthetic responses to temperature which was observed for single leaves do not explain adaptation of these eucalypts to their particular habitats. Whole plant studies, particularly of growth and dry matter allocation would be useful.

In addition to the above studies, a bibliography has been compiled from published scientific papers, reports and PhD, MSc and BSc(Hons) theses which have investigated photosynthetic responses and/or aspects of water relations from forest hydrology through to responses of individual leaves to water stress. As many citations as possible have been annotated (usually from the author's abstract). Information from the photosynthesis bibliography has been summarised in tabular form. The bibliography is sorted by area of research and by plant species. The bibliography has been compiled with the aim of highlighting areas of work where research might be directed in the future.

Molecular Analysis of Plant Performance

Investigators: Murray Badger, John Andrews, Kam Chau Woo, Dean Price, Mathew Morell, Daryl Edmondson, Sally Henderson, Chin Wong, David Bagnall, Anne Gallagher, Veronica Ross, Susan Kirby, Deborah Singleton*, P. Whitfeld+, W. Bottomley+, G. Hudson+, J. Mahon+

The tools of molecular biology are powerful instruments with which to explore many of the long standing problems of plant physiology and biochemistry. We have continued to apply these techniques to research projects which aim to identify key genetic and biochemical processes controlling the acquisition and use of photosynthate by photosynthetic organisms. Through an increased understanding of these processes, it is hoped that assessment can be made of the potential for genetic modification of commercially important species, so as to improve the cost efficiency of their yield. Research projects are currently being pursued in the following areas:

a Biochemical and molecular analysis of Rubisco

Ribulose bisphosphate carboxylase/oxygenase (Rubisco) is a primary determinant of photosynthetic efficiency, as it is the primary mechanism for the incorporation of CO_2 into organic matter during photosynthesis. Kinetic analysis of the enzyme has showed that there may be potential for improving the efficency of this enzyme by means of modifying its affinity for the two alternate gas substrates, CO_2 and O_2, as well as increasing the V_{max} of the carboxylase reaction.

The role of small subunit (S) of the L_8S_8 type enzyme in modifying the catalytic properties of the large subunit (L) active site has been of considerable interest. Rubisco from *Rhodospirillum rubrum* is an L_2 type enzyme which lacks small subunits and shows considerably different kinetic properties to the L_8S_8 type enzyme. An amino acid sequence from the L_2 *rubrum* enzyme has been identified as having substantial homology with a highly conserved region of the small subunit from L_8S_8 enzymes. The region of interest is located at the C-terminus, where the large and the small subunits are thought to interact. The functional significance of this target sequence is being assessed by creating mutants which lack all or part of the target sequence, using site directed mutagenesis in *E. coli* (Morell and Andrews). These mutants have been created and their kinetic properties are currently being examined.

Study and manipulation of the L_8S_8 enzyme, which is found in all higher plants and algae, has been hindered by the lack of a suitable gene expression system for the large subunit. Expression of various large subunit genes in *E. coli* has resulted in insoluble aggregates of inactive protein, presumably because the large subunits are insoluble in the absence of the small subunits. However, during the last year, research in the group (Andrews, Ross and Singleton) has shown that the large subunit gene from the cyanobacterium *Synechococcus* PCC6301 directs the synthesis in *E. coli* of a product which is at least sparingly soluble. The soluble fraction assembles predominantly to the octameric L_8 form and it futher assembles *in vitro* with small subunits isolated from spinach Rubisco to form a fully functional L_8S_8 enzyme. Using a very sensitive assay, the L_8 form has been shown to retain about 1% of native activity. This is the most direct demonstration yet that the small subunits are not directly and obligatorily involved in the catalytic chemistry. The solubility properties of the cyanobacterial L_8 are now being investigated in the hope that insights may be obtained which will be useful in designing a strategy for expressing higher-plant large subunits in *E. coli.*

There are naturally occurring differences in the kinetic properties of higher plant Rubiscos, as evidenced by the difference in both $K_m(CO_2)$ and V_{max} between the enzyme from C_3 and C_4 plants. Early evidence from other workers suggested that this kinetic variation was inherited in a manner which suggested that differences in the amino acid composition of the large subunit were responsible. In an attempt to identify the key amino acid changes which are responsible for this kinetic variation, we have examined the gene sequences for the large subunit from three pairs of close C_3/C_4 relatives: *Neurachne tennuifolia* and *N. munroi, Flaveria pringleii* and *F. trinervia*, and *Atriplex patula* and *A. rosea* (Badger, Andrews, Whitfeld, Bottomley, Hudson, Mahon). The sequences of the *Neurachne* pair differ by six amino acids and those of the *Flaveria* pair by three. Only one of these differences is in common between *Neurachne* and *Flaveria*. Whether this is a significant difference or not we hope will become clear when we finalise the sequence of the *Atriplex* pair.

In view of the small differences between the sequences of the $C_3/_4$ pairs, especially for the *Flaveria* genus, the question has arisen as to whether the differences in kinetic properties might not be due to the properties of the small subunit. Clear proof that these kinetic differences are linked to inheritance of the large subunit does not exist. In an attempt to answer this question, a project has begun which will analyse the kinetic properties and small subunit content of Rubisco produced in hybrids between

C_4 and $C_3/_4$ intermediate *Flaveria* species (Henderson, Morell, Andrews, Badger). Isoelectric focussing procedures are being developed to separate and identify the different small subunits, whilst standard assays will measure $K_m(CO_2)$. The intermediate species contain Rubisco with C_3 kinetics and by following the properties of the F1 and F2 progeny, we hope to obtain answers to the questions of whether the small or large subunit are the source of the kinetic differences and whether small subunits from both sources are equally able to bind to foreign large subunits.

The interaction of Rubisco from spinach with its substrate RuP_2 has continued to provide intriguing results (Edmondson, Andrews, Badger). During an *in vitro* reaction, enzyme activity shows a first order decay in activity to reach a lower steady-state value. This loss of activity is not accompanied by a decarbamylation of the enzyme and is thus not due, as previously thought, to binding of RuP_2 to the decarbamylated form of the protein. Inhibition appears to be due to the production of a slow, tight binding phosphorylated inhibitor on the enzyme. This inhibitor may be produced as a consequence of the catalytic reaction, or it may be present in the RuP_2 preparation, and these possibilities cannot be distinguished at present. The inhibitor can be isolated from enzyme which has lost activity and can be used to reinhibit fresh enzyme. Future work is being directed towards the identification of the inhibitor and it is hoped that its relevance to the *in vivo* operation of the enzyme can be assessed.

b Analysis of the CO_2 Concentrating Mechanism in Cyanobacteria

Studies on the mechanism responsible for transport and accumulation of inorganic carbon (Ci) by cyanobacteria have continued (Price and Badger). It now seems that *Synechococcus* R2 possesses a CO_2 pump which forms the basis of the transport mechanism. This pump can be inhibited by various carbonic anhydrase inhibitors and from this we deduce that it must have some mechanistic similarities with carbonic anhydrase. Despite this assumption, we are unable to detect carbonic anhydrase activity associated with the cytoplasmic membrane fraction, which is the supposed location of the pump. Intracellular carbonic anhydrase (CA) does, however, play an important role in the functioning of the CO_2 concentrating mechanism. Using conventional CA assays, CA activity in crude extracts of *Synechococcus* R2 have been previously undetectable. A new sensitive CA assay has been developed and has allowed us to readily detect CA activity (Badger and Price). This assay is based on the use of mass spectrometry to follow the loss of ^{18}O label out of doubly labelled CO_2 in solution. Using this assay, high and low Ci grown cells have been found to contain equivalent levels of activity, which is contrary to results reported for other cyanobacteria. Cell localization studies indicate that this CA may be loosely associated with a pelletable fraction, and at this stage an intimate relationship with the carboxysome fraction cannot be ruled out. We hope to reach firmer conclusions on this issue, particularly through the use of a CA minus mutant which has been isolated from the high-CO_2 requiring screen, described below.

Work has proceeded on the use of various techniques to produce mutants of *Synechococcus* R2 which are impaired in the operation of the CO_2 concentrating mechanism. Various procedures which have attempted to insertionally inactivate genes with DNA fragments have proved unsuccessful. Despite this we have found that chemical mutagenesis using EMS is a very effective means of producing mutants which can grow at 1% CO_2 but not at air. Using this technique, 25 high-CO_2 requiring mutants have been isolated (Price, Kirby, Badger). Two of these mutants have been partially characterized. One of these can accumulate inorganic carbon but is unable to use it effectively for photosynthesis. This fact, combined with 10-fold reduction in internal CA activity, suggests it is defective in internal CA. This mutant is being subjected to genetic complementation analysis with gene bank DNA (Price and Kirby), in an effort to isolate the mutated gene. Using these mutants as the basis

for both biochemical and genetic analysis, we hope to make significant progress in understanding the CO_2 concentrating mechanism.

c Analysis of the Relationships between Photosynthesis and Plant Performance

The interaction between the production of photosynthate by the leaf and its subsequent utilization by the growth processes of the plant continues to be an area of developing interest. The studies started last year on the effect of low temperature on photosynthesis in peanut cultivars has concentrated on identifying the relationships between photosynthesis and important metabolic substrates in the leaf (Woo, Wong, and Bagnall). As photosynthesis declines with a drop in temperature from 30-20°C, a corresponding fall in the levels of PGA and hexose phosphates was found. This was in contrast to the increase in the levels of fructose-2,6-bisphosphate, UDP-glucose and starch, and the relatively constant pool of RuP_2. These results add further weight to the initial hypothesis that sucrose synthesis is limiting photosynthesis at low temperature in these peanut cultivars.

The project intiated last year, on screening chemical mutants of *Arabidopsis thaliana* for growth at low and high-CO_2 concentrations (Andrews, Badger, and Gallagher), has been slow to progress through lack of facilities. We are preparing a mutant seed bank from single seed descent, but the screening program has been delayed through the lack of controlled growth facilities. These growth cabinets are currently being constructed and screening will begin in 1988.

d Molecular Evolution of C_4 Photosynthesis in the Neurachne Genus

The molecular evolution of C_4 photosynthesis is one of the outstanding problems to which the techniques of molecular biology can offer an insight into the series of events that has taken place in the development of this complex syndrome. The ideal system to which this approach can be applied is to a genus of plants which are closely related and contain members that are C_3, C_3/C_4 intermediate and C_4 with regard to phtosynthetic pathway. The native Australian grass genus of *Neurachne* has all these attributes, and has been chosen as a model in which to intiate these studies. The key C_4 enzymes PEP carboxylase and Pyruvate, Pi-dikinase have been selected as model proteins with which to study molecular genetic changes that have taken place between the three species types (Woo, Badger and Andrews). Genes will be isolated from cDNA libraries using conventional antibody screening techniques, hybridization with cloned genes from maize, and phenotypic complementation of *E. coli* mutants by expression plasmids containing cDNA. Analysis of both the gene sequences and the flanking regions will be undertaken to find what specific changes have taken place during the evolution of the C_4 pathway in these species.

ECOSYSTEM DYNAMICS

Introduction

Successful management of areas of natural or semi-natural vegetation that constitute much of our grazing, forestry, conservation and recreation land depends on our ability to understand and predict changes in plant communities. The work of the Group combines the development of modelling techniques and models of plant change with experimental and field studies of the functioning of native plant communities.

Modelling Vegetation Change

Investigators: Ian Noble, Tom Smith, Andrew Moore, Mike Strasser, Ralph Slatyer, Joe Connell[§], Hank Shugart[+], Mike Huston[+], Dean Urban[+]

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.

This year we have developed a model of intermediate resolution which fills both a gap in modelling theory and in model application. The FATE model is a qualitative model in that it predicts roughly the amounts of each size class of each group of species. It is based on an understanding of the functioning of individual plants which comprise the vegetation and deals with aspects of their life history, resource depletion, tolerance to resource restriction, and response to natural disturbance. The model requires of the user a greater knowledge of the vegetation community than the vital attributes model, but less than that required to build a stand model. We are testing the model and its utility in management by applying it to problems associated with fire policy in Kakadu National Park.

Next year we will continue with field testing of the model and mathematical analysis of the behaviour of the model. The FATE model is mathematically more tractable than large process models such as the stand models and may be explored mathematically to find 'optimal' management strategies and tactics.

In some situations greater resolution than that provided by the FATE model is required; thus we have continued to construct and test models of forest stands. We have demonstrated that the structure of the widely-used JABOWA group of stand models is such that, even though they are based on an assumed competition for light, they effectively mimic below-ground competition. We have also analyzed data from high montane eucalypt communities which show that in these forests rainfall rather than temperature is the most important driving variable, and that competition is one-sided—i.e. larger trees affect smaller trees but not vice versa. These results are being incorporated into improved stand models.

Broader areas of interest include: the extension of our theoretical approaches to assist in the resolution of practical ecological problems; linking ecological processes across temporal and spatial scales (e.g. remotely-sensed data and landscape ecology); and the use of expert systems and rule-based modelling techniques to assist managers to develop models that reflect and extend their knowledge and capabilities.

Vegetation Theory and Environmental Response

Investigator: Mike Austin[#]

Work on the theoretical assumptions implicit in vegetation science has continued with tests of the continuum proposition of Gauch and Whittaker. The propositions are not applicable to the distribution of eucalypt species in forests in south-eastern New South Wales. The relationship between these results and experimental studies of community structure has been reviewed. While there is increasing agreement on the importance of nitrogen and light, process-oriented theory is not yet capable of explaining the species pattern found in nature.

Experimental Studies of Species Distributions and Adaptations

Investigators: Tom Smith, Bruce Wellington, Mike Austin[#], Ian Noble, Penny Butcher, Peter Cochrane, Graham von Schill

A major commitment of the group this year has been to an experiment which draws together ideas spanning the disciplines of ecology and physiology. The aim is directed towards finding a general explanation for species distributions. Adaptation of a species to particular environments imposes constraints which limit plant performance and survival under other environmental conditions. 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.

The experiment is designed to investigate the physiological and whole plant growth performance of eight eucalypt species selected from particular environmental gradients. Species are being grown under combinations of water and light availability both in isolation and in intra- and inter-specific competition. Results from a preliminary experiment were consistent with documented ecological differences between the species. Species from drier sites maintained lower rates of water usage at the expense of carbon assimilation even when water was plentiful.

Field Studies on Factors Controlling Community Structure and Composition

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

i Factors leading to the lower altitudinal limit of snow gum

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

We are investigating factors influencing the lower altitudinal limits of the tree-line species *Eucalyptus pauciflora*. We have found that the present environmental conditions do not limit the successful establishment of seedlings of *E. pauciflora* below its usual altitudinal distribution. In fact there is some evidence that establishment is better at lower altitudes. Demographic and spatial patterns, dendrochronological data, and field experiments are being used to investigate the role of over- and understorey competition. Further studies to investigate responses to water and nutrient restrictions are under way.

ii The ecology of rare eucalypts

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

We are exploring why a species (in this case *Eucalyptus paliformis*) is rare. Is it because the only habitats in which it can survive are rare? Is it a relic species being displaced by better competitors? Or is it a new species yet to expand to its full range? Detailed studies relating the distribution of *E. paliformis* to environment show that the first hypothesis is not tenable. Demographic and electrophoretic studies are being carried out to test the remaining hypotheses.

iii The impact of low intensity prescribed fires on nitrogen cycling and tree growth in subalpine forests

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

In this study the impact of low intensity prescribed fires on nitrogen cycling and consequent growth responses in an *E. pauciflora* community is being assessed by manipulating available nitrogen on plots subject to a variety of fire regimes. A second season of monitoring has commenced, and the data from the first is being analysed.

iv The role of harvester termites in a tropical savannah

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

Little is known about how termites interact with other components of natural ecosystems in Australia. This project, which includes a substantial field component in Kakadu National Park, is examining the impact of termites on tropical woodlands in relation to gradients of water availability, fire regimes and buffalo grazing. Detailed surveys of termite distributions have been carried out. Future work includes an investigation of feeding habits of termites, and their impact on surrounding vegetation.

v Population dynamics of mallee eucalypts

Investigator: Bruce Wellington

Work is continuing on quantifying key processes in the life cycle of mallee eucalypts. Measurements of growth and mortality of a cohort of seedlings of *E. incrassata* commenced in 1979 and have continued to the present. Analysis of the data is being carried out to determine the effects of seedling size and densities, nearest neighbours, topography, distance to nearest adult and levels of nutrient and water availability on seedling growth and survivorship.

JOINT RESEARCH PROJECTS UNDERTAKEN WITH OTHER UNIVERSITIES AND CSIRO

DEVELOPMENTAL NEUROBIOLOGY

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

Studies on the putative roles of calpain-like enzymes in vertebrate retinae. By Dr A.D. Blest with Dr D.S. Williams, School of Optometry, University of Indiana.

Studies on the synaptic mechanisms of information transfer in the moth auditory system, by Dr G.S. Boyan with Dr J. Fullard, the University of Toronto.

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

Experiments on human spinal reflexes, by Professor Mark with Dr U. Proske, Reader in Physiology, Monash University.

Molecular cloning of the *maroonlike* and *melanized-like* genes, by Dr G. Miklos with Professor V. Finnerty, Emory University, Atlanta, Georgia, USA.

Molecular cloning and neuroanatomy of the *small optic lobes* and *sluggish* genes, by Dr G. Miklos and Dr H.G. de Couet with Professor K. Fischbach, University of Freiburg, Freiburg, FRG.

Characterization of embryonic ventral nervous system mutants, by Dr G. Miklos with Professor C. Goodman, Stanford University, Stanford, California, USA.

Molecular cloning of the *tumorous head* gene. By Dr G. Miklos with Professor D. Kuhn, University of Central Florida, Orlando, Florida, USA.

Neuroanatomical and neurophysiological studies of the *Passover* gene complex, by Dr G. Miklos and Dr J. Davies, with Professor R. Wyman, Yale University, New Haven, Connecticut, USA.

Molecular cloning of the *folded gastrulation* and *short egg* genes, by Dr G. Miklos with Professor E. Wieschaus, Princeton University, Princeton, New Jersey, USA.

Genetical characterization of maternal effect mutants, by Dr G. Miklos with Professor N. Perrimon, Harvard University, Boston, Massachusetts, USA.

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

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

Molecular characterization of repetitive DNA sequences from divisions 19 and 20, by Dr G. Miklos with Dr A. Blanchetot, Centre de Recherches, D'Antibes, France.

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

Molecular cloning of the *stoned* and *uncoordinatedlike* genes, by Dr G. Miklos with Dr L. Kelly, University of Melbourne, Australia.

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

Molecular evolutionary analysis of DNA sequences from chromosome 4, by Dr G. Miklos with Professor D. Hartl, Washington University, St. Louis, Missouri, USA.

Localization of P-element mutations at the *Passover* locus, by Dr J. Davies with Professor R. Dennell, University of Kansas,Kansas, USA.

Functional domains of *Drosophila* rhodopsin, by Dr H.G. de Couet with Professor C. Zuker, University of California, San Diego, La Jolla, USA.

Molecular analysis of rhodopsin gene mutations, by Dr H.G. de Couet with Professor J. O'Tousa, University of Notre Dame, Notre Dame, Illinois, USA.

Photoreceptor membrane turnover in *Drosophila* , by Dr H.G. de Couet with Professor W. Stark, University of Missouri, Columbia, Missouri, USA.

Regulation of rhodopsin biosynthesis by Dr H.G. de Couet with Dr T. Tanimura, Fukuoka University, Japan.

Studies on neuromuscular development in embryonic locust, by Dr Camilla Myers and Dr Eldon Ball with Dr Paul Whitington, the University of New England, Armidale, NSW.

Studies on monoclonal antibodies to muscle fibre types, by Dr I.S. McClennan 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.

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

VISUAL SCIENCES

The Centre for Visual Sciences was established by the ANU Council in early 1987 to provide a focus for a number of previously separate areas of research on various aspects of vision research. They were:

- in the Research School of Biological Sciences the principles of visual information processing mechanisms, particularly in simple systems such as insects, and the transmitters and associated neural circuitry of vertebrate retina;
- in the Research School of Physical Sciences the group working on optics, visual information and psychophysics; and
- in the John Curtin School of Medical Research the single-unit recording in mammalian visual systems.

The Centre will encourage association with other researchers working in related areas, both within the Australian National University and elsewhere in Australia.

The Centre's function is to promote interaction between different parts of the University and develop task-oriented interdisciplinary groups to take advantage of new technology and equipment. As the principles of visual processing in relatively simple systems like the vertebrate retina or insect optic lobe are relevant to the understanding of parallel-processing strategies for machine and robot vision, the Centre for Visual Sciences is affiliated with the newly established Centre for Information Sciences, which was approved on the same day, as part of a Strategic Plan to re-group resources in the University.

At present the participants' laboratories lie in a number of locations on campus. During 1988 an extension will be constructed on the Research School of Biological Sciences' building to provide a single location for much of the University's vision-science research.

Other specific collaborations undertaken by members of the Visual Sciences Group were:

3-dimensional vision via motion cues in honey bees, by Prof Horridge, Dr Srinivasan with Dr M Lehrer, University of Zurich and Prof S W Zhang, Academia Sinica, Beijing.

Visual tracking behaviour in honeybee, by Dr Srinivasan with Prof S W Zhang, Academia Sinica, Beijing.

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

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

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

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

MOLECULAR GENETICS

Dr H. Naora, Mr E.E. Decruz and Mrs F. Driver are working on the characterization of a novel gene, *nbl* , isolated from Burkitt lymphoma with Dr N.J. Deacon from the University of Melbourne

Dr H. Naora collaborates with Professor R.N. Curnow, University of Reading on Genome Evolution.

Dr H. Naora also works on regulatory mechanisms of *c-myc* expression with Mr. L.-Q. Sun,4th Military Medical University, China and Dr. N.J. Deacon, University of Melbourne.

Dr. H. Naora and Mrs F. Driver are conducting studies on intracellular localization of *nbl* products in conjunction with Dr. T. Tsujii, Shigei Medical Research Institute.

Dr. E.H. Creaser works on engineering of yeast alcohol dehydrogenase with Professor Bryan Jones, University of Toronto.

Dr. E.H. Creaser is working on enzyme kinetics of Aspergillus alcohol dehydrogenase in association with Professor John McKinley-McKee, Oslo University.

Dr. E.H. Creaser collaborates on protein engineering of p-hydroxy benzoate hydroxylase with Dr. B.Entsch, University of New England.

Dr G.D. Clark-Walker, Dr R. Maleszka and Mr C. Hardy are working on characterization of hybridy following intergeneric fusion of yeast protoplasts in collaboration with Dr C. Galeotti, Sclavo Research Center, Siena, Italy.

Dr G.D. Clark-Walker and Dr I. Macredie, CSIRO Division of Protein Chemistry, Parkville, Victoria are collaborating on the isolation and characterization of metallothionein genes.

POPULATION GENETICS

Dr M. Arnold on molecular genetic studies of the grasshopper *Caledia species nova* with Dr P. Luykx, University of Miami, Florida.

Dr M. Arnold on cytogenetic analysis of the grasshopper *Caledia* using chromosome fluorescence with Professor D. Schweizer and Dr M. Mendelak, University of Vienna.

Dr J.B. Gibson on research on population structure with Professor G.A. Harrison, Dr R.W. Hiorns and Dr H. Macbeth, University of Oxford.

Dr J.B. Gibson on population and biochemical genetics with Dr M.C.G. Mascie-Taylor, University of Cambridge and Professor G. Bewley, North Carolina State University.

Dr D.D. Shaw and Mrs N. Contreras on phylogenetic relationships of the Australian burrowing cockroaches with Dr H. Rose, University of Sydney.

Dr D.D. Shaw and Ms S. Maynes on evolutionary relationships of the Australian avifauna with Dr L. Christidis, Museum of Victoria.

Dr D.D. Shaw and Ms S. Maynes on evolution of the Australian avifauna with Dr R. Schodde, Division of Wildlife & Rangelands Research, CSIRO.

PLANT CELL BIOLOGY

Professor B. Gunning and Dr D. McCurdy collaborated with Professor A. Staehelin, University of Colorado on high pressure freezing of plant tissues for immunoelectron microscopy.

Research on biology of *Azolla* by Professor B. Gunning, Dr B. Rolfe and Dr J. Plazinski with Mr Liu Xhong-Xhu, National Azolla Research Centre, Fuzhou, PRC, and Dr W. Shaw, Darwin Institute of Technology.

Fluorescence microscopy of water and nutrient pathways in *Eucalyptus* roots by Professor B. Gunning with Dr L. Thomson, School of Agriculture and Forestry, University of Melbourne.

Cell biology of reproductive structures in flowering plants by Professor B. Gunning and M. Webb with Professor R.B. Knox, School of Botany, University of Melbourne.

Studies on ultrastructure of fungal zoospores by Dr A. Hardham and Dr F. Gubler with Dr G. Beakes, Department of Plant Biology, The University, Newcastle Upon Tyne.

Studies on dynein in higher plants by Dr P. Jablonski and Dr R. Williamson with Drs G. Witman and S. King, Worcester Foundation, USA.

Research on myosin in plants by Dr Williamson and Dr P. Jablonski with Dr C. Miller, University of Leicester, UK.

Studies on conserved cell division proteins by Dr P. John with Drs P. Nurse and M. Lee, Imperial Cancer Research Laboratories, London.

Research on cyclic AMP and cell division by Dr P. John with Dr P. Hunt, JCSMR, ANU.

Cytokinin studies by mass spectrometry by Dr D.S. Letham and Dr L. Palni with Dr J. MacLeod and S.A.B. Tay, RSC, ANU.

Dr D.S. Letham collaborated with Professor L.D. Noodén, University of Michigan on hormonal control of leaf senescence.

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

Studies on hormones in xylem sap in relation to root stress by Dr D.S. Letham with Drs R.A. Fisher and R.E. Munns, Division of Plant Industry, CSIRO.

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

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

Research on the effect of gliotoxin on plant cells by Dr L. Palni, with Dr A. Mullbacher, JCSMR, ANU.

Growth regulating activity of humic acids by Dr L. Palni with Dr J. MacLeod, RSC, ANU.

Studies on initiation of polarity in plant tissues by Dr P. Warren Wilson with Dr R. Overall, School of Biology, University of Sydney.

IAA conjugates and abscission induction in explants by Dr P. Warren Wilson with Dr P. Hall, Michigan State University.

Research on auxin transport inhibitors and induced abscission by Dr P. Warren Wilson with Drs G. Katekar and A. Geissler, Division of Plant Industry, CSIRO.

PLANT MOLECULAR BIOLOGY

Clover plant signals and non-legume plant signals by B. Rolfe, M. Djordjevic, M. Nayudu, J. Plazinski, G. Bender S. Djordjevic, H. Chen, B. Bassam, L. Sargent, J. Gray, A. Richardson, S. Huang, J.J. Weinman, J. McIver, J. Miller, A. Moten, K. Le Strange, J. Bolten-Gibbs, L. Currie, T. Brown, E. Gartner, M. Oakes, R. Taylor; Honours Students T. Arioli, W. Lewis with Professor J. Redmond and Dr M. Batley, Macquarie University; Dr P. Kuempel and Dr R. Innes, University of Colorado, USA.

Gene Regulation in *Neurospora* by Dr B. Tyler with Professor N. Giles, University of Georgia, USA.

Function of fungal genes *in vitro* by Dr B. Tyler with Professor J. Fincham, University of Cambridge, UK; Dr J. Kinnaird, University of Edinburgh, UK; Professor C. Yanofsky, Stanford University, USA; Professor W. Timberlake, University of Georgia, USA; Dr K. Munger; and Dr K. Lerch, University of Zurich, Switzerland, Professor M. Hynes, University of Melbourne and Dr P. Molloy CSIRO Division of Molecular Biology.

Gene of *E.coli* as a DNA transformation marker for fungi by Dr B. Tyler and Ms B. Austin with Dr Ruth Hall, CSIRO Divison of Molecular Biology.

Development of vectors for the transformation of oomycetes by Dr B. Tyler Dr W. Thompson and Ms A. Kashemsanta with Dr H. Judelson, Dr R. Michelmore, University of California at Davis, USA

Molecular genetics of maize rust by Dr B. Tyler with Mr P. Anderson and Dr Tony Pryor, CSIRO Division of Plant Industry.

Rhizobium trifolii surface polysaccharides and clover infection by B. Rolfe, M. Djordjevic, L. Sargent, A. Richardson, S. Huang, J.J. Weinman, J. McIver, A. Moten, E. Gartner, M. Oakes with Professor J. Redmond, Dr M. Batley, Macquarie University; Dr F. Dazzo and Dr R.Hollingsworth, Michigan State University, USA; Dr R. Carlson, Eastern Illinois University, USA.

R. trifolii nod gene regulation (the *nodD* and *nodIJ* genes) by B. Rolfe, M. Djordjevic, J. Plazinski, L. Sargent, A. Richardson, S. Huang, J.J. Weinman, J. McIver, A. Moten, M. Oakes with Dr C. Wijffelman, Dr. H. Spaink, Dr R. Okker, University of Leiden, The Netherlands.

Acid tolerant *R. trifolii* strains by B. Rolfe, M. Djordjevic, G. Bender, L. Sargent, A. Richardson, J. McIver, A. Moten, E. Gartner, M. Oakes with Dr R. Roughley, NSW Department of Agriculture Gosford, NSW and Dr R. Simpson, University of Melbourne.

Automation of taxonomic descriptions and practical applications by Mr L. Watson with Dr M.J. Dallwitz, Division of Entomology, CSIRO, Canberra.

Automated accounts of the grass genera of Southern Africa by Mr L. Watson with Dr G.E. Gibbs Russell, Botanical Research Institute, Pretoria and of Greece, with Dr. M. Damanakis, University of Crete.

Taxonomic work on grasses and the classification of flowering plant families by Mr Les Watson with Professor H.T. Clifford, University of Queensland.

Virus Identification Data Exchange Project, by Dr C. Buchen-Osmond, Ms K. Crabtree Dr A.J. Gibbs and L. Watson with the active participation of Dr M.J.Dallwitz and Ms T.A.Paine, Division of Entomology, CSIRO and Dr G.D. McLean, Bureau of Rural Sciences. This project involves about 200 virologists around the world including Dr A.A. Brunt, AFRC Institute of Horticultural Science, Littlehampton, UK.

Studies into the structure and regulation of liguin degrading genes in *P.aeruginoa* by Dr K. Scott with Dr B. Entsch from the University of Adelaide.

PLANT ENVIRONMENTAL BIOLOGY

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

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

Drs M.R. Badger and T.J. Andrews collaborated on Investigation of the regulation of Rubisco activity in horticultural and woody crop species, with Dr S.P. Robinson, CSIRO Division of Horticultural Research.

Dr T.J. Andrews collaborated on Studies on CO_2 assimilation and activities of photosynthetic enzymes in maize mutants with chlorophyll deficiency or high chlorophyll fluorescence, with Dr G.E. Edwards, Washington State Univ., Pullman, and Drs C.L.D. Jenkins and M.D. Hatch, CSIRO Division of Plant Industry.

Drs G.D. Farquhar, K.T. Hubick and S. von Caemmerer collaborated on Isotope discrimination in recently fixed photosynthate, with Dr E. Brugnoli, CNR Institute per l'Agroselvicoltura, Italy.

Drs K.T. Hubick and G.D. Farquhar collaborated on Isotope discrimination in barley genotypes, with Dr D.H.B. Sparrow, 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.

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

Drs K.T. Hubick and G.D. Farquhar collaborated on Isotope discrimination in sunflower, with Drs H. Rawson and R. Downes, CSIRO Division of Plant Industry.

Drs K.T. Hubick and G.D. Farquhar collaborated on Isotope discrimination in peanut, with Dr R. Shorter, Qld. Dept. Primary Industry, Brisbane, and Dr G. Wright & Mr. A. Cruikshank, Qld. Dept. Primary Industry, Kingaroy.

Drs G.D. Farquhar and S.C. Wong collaborated on Water-use efficiency of crop growth, 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.

Drs K.T. Hubick and G.D. Farquhar collaborated on Isotope discrimination in cowpea, with Prof. A.E. Hall, University of California, Riverside.

Drs G.D. Farquhar and K.T. Hubick collaborated on Isotope Discrimination, ABA control & Water-use efficiency in Wheat, with Dr R. Johnson, Oklahoma State University.

Mr Derek Millar collaborated on Isotope composition in aquatic organisms, with Mr A. Mower, S.A. Dept. of Fisheries.

ECOSYSTEM DYNAMICS

Ian Noble and Ralph Slatyer collaborated on Review of biotic succession with Professor Joe Connell, University of California, Santa Barbara, USA.

Ian Noble collaborated on Vegetation dynamics in the wet/dry tropics with Professor Pat Werner, CSIRO Div Wildlife & Ecology, Darwin.

Ian Noble and Andrew Moore collaborated on Models of plant succession in the wet/dry tropics with Dr A Press, ANPWS, Jabiru.

Ian Noble collaborated on Application of expert systems to land management with Dr Geoff Norton, Imperial College, UK.

Ian Noble collaborated on Models in fire ecology (review book) with Dr Malcolm Gill, CSIRO Div Plant Industry.

Ian Noble collaborated on Functional attributes of savannah ecosystems with Professor Brian Walker, CSIRO Div Wildlife & Ecology.

Ian Noble collaborated on Modelling weed seed biology with Dr P Weiss, School of Horticulture, Woden TAFE.

Tom Smith, Bruce Wellington and Ian Noble collaborated on Physiological responses of eucalypt species across interacting resource gradients with Dr M P Austin, CSIRO Div. Wildlife and Ecology.

Tom Smith collaborated on Models of forest dynamics with Prof H H Shugart,Dr D Urban, Univ Virginia, USA.

Tom Smith collaborated on Plant successional theory with Dr M Huston, Oak Ridge National Lab, Tennessee, USA.

CONFERENCES

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

DEVELOPMENTAL NEUROBIOLOGY

Local

Marotte, L. Australian Neuroscience Society Meeting at the University of Newcastle. February. On the development of the wallaby retina.

Millar, T.J., McLennan, I.S., Shanin, S.+ and Rostas, J.A.P.+ Australian Neuroscience Society, Newcastle, February. Monoclonal antibodies against the tubular system of slow muscles.

McLennan, I.S. and Porter, M.L. Australian Neuroscience Society, Newcastle, February. The effect of prostaglandins on erythrocyte shape in Duchenne's muscular dystrophy.

Overseas

Mark, R. Winter Conference on Brain Research in Queenstown, New Zealand, September. Plenary lecture on the development of the marsupial visual system.

Mark, R. NATO Studies Workshop in Bergen, Norway, September. The use of exotic animals in neurobiological research; and the development of the marsupial visual system.

Miklos, G.L.G., Davies, J., de Couet, H.G., Yamamoto, M., Kelly, L.+, Coombe, P.E., Fischbach, K.+, Pirrotta, V.+, Schalet, A.+ and Lefevre, G.+ 28th Annual *Drosophila* Research Conference, Chicago, May. Genetic and molecular studies of genes affecting behaviour in the *mal* to *su(f)* region.

Miklos, G.L.G., Yamamoto, M., Davies, J., Mitchelson, A.+ and O'Hare, K.+ 28th Annual *Drosophila* Research Conference, Chicago, May. Repetitive sequences and beta-heterochromatin.

Baird, D.+ Davies, J., Miklos, G.L.G., Pirrotta, V.+ and Wyman, R.+ 28th Annual *Drosophila* Research Conference, Chicago, May. Genetics and cloning of Passover, a mutant with altered neuronal connectivity.

de Couet, H.G., Yamamoto, M., Davies, J., Pirrotta, V.+ and Miklos, G.L.G. Molecular Neurobiology of *Drosophila*. Cold Spring Harbor, New York, USA, October. Genetic characterization and molecular cloning of a "flightless" locus at the base of the X-chromosome of *Drosophila melanogaster*.

Trowell, S.C. American Society for Experimental Biology Summer Symposium, Biology and Chemistry of Vision, Copper Mountain, Colorado USA, July.The role of some phosphatase enzymes in the microvillar photoreceptors of invertebrates.

VISUAL SCIENCES

Local

Boelen, M.K. and Dvorak, D.R. Disruption of dopaminergic transmission in chicken retina increases sensitivity to light. Australian Neuroscience Society, Newcastle, February.

Jones, M., Yang, G. and Dvorak, D.R. Effects of NMDA-induced amacrine cell loss on the receptive field properties of ganglion cells in chicken retina. Australian Neurosciences Society, Newcastle, February.

Millar, T.J., McLennan, I.S., Shahin, S. and Rostas, J.A.P. Monoclonal antibodies against the tubular system of slow muscles. Australian Neurosciences Society, Newcastle, February.

Millar, T.J. and Morgan, I.G. The ultrastructure of serotonergic cells in the chicken retina. Australian Neurosciences Society, Newcastle, February.

Tung, N.N.+, Morgan, I.G. and Ehrlich, D.+ Shrinkage of the optic tectum following kainate-induced damage to retinal ganglion cells in the chick. Australian Neurosciences Society, Newcastle, February.

van der Valk, J. and Dvorak, D.R. Presence of inhibition: a possible distinction between retinal amacrine and ganglion cells. Australian Neurosciences Society, Newcastle, February.

Yang, G. and Dvorak, D.R. Dynamics of surround inhibition in avian retinal ganglion cells. Australian Neurosciences Society, Newcastle, February.

Morgan, I.G. Cell-specific excitotoxicity in the chicken retina. IUPNAR Satellite Symposium on "Excitatory Amino Acids", Canberra, August.

Dvorak, D.R. and van der Valk, J. Electrophysiological effects of excitatory amino acids on inner retinal neurons. IUPNAR Satellite Symposium on "Excitatory Amino Acids", Canberra, August.

Morgan, I.G. Excitatory amino and receptors in chicken retina. International Union of Pharmacology, Canberra, August.

Overseas

Lehrer M., Srinivasan M.V., Zhang S.W. and Horridge G.A., How bees use motion cues to estimate depth. Neurobiologen Tagung, Gottingen, June.

Horridge G.A., Barlow-Fest Cambridge UK, September, Cambridge, England.

Thacker, J. Developing lenses in dung beetle eyes. Vision Coding and Efficiency Symposium, Cambridge, September.

Thacker, J. Dung Beetle eyes—anatomy and optics. Sechenov Institute of Evolutionary Symposium Physiology and Biochemistry. Academy Science Leningrad, USSR, September.

MOLECULAR GENETICS

Local

Naora, H. and Decruz, E.E. Symposium at the Australian National University, February.

Sun, L.-Q. and Naora, H. 31st Annual Meeting of the Australian Biochemical Society, Perth, May.

Creaser, E.H. Australian Biochemical Society Meeting, Perth, May.

Overseas

Clark-Walker, G.D. The expanding realm of yeast-like fungi Conference, Amersfoort, The Netherlands, Aug 2–7.

Clark-Walker, G.D. Molecular biology of mitochondrial chloroplasts, Cold Spring Harbour, New York, Aug 25–30

POPULATION GENETICS

Local

Arnold, M.L., Contreras, N. and Shaw, D. Asymmetrical introgression of rDNA between subspecies: evidence for the involvement of biased gene conversion. 34th Genetics Society of Australia Conference, Canberra, August.

Christian, P. The distribution of *Drosophila* A virus in Australian populations of *Drosophila melanogaster* and *D. simulans*. 34th Genetics Society of Australia Conference, Canberra, August.

Christian, P. Distribution of *Drosophila* A virus in Australian populations of *D. simulans* and *D. melanogaster*. Australian Dipteran Molecular Biology Meeting, Corowa, April.

Colgan, D.G. and Willcocks, D.A. Electrophoretic variation and plasmid diversity in the enteric bacteria of *Caledia captiva*. 34th Genetics Society of Australia Conference, Canberra, August.

Cooke, P.H. and Oakeshott, J.G. Nucleotide and amino acid polymorphisms Q within and between Esterase 6 electromorphs of *Drosophila melanogaster*. 34th Genetics Society of Australia Conference, Canberra, August.

Freeth, A.L., Gibson, J.B. and Wilks, A.V. Molecular analysis of alcohol dehydrogenase null alleles from natural populations of *Drosophila melanogaster*. 34th Genetics Society of Australia Conference, Canberra, August.

Game, A.Y. and Oakeshott, J.G. Esterase 6 activity variation in *Drosophila melanogaster*: associations with restriction site polymorphism. 34th Genetics Society of Australia Conference, Canberra, August.

Gibson, J.B. Molecular analysis of activity variants at the alcohol dehydrogenase and sn-glycerol-3-phosphate dehydrogenase loci in *Drosophila melanogaster*. Australian Dipteran Molecular Biology Meeting, Corowa, April.

Jiang, C., Gibson, J.B., Wilks, A.V. and Freeth, A.L. Comparison of restriction endonuclease variation surrounding *Adh* null and normal alleles from natural populations of *Drosophila melanogaster*. 34th Genetics Society of Australia Conference, Canberra, August.

McIntyre, C.L. Evolutionary change in species of the *Triticeae*. 34th Genetics Society of Australia Conference, Canberra, August.

Marchant, A.D., Arnold, M.L. Wilkinson, P., Shaw, D.D. and Rowell, D. Comparison of allozyme, mitochondrial and ribosomal DNA variation across a chromosomal tension zone. 34th Genetics Society of Australia, Canberra, August.

Matthews, P. Ribosomal DNA variation in Taro. 34th Genetics Society of Australia Conference, Canberra, August.

Shaw, D.D., Arnold, M.L., Marchant, A.D., Contreras, N. and Kohlmann, B. Evolution below the species level: molecular and chromosomal divergence in the Australian grasshopper *Caledia captiva*. Australian Institute of Biology, Canberra, July.

Overseas

Gibson, J.B., Jiang, C., Wilks, A.V. and Freeth, A.L. Restriction endonuclease variation in the region surrounding alcohol dehydrogenase null and normal alleles in *Drosophila melanogaster*. 10th European Drosophila Research Conference, Barcelona, Spain, September.

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. 3rd Kew Chromosome Conference, Royal Botanic Gardens, Richmond, England, September.

PLANT CELL BIOLOGY

Local

Galway, M.E. and Hardham, A.R. Microtubule reassembly and reorganization after drug-induced disassembly in regenerating algal protoplasts. Sixth Annual Meeting of the Australia and New Zealand Society for Cell Biology. Auckland, New Zealand, May.

Gubler, F. and Hardham, A.R. Secretion of adhesive material during encystment of zoospores of *Phytophthora cinnamomi*. Australian Society of Plant Physiologists. Perth, May.

Mineyuki, Y. and Gunning, B.E.S. Analysis of protoplasmic dynamics in cell division by digital image processing techniques. Australian Society of Plant Physiologists. Perth, May.

Mineyuki, Y. and Gunning, B.E.S. Involvement of preprophase band sites in cell plate maturation. Australian Society of Plant Physiologists. Perth, May.

Wasteneys, G.O. and Williamson, R.E. Microtubule assembly and alignment in the giant internodal cells of Nitella. 6th Annual General Meeting of the Australia and New Zealand Society for Cell Biology, Auckland, May.

Overseas

Franche, C.[#], Gunning, B.E.S., Rolfe, B. and Plazinski, J. Use of heterologous hybridization in phylogenetic studies of symbiotic *Anabaena* strains. Third International Symposium on the Molecular Genetics of Plant Microbe Associations, Montreal, Canada, July.

Gunning, B.E.S. Cytoskeleton and morphogenesis. XIV International Botanical Congress, Berlin, Fed. Rep. Germany, July.

Hall, P.J.*, Letham, D.S. and Barlow, B.A.[+] The influence of hormones on development of *Amyema* seedlings cultured *in vitro*. Fourth International Symposium on Parasitic Flowering Plants, Marburg, FRG, August.

Hardham, A.R. The spore surface: the use of lectin and antibody probes to study the surface properties of zoosporic pathogens. Fourth International Fungal Spore Conference. Stirling, Scotland, June.

Hardham, A.R. Reprogramming of vascular tissue following wounding with special regard to xylem elements. XIV International Botanical Congress. Berlin, Fed. Rep. Germany, July.

Mineyuki, Y. Cell division and the site of cell plate formation: involvement of PPB sites in cell plate maturation. XIV International Botanical Congress. Berlin, Fed. Rep. Germany, July.

Plazinski, J., Franche, C.[#], Liu, C-C.[+], Lin, T.[+], Shaw, W.[§], Gunning, B.E.S. and Rolfe, B. Taxonomic status of *Anabaena azollae*. Symposium on the Contribution of Biological Nitrogen Fixation to Plant Production, Cisarua, Indonesia, August.

Warren Wilson, J.[†], Warren Wilson, P.[#] and Walker, E.S.[†] Regulation of xylogenesis in pith explants. British Plant Growth Regulator Group, Wye College, University of London, July.

Williamson, R.E., McCurdy, D.W. and Hurley, U.A. Actin isoforms and related proteins in *Chara* and higher plants. XIV International Botanical Congress, Berlin, July.

Williamson, R.E., J. Plazinski, B.E.S. Gunning, B. Rolfe, U.A. Hurley, P.P. Jablonski, Y. Mineyuki, D.W. McCurdy. Root morphogenesis, the cytoskeleton and calcium regulation. 3rd International Meeting on *Arabidopsis*, Michigan, April.

PLANT MOLECULAR BIOLOGY

Local

Piskur, J., Clark-Walker, G.D. and Wimmer, E. Intergenic sequences are involved in transmission of the yeast mitochondrial genome, Genetics Society of Australia, Canberra, August

Piskur, J., Wimmer, E. and Clark-Walker, G.D. A site-specific recombination through short direct repeats is involved in the generation of smaller Rho^+ yeast mitochondrial genomes, Genetics Society of Australia, Canberra, August.

Rolfe, B.G. The genetic organization of nitrogen-fixing *Rhizobium* species: past and future applications to agriculture, Australian Society of Agronomy, 4th Australian Agronomy Conference, La Trobe University, Melbourne, August.

Rolfe, B.G. Plant and bacterial signals in the *Rhizobium* legume symbiosis, Annual Meeting of the Australian Biochemical Society, University of Western Australia Perth, May.

Rolfe, B.G. *Rhizobium* bacteria as a model system for plant pathogens, Royal Society of Western Australia, Perth, May.

Scott, K.F., Keese, M,, Price, G.D., Gresshoff, P.M., Kane, H., Tellam, J., MacDonald, P. and Chua, K.Y. Host-specific nodulation of the nonlegume plant *Parasponia*. 9th Annual Genome Conference 1987, Lorne, Victoria, February.

Tyler, B.M. Control sequences in the promoters of *Neurospora* rRNA Genes. 9th Annual Genome Conference, Lorne, Victoria, February.

Upadhyaya, N., Scott, K.F., Tucker, W. and Dart, P. At least three genetic loci in *Rhizobium* strain IC3342 directly encode leaf-curling of pigeonpea. 9th Annual Genome Conference, 1987, Lorne, Victoria, February.

Upadhyaya, N., Scott, K.F. and Dart, P. Bacterial Genes essential for Systemic Pathogenesis in Plants. Genetics Society, Canberra, August.

Overseas

Djordjevic, M., Molecular biology of the Rhizobium plant interaction. Amalfi. Italy.

Gibbs, A.J. Evolutionary sources of viral genes. Symposium "Evolution and ecology" at the 7th International Congress of Virology, Edmonton, Canada, August.

Meek, A.D. Rates of tymovirus evolution, Symposium "Evolution and ecology" at the 7th International Congress of Virology, Edmonton, Canada, August.

Rolfe, B.G. The current status of *Rhizobium* studies. 7th Annual Agrigenetics Meeting, Geneva, Min. USA.

Scott, K.F. Annual Meeting of the Australian and New Zealand Microbiology Societies, Auckland, May.

Tyler, B.M. In vitro transcription Systems for Genes from *Neurospora crassa* and *Aspergillus nidulans* Fourteenth Fungal Biology Conference, Asilomar, California, USA, April

Tyler, B.M. Common Control Sequences in the Promoters of *Neurospora crassa* 5S and 40S rRNA Genes, Fourteenth Fungal Biology Conference, Asilomar, California, USA, April

Watson, L., Dallwitz, M.J., Gibbs A.J. and Pankhurst R.J. Automated taxonomic descriptions. 'Prospects in Systematics'. Jubilee Symposium of the Systematics Association, London.

PLANT ENVIRONMENTAL BIOLOGY

Local

Andrews, T.J. Structure & mechanisms of ribulose bisphosphate carboxylase-oxygenase. Aust. Biochemical Society Annual Meeting, Perth, May.

Badger, M.R. The CO_2 concentrating mechanism in unicellular algae and cyanobacteria. Aust. Biochemical Society Annual Meeting, Perth, May.

Cowan, I.R. International Symposium—Flow and Transport in the Natural Environment: Advances and Applications—Canberra, September.

Osmond, C.B. Robertson Symposium, RSBS.

Wong, S.C. Cotton Breeding Workshop, Narrabri, July.

Woo, K.C. Aust. Biochemical Society Annual Meeting, Perth, May.

Overseas

Andrews, T.J. Catalytic properties of Rubisco large-subunit octamers and subunit hybrids. International meeting "Rubisco 87", Tucson, Arizona,USA, April.

Caemmerer, S. von, Gordon Conference on CO_2 fixation in green plants. Plymouth, New Hampshire, July.

Caemmerer, S. von, XIV International Botanical Congress, Berlin, July–August.

Edmondson, D.L. International meeting "Rubisco 87", Tucson, Arizona, USA, April.

Farquhar, G.D. 6th Annual Plant Biochemistry and Physiology Symposium, Columbia, Missouri, USA, April.

Farquhar, G.D. International meeting "Rubisco 87", Tucson, Arizona, USA, April.

Farquhar, G.D. Vth International Conference on Mediterranean-Climate Ecosystems, Montpellier, France, July.

Farquhar, G.D. Society for Experimental Biology Meeting, Colchester, UK.

Farquhar, G.D.Second German–French Colloquium, Maria Laach, F.R. Germany.

Farquhar, G.D. NATO Advanced Research Workshop. Forest Biomass for Fibre and Energy. Obidos, Portugal.

Farquhar, G.D. International Symposium on Improving Winter Cereals Affected by Temperature and Salinity Stresses. Cordoba, Spain.

Hubick, K.T., Farquhar, G.D. and Shorter, R.+ Genetic variation of carbon isotope discrimination in C_3 plants. XIV International Botanical Congress, Berlin, July–August.

Osmond, C.B. Defining the role of light in stress effects on photosynthesis. 6th Annual Plant Biochemistry and Physiology Symposium, Columbia, Missouri, USA, April.

Osmond, C.B. Enzyme action in plants. International meeting "Rubisco 87", Tucson, Arizona, USA, April.

Osmond, C.B. Symposium Chairman. Gordon Conference on CO_2 metabolism in green plants, Plymouth, New Hampshire, July.

Osmond, C.B. Mechanistic and comparative aspects of photosynthetic assimilations using stable isotopes. XIV International Botanical Congress, Berlin, July–August.

Terashima, I. Modelling of the effects of gradients of light and photosynthetic properties of chloroplasts within a leaf. XIV International Botanical Congress, Berlin, July–August.

ECOSYSTEM DYNAMICS

Local

Prober, S. Causes of rarity in *Eucalyptus paliformis*, National Conference on Conservation of Threatened Species and their Habitats, Sydney, February.

Smith, T. Patterns in whole plant light responses: implications for vegetation patterns, Robertson Symposium on the Ecology of Sun and Shade Plants, Canberra, February.

Noble,I. Moore,A. and Strasser, M. Models of vegetation dynamics after fire, Workshop on Computer Modelling and Remote Sensing in Relation to Bushfires in Australia,the (former) Division of National Mapping, Department of Resources and Energy, Canberra, June.

Moore, A. A simple quantitative model of vegetation dynamics, Ecological Society of Australia Open Forum, Adelaide, August.

Prober, S. Habitat peculiarity as a cause of rarity in *Eucalyptus paliformis* L. Johnson et Blaxell, Ecological Society of Australia Open Forum, Adelaide, August.

Strasser, M. Modelling radial growth in *Eucalyptus pauciflora*, Ecological Society of Australia Open Forum, Adelaide, August.

Williams, J. Growth and survival of *Eucalyptus pauciflora* seedling transplants across its lower altitudinal boundary in the Brindabella Ranges, Ecological Society of Australia Open Forum, Adelaide, August.

Overseas

Hodda, M. Ecological Advantages, Disadvantages and Implications of Fungus Growing: a Comparison of Australian and African Termites, Symposium on Fungus-growing Termites in the Tropical Environment, Nairobi, November.

Noble, I. (with co-authors Andrew Moore and Mike Strasser), Predicting Vegetation Dynamics based on Structural and Functional Attributes, International Symposium on Vegetation Structure in Utrecht, July. Dr Noble also convened the Populations and Systems Dynamics Session.

VISITORS AND SEMINARS

The School receives a large number of Visiting Fellows. Set out below are a list of visitors and an indication of some of the seminars and lectures given. It also hosted two major meetings, the First Sir Rutherford Robertson Symposium, entitled 'Ecology of Photosynthesis in Sun and Shade' and a workshop on the "Molecular Taxonomy and Evolution of Plants" organized by the Plant Molecular Biology Group.

DEVELOPMENTAL NEUROBIOLOGY

Dr Michael Bastiani, Department of Biological Sciences, Stanford University, Stanford, California, U.S.A.

Dr Jim Fullard, Biology Department, University of Toronto (Erindale Campus),Missisauga, Ontario, Canada.

Professor Alan Parker, Professor of Veterinary Medicine, University of Illinois, Urbana, USA. (Marsupial neuromuscular development).

Dr J.L.D. Williams, Max Planck Institut fur Verhaltensphysiologie, Seewiesen, West Germany.

VISUAL SCIENCES

Dr A. Freeman, Department of Physiology, University of Sydney: What ganglion cells do in flickering light.

Dr M. Lehrer, Zoologisches Institut, Universitaet Zuerich: Multiporous's smaller sister.

Dr W. Kirchner, Zoologisches Institut der Universitaet, Wurzburg: Acoustical communication in honeybees.

Professor R. Pinter, University of Washington: Laterial inhibition in DCMD neuron.

Professor K. Singarajah, Federal University of Paraiba, Brazil: Spectral and motion sensitivity of units of butterfly ventral nerve cord.

MOLECULAR GENETICS

Dr Cesira Galeotti, Sclavo Research Center, Siena, Italy.

POPULATION GENETICS

Professor Peter Luykx, University of Miami, Florida, USA: Chromosomal variation and social structure in termites.

Professor Craig Moritz, University of Michigan, Ann Arbor, USA: Mitochondrial DNA variation in parthenogenetic lizards.

Professor Rollin Richmond, University of Indiana, USA: Population genetics of the esterase locus in *Drosophila melanogaster*.

Professor Jack Sites, Brigham Young University, Utah, USA: Speciation in the North American lizard *Sceloporus grammicus*.

Professor David Woodruff, University of California, USA: Speciation and evolution in the Caribbean snail.

PLANT CELL BIOLOGY

Professor U. Sleytr, Centre for Electron Microscopy, Vienna, visited in February and presented a seminar: Structure, chemistry, assembly and technical applications of crystalline bacterial cell envelope layers.

Professor Bruce Knox, Plant Cell Biology Research Centre, School of Botany, University of Melbourne, visited in March and presented a seminar: New concepts in pollen biology and fertilization.

Dr Colin Sheppard, Oxford University, also visited in March and presented a seminar: Confocal scanning microscopy—a new tool for biologists.

Dr Geoff McFadden, Plant Cell Biology Research Centre, School of Botany, University of Melbourne, visited in April and presented a seminar: Gene expression in germinating barley: localisation of (1-3, 1-4)-β-glucanase mRNA by hybridization histochemistry.

Dr Kim Tranh Than Van, CNRS, Gif-Sur-Yvette, visited in May and presented a seminar: Plant organogenesis in thin cell layer systems.

Professor H. Woolhouse, John Innes Research Institute, Norwich, also visited in May and presented a seminar: Genetic engineering and energy sources in agriculture.

Dr Diana Harvey, School of Biological Sciences, University of Sussex, visited in June and presented a seminar: The application of cryotechniques in the localisation of freely diffusible ions with particular reference to freeze-substitution.

Dr Rosemary White, School of Biological Sciences, University of Sydney, visited in October and presented a seminar: Plant gravitropism and the cytoskeleton.

Professor J. Murdoch Mitchison, FRS, Professor of Zoology, University of Edinburgh, visited in November and presented a seminar: The cell cycle of *Schizosaccharomyces pombe*—periodicities, sequences and oscillators.

Professor W.W. Thomson, Department of Botany and Plant Sciences, University of California, Riverside, visited in November and presented a seminar: The organization of chloroplasts—a re-look.

PLANT MOLECULAR BIOLOGY

Dr M. Damanakis, Department of Biology, University of Crete, visited us in September–October, to finalise for publication descriptions and keys (in Greek) for the grass genera of Greece, generated by computer from Mr Watson's automated database.

Dr A.A. Brunt, A.F.R.C. Institute of Horticultural Science, Littlehampton, UK, worked with VIDE project for the month of January.

Dr E. Zimmer, Louisiana State University, Baton Rouge, and Professor Peter Martin, University of Adelaide in November to participate in a workshop organized by the plant Molecular Biology Group entitled "Molecular taxonomy and evolution of plants".

PLANT ENVIRONMENTAL BIOLOGY

Mr. Frank Dunin, CSIRO Plant Industry (joint seminar with Dr. Suan Chin Wong, Plant Environmental Biology, RSBS) "Photosynthesis and transpiration of irrigated wheat. Field gas exchange measurements". March.

Dr. Richard Leegood, Research Institute of Photosynthesis, University of Sheffield, UK "PEP carboxylase and the regulator of C_4 photosynthesis". April.

Dr. John Mahon, Plant Biotechnology Institute, National Research Council, Saskatoon, Saskatchewan. "Photosynthesis and the growth of peas—a genetic approach". May.

Dr. Heino Moldau, Institute of Astrophysicas and Atmospheric Physics, Estonian Academy of Science, USSR. "Interactions between whole-plant photosynthesis, accumulation of sugar and starch, synthesis of structural matter and functional components of dark respiration (laboratory experiments with *Phaseolus vulgaris* L.)" May.

Dr. David Day, Botany Department, ANU. "Physiology of a supernodulating soybean mutant" June.

Jeremy J. Bruhl, Taxonomy laboratory, RSBS, ANU. "Anatomy, biochemistry, CO_2 compensation point analysis and $\delta^{13}C$ values in the *Cyperaceae*". July.

Professor Gerhard Glatzel, Institute of Forest Ecology, Universitat f. Bodenkultur, Vienna, Austria. "Physiology of Mistletoes". October.

Dr. Joaquim Azcon-Bieto, University of Barcelona, Spain. "Has the non-phosphorylating mitochondrial alternative pathway a function in non-thermogenic plant tissues?" November.

Drs. Greg Unwin and Paul Kriedemann, CSIRO Division of Forest Research. "Drought tolerance and rainforest tree growth on a North Queensland rainfall gradient". November.

Dr. Fred (W.S.) Chow, CSIRO Plant Industry (joint seminar with Professor Barry Osmond of Plant Environmental Biology Group, RSBS). "Not the last word on photoinhibition". November.

Dr. Bill Thompson, CSIRO Forest Research. "Growth and photosynthesis in rainforest trees of contrasting shade tolerance". December.

THE FIRST SIR RUTHERFORD ROBERTSON SYMPOSIUM

The first Robertson Symposium on Biological Science, with the title Ecology of Photosynthesis in Sun and in Shade, was organised by Professor Cowan and colleagues and took place on the campus in February. There were some forty participants, eight of them from overseas. Professor Sir Rutherford Robertson delivered the opening address and attended throughout. The proceedings will appear as two numbers of the Australian Journal of Plant Physiology in 1989.

The Symposium will be held annually and is named in honour of Sir Rutherford Robertson, FAA FRS, who was Director of the School between 1972 and 1978.

The Plant Molecular Biology Group organized a November workshop on the "Molecular Taxonomy and Evolution of Plants". Over 50 plant scientists attended and contributed to the one-day meeting.

One guest speaker was Dr Elizabeth Zimmer from Louisiana State University, Baton Rouge. She described how she is determining the nucleotide sequences of ribosomal RNA genes, and using this information to assess the relatedness of the major lineages of plants. The other special guest was Professor Peter Martin of Adelaide University, who has directly sequenced part of the small *Rubisco* subunits of many flowering plant species, to obtain measures of their relatedness. The results of these studies mostly confirm the relationships found by more conventional taxonomic methods, but differ in some significant and interesting respects. Other topics that were discussed included studies of plant haemoglobins, alcohol dehydrogenases, ribosomal gene spacer regions and the genetic changes associated with speciation and domestication. The workshop demonstrated that many parts of the study of plant taxonomy and evolution are being rejuvenated by the new techniques of molecular biology and computerized means of handling information.

Emeritus Professor Sir Rutherford and Lady Robertson with the Director, Professor Slatyer (right) at the opening of the first Robertson Symposium. The Symposium will be held annually by the School and will present research results in areas in which the School has a strong international reputation. The Symposium's title honours Sir Rutherford for his contribution to the School, the University and Australian science.

EXTERNAL GRANTS RECEIVED

DEVELOPMENTAL NEUROBIOLOGY

Dr A.D. Blest received a grant from the National Geographic Society (USA) of $10,400 to support field studies on neotropical jumping spiders at the Smithsonian Tropical Research Institute, Republic of Panama.

Professor Mark and Dr C.H. Tyndale-Biscoe, CSIRO Division of Wildlife and Rangelands Research, received a CSIRO-ANU grant to support the creation of a stereotaxic atlas of the wallaby brain. This project has already started in the hands of a former student, Dr Lydia Mayner, and she will continue it next year. The value of the grant was $8,500.

MOLECULAR GENETICS

Dr Naora received an award of $34,665 from the Toyoto Foundation for studies on carcinogenesis with special reference to territorial effects.

Dr Clark-Walker was awarded a CSIRO-ANU collaborative Research Fund Grant for studies on the cloning and characterization of a copper metallothionein gene from yeasts, in conjunction with Dr Ian Macreadie, CSIRO Division of Protein Chemistry, Parkville, Victoria ($16,000).

POPULATION GENETICS

Dr D. Shaw and Dr R. Schodde (CSIRO Division of Wildlife and Rangelands Research) continued receipt of a grant from the CSIRO-ANU Collaborative Research Fund to study aspects of the origins and evolution of the Australian avifauna ($21,900).

PLANT CELL BIOLOGY

Professor B. Gunning (with Dr 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 at the National *Azolla* Research Centre in Fuzhou, PRC, and Dr W. Shaw, Darwin Institute of Technology. ($115,000).

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

Dr A. Hardham's National Research Fellowship, for research on the cell biology of the dieback fungus, *Phytophthora cinnamomi*, continued in 1987. ($27,000).

Dr P. Warren Wilson (with Prof J. Warren Wilson and Dr R. Overall) was awarded $22,160 for work on Initiation and Stabilization of Polarity in Plant Tissues, and (with Prof J. Warren Wilson), $8000 for a study of Mechanisms Controlling the Spatial Patterns of Differentiating Tissues in Plants, both from the Australian Research Grants Scheme.

Dr D.S. Letham was awarded a CSIRO-ANU Collaborative Research Fund Grant (with Dr T.J. Higgins) for research on molecular studies of cytokinin delayed leaf senescence. ($15,000)

Dr D. McCurdy was awarded a Queen Elizabeth II Fellowship to conduct research on actin in plant cells.

Dr L. Palni (with Dr J. MacLeod, RSC) was awarded a grant of $15,000 from the Coal Corporation of Victoria to investigate the growth promoting activities of humic acids.

Dr R. Williamson was awarded a National Research Fellowship for work on microtubule-associated proteins in plant cells. ($29,173).

PLANT MOLECULAR BIOLOGY

Betatene Pty. Limited of Melbourne, provided grants for research on the development of naturally derived products for the control of plant diseases and for research on viral inhibitors.

Dr B.G. Rolfe received grants from—The Agrigenetics Research Corporation for research on *Rhizobium*-legume symbiosis; Australian Wool Corporation and Australian Meat and Livestock Research and Development Corporation for research on the construction of *Rhizobium trifolii* strains which can nodulate subterranean clovers in acid soils. Public Interest Grant, Section 39, Department of Industry, Technology and Commerce continuation of studies on the development of a supernodulating soybean and its optimum *Rhizobium* inoculant strains. ACIAR grant (jointly with B.E.S. Gunning) for the development of molecular probes to identify symbiotic *Anabaena* strains and their host fern Azolla.

Dr K.F. Scott and Dr J. Watson received a joint CSIRO/ANU grant for work on *Rhizobium*. ($4,500).

Dr B.M. Tyler continued receipt of a CSIRO-ANU collaborative research Fund Grant in 1986/87 for 'Identification of multicopy transformants of *Neurospora* for bioengineering using phleomycin selection' jointly with Dr R. Hall (CSIRO Division of Molecular Biology).

Dr B.M. Tyler continued receipt of a National Research Fellowship for 1987–1990 for the study of 'Gene transfer between agriculturally important fungi and laboratory fungi'.

Support for the VIDE project was received from the Australian Centre for International Agricultural Research and from the Rural Credit Development Fund.

PLANT ENVIRONMENTAL BIOLOGY

Drs Terashima and Farquhar—$14,934 from CSIRO/ANU collaborative research project funds—Chloroplast thylakoid membrane composition in relation to electron transport capacity of leaves (with Drs. J.R. Evans, W.S. Chow and J.M. Anderson)

Dr Farquhar—$96,181 from ACIAR—Water-use Efficiency in Tropical Legumes.

Drs Farquhar and Hubick—$17,843 from Barley Research Council—Water-use Efficiency of Barley Genotypes.

Drs Farquhar and Hubick—$19,343 from Cotton Research Council—Water-use Efficiency and Response to Irrigation of Cotton Genotypes

ECOSYSTEM DYNAMICS

Dr I R Noble received a grant from the Australian National Parks and Wildlife Service for $15,000 to investigate plant life history characters and fire response categories of vegetation and develop a model predicting short- and long-term responses of woodland and forest communities in Kakadu National Park to different fire regimes.

OTHER ACTIVITIES OF THE SCHOOL'S ACADEMIC STAFF

DIRECTOR'S GROUP

The Director completed his term as Chairman of the Australian Science and Technology Council (ASTEC) in December. The Council reports to the Prime Minister on a range of subjects related to science and technology and, in particular, on the role of science and technology in Australia's economic development.

He visited Korea, Singapore and Hong Kong in May to examine education and skill formation programmes and research links between publicly funded research institutions, including universities, and industry.

The Director has continued to serve on a number of University Committees. In 1987 these included the ANU Council, as a representative of Heads of Research Schools; and the Committee established to review the Centre for Resource and Environmental Studies (CRES).

In relation to outside bodies, he has become Chairman of an Advisory Committee to the CSIRO Division of Plant Industry and Chairman of the Science Advisory Council of Calgene Pacific. He also joined the Board of Street Thompson Holdings Ltd.

DEVELOPMENTAL NEUROBIOLOGY

Dr Eldon Ball served on Review Committees for the Departments of Environmental Biology and Developmental Biology, RSBS, and for the Neurosciences Program of The Faculties. He co-ordinated the neuroscience contribution from RSBS to the 1987 National Science Summer School.

Dr A.D. Blest spent four months at the Barro Colorado Island Field Station of the Smithsonian Tropical Research Institute, Republic of Panama, from June to September. With Dr S.C. Trowell, he attended an ASEB Summer Symposium "*Biology and Chemistry of Vision*" at Copper Mountain, Colorado, by invitation, and visited the Neurobiology Division, the University of Arizona at Tucson, where he gave a seminar on the physiological optics of jumping spiders. He continues to be an Associate Editor of *The International Journal of Insect Morphology and Embryology*, and to chair the ANU Transmission Electron Microscope Advisory Committee. He is a member of the International Scientific Advisory Council of the International Conference on the Neurobiology of Sensory Systems, Goa, 1988.

Dr G.S. Boyan visited the following institutions and presented seminars: The Biology Department, Odense University, Denmark; the Institute für Vorklinische Medizin, University of Regensburg, FRG; the Lehrstuhl für Allgemeine Zoologie, Ruhr University, Bochum, FRG; Zoologisches Institut, University of Hamburg, FRG; Zoologisches Institut, University of Göttingen, FRG; Fakultat Biologie, Philipps University, Marburg, FRG; Institut für Biologie, University of Konstanz, FRG; Institut für Zoologie, University of Erlangen, FG; Department of Zoology, Cambridge University, U.K.; Section of Neurobiology and Behaviour, Cornell University, Ithaca, USA; Biology Department, Queens University, Ontário, Canada; the Departments of Physiology and Pharmacology, John Curtin School of Medical Research, ANU.

Dr K. Hill gave lectures at the Department of Psychology, Monash University, and the Department of Physiology, University of Western Australia.

Dr A. Gummer gave a seminar at the Department of Physiology, University of Queensland.

Professor Mark is Regional Editor for two journals, *Physiology and Behavior* and *Behavioural Brain Research*. He presented a seminar to the Medical Research Council Unit on Development and Regeneration at the University of Edinburgh and conferred with Dr Shin Ho Chung, a prospective visitor to the School, at the National Institute for Medical Research, Mill Hill, London. He was elected to the membership of the New York Academy of Sciences.

Dr I.S. McLennan was a member of the Boden Research Conference on *Muscle Activation, Contractility and Organisation* at Thredbo, March.

Dr H.G. de Couet was invited to teach in an advanced international molecular neurobiology course at the University of Freiburg, FRG, in September 1987 with scientists and students from Switzerland, France and West Germany. He gave research seminars at the University of Salt Lake City, Utah, USA;, the University of London, Western Ontario, Canada, and the University of Freiburg, FRG. He also conducted a course in Marine Biology for the Centre for Continuing Education, Canberra, April 1987.

Dr G. Miklos gave lectures to the CO2 Biochemistry students on molecular evolutionary genetics, The Faculties; to RSBS and JCSMR graduate students on introductory genetic engineering; and to the Evolution Series in the Geology Department, The Faculties. He also served on the editorial Board of *Molecular Biology and Evolution*.

In May, Dr J. Davies accepted a tenured lectureship in the Genetics Department, University of Glasgow, Glasgow, Scotland.

In May, Dr M. Yamamoto returned to his tenured post in the Department of Cell Genetics, National Genetics Institute, Mishima, Japan.

Dr H.G. de Couet accepted a tenured lectureship in the School of Biological Sciences at the University of New South Wales, Sydney, and will take up his appointment in January 1988.

VISUAL SCIENCES

Dr Dvorak was an invited Lecturer in Neurobiology in the Department of Zoology, coordinating a six week unit. He was also invited to give a seminar in the Department of Physiology, University of Sydney.

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 acted as 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. He was invited to give a seminar at the School of Nursing, Northern Rivers College of Advanced Education.

Professor Horridge has been appointed as Executive Director of the Centre for Visual Sciences, and as a member of the management committee for the Centre for Information Sciences. He is an Editor of the *Journal of Comparative Physiology* and was invited to the America Cup Challenge in Perth as a public speaker.

Dr Srinivasan was invited to give the following seminars: "Honeybee Vision", Dept. Psychology, ANU; "Vision in Invertebrates", in the Neurosciences Course, ANU; "Visual Behaviour of Honeybees", Institute of Biophysics, Academia Sinica, Beijing; "Behavioural Studies of Honeybee Vision", Institute of Apiculture, Beijing; "Neural Mechanisms Underlying Motion Perception in Insects", Institute of Biophysics, Academia Sinica, Beijing'; "Insect Vision: From Behaviour to Neural Circuitry", Fourth Military University of Medicine, Xi'an, Peoples Republic of China.

MOLECULAR GENETICS

Dr Clark-Walker gave a seminar at the Sclavo Research Center, Siena, Italy and lectured in the Department of Biochemistry in the course on Molecular Evolution. He also served as a course co-ordinator for the joint RSBS-Faculty of Science 4th year (Honours and Graduate Diploma) course in Cell Biology.

Dr Creaser gave four lectures on protein structure and purification and assisted with four practical sessions in the third year unit Advanced Biochemistry (CO7) in the Department of Biochemistry—The Faculties. Dr Creaser is a member of the Occupational Health and Safety Committee for RSBS and the Chemistry Library Advisory Committee

Mr Sun and Dr Naora presented their paper on "A novel regulatory mechanism for *c-myc* oncogene expression" at the meeting of the Australian Biochemical Society in Perth. Dr Naora and Mr Decruz presented a paper at the Cancer Symposium held at the Australian National University. Dr Naora organised a Symposium on "Recent Advances in Cancer Research" at the Australian National University with Drs I.A. Ramshaw and A.J.D. Bellett.

POPULATION GENETICS

Dr M. Arnold gave seminars at the Department of Biology, Texas Tech University, Lubbock, Texas, USA; the Department of Biology, University of Nevada-Reno, Nevada, USA; the Department of Organismic and Evolutionary Biology, Harvard University Cambridge, Mass. USA; the School of Biological Sciences, University of Nebraska-Lincoln, USA; the L.H.Bailey Hortorium, Cornell University, Ithaca, N.Y., USA; and the Smithsonian Tropical Research Institute, Balboa, Panama.

Dr D. Colgan visited and gave a seminar at the Waite Agricultural Research Institute, University of Adelaide.

Dr Gibson served on the Advisory Committee of the NH & MRC Australian Twin Registry. Dr Gibson continued to serve on the Editorial Board of The Annals of Human Biology, (UK).

Dr Shaw organised a symposium The Australian Biota: Contemporary Research in Evolution Biogeography and Systematics, for the Institute of Biology Annual General Meeting held at ANU in July. Dr Shaw was re-elected as ACT representative, Australian Institute of Biology.

PLANT CELL BIOLOGY

Professor B.E.S. Gunning was a member of the Biological Advisory Committee for the National Research Fellowships and Queen Elizabeth II Fellowships Scheme, Commonwealth Government Department of Science. He chaired the Australian Academy of Science Boden Research Conferences Committee and sat on the ANU Transmission Electron Microscope Advisory Committee and the Faculties—RSBS Cell Biology Honours Course Management Committee. He was Editor of the journal *Protoplasma* and a member of the Editorial Boards of the journals *Botanica Acta* and *The Journal of Cell Science*. He co-organized three symposia on the cytoskeleton and morphogenesis at the International Botanical Congress in Berlin.

Professor Gunning, Moira Galway, Ann Cleary, and Cathy Busby ran a two day laboratory course on plant cell biology for a class of 24 3rd year students from the School of Biological Sciences, University of Sydney.

Dr A. Hardham gave research seminars in the Department of Plant Sciences, Oxford University, U.K., and in the Institute fur Pflanzenbiologie, University of Zurich, Switzerland. She participated in running the ANU National Science Summer School in January, and co-supervised Geoffrey Hyde, an Honours student at the School of Biological Sciences, University of Sydney, working on factors affecting reestablishment of the growth axis in regenerating *Mougeotia* protoplasts. She served on the ANU Biological Science Library Advisory Committee and the ANU Transmission Electron Microscope Advisory Committee.

Dr Mineyuki presented seminars in the Department of Botany, University of Edinburgh, U.K., Institut fur Zellenlehre, Universitat, Heidelberg, FR Germany., and the Department of Plant Molecular Biology, Universiteit, Leiden, Netherlands.

Dr D. McCurdy spent the month of November performing collaborative research in the Department of Molecular, Cellular and Developmental Biology, University of Colorado, Boulder, USA. He also presented a seminar in that Department.

Dr L. Palni gave a seminar at the Horticultural Research Institute, Knoxfield, Melbourne, and worked as convener of a symposium on Plant Growth Regulators, International Plant Physiology Congress, New Delhi, India.

Mr G. Wasteneys won the prize for the best student paper at the annual meeting of the Australia and New Zealand Society for Cell Biology, and taught a course on Plant Microculture Techniques at the Bruce College of Technical and Further Education.

Dr R. Williamson served on the editorial boards of the *European Journal of Cell Biology* and of *Cell Biology International Reports*, and was co-organizer of a symposium on intracellular motility at the International Botanical Congress. He presented a seminar at the CSIRO Division of Plant Industry.

PLANT MOLECULAR BIOLOGY

Dr Gibbs was convenor of a third-year "Molecular Evolution" course in the Faculty of Science and Drs Keese and Meek contributed to the course, and Dr Gibbs gave lectures on virology in the Faculty of Science and at the C.C.A.E. Dr Gibbs organized a symposium at the 7th International Congress of Virology to which he and Dr Meek contributed invited papers, Dr Gibbs is a member of the Scientific Advisory Board of *Plant Pathology* and a member of the Editorial Advisory Board of *Archives of Virology*. He concluded a 3 year term as a member of the Board of the Institute of Advanced Studies, continued to serve on the Committee on Public Affairs and Continuing Education and joined the Scientific Advisory Committee of the Centre for Resource and Environmental Studies.

Dr B.G. Rolfe consulted with the Patent Department, Agrigenetics Corporation, Boulder, Colorado, visited and presented seminars at UCLA, Los Angeles; University of Colorado, Department of Molecular, Cellular and Developmental Biology, Boulder; Department of Microbiology, Michigan State University, East Lansing, USA.

Dr Scott presented a seminar in the Department of Botany, The Faculties, ANU and another in the Department of Microbiology and Genetics, Massey University, New Zealand.

Dr Tyler devised and supervised a practical class in recombinant DNA techniques in the Department of Biochemistry, ANU. Dr Tyler presented seminars in the Department of Biochemistry, ANU and at the Department of Plant Pathology, University of California at Davis, USA. Dr Tyler served on the ANU Hazardous Wastes Committee.

Mr Watson represented the School on the Graduate Degrees Committee, and represented the Institute on the Divisional Board of Educational Services.

PLANT ENVIRONMENTAL BIOLOGY

Professor Osmond took Outside Studies for two periods. The first, in March and April, included lecturing at the 6th Annual Symposium in Plant Biochemistry and Physiology (in which Dr Graham Farquhar also participated) at the University of Missouri and the Symposium "Rubisco 87" (in which Drs Andrews and Farquhar also participated), University of Arizona, and working visits to Duke University and the Desert Research Institute, Reno, Nevada. During the second, in July and August, Professor Osmond was Symposium Chairman and discussion leader at the Gordon Conference on CO_2 metabolism in green plants (in which Dr von Caemmerer also took part), Plymouth, and the Symposium Chairman at the International Botanical Congress in Berlin. He visited and was involved in scientific meetings at, Duke University and the Universities of Sheffield and Bayreuth. Five other members of the Group, Professor Cowan, Drs von Caemmerer, Farquhar, Hubick and Terashima also contributed to the Congress in Berlin.

Dr Farquhar spent a short Outside Studies period, in March and April, lecturing at the Universities of Illinois and Washington and taking part in symposia mentioned above. He left again in July on a more extensive programme and is working at the University of Paris-Sud, Structure et Metabolisme des Plantes. In addition to his attendance at the International Botanical Congress in Berlin, at which he was a Symposium Converor, he has taken the opportunity to participate in the Society for Fxperimental Biology Meeting, Colchester, July, the VIth International Conference on Mediterranean-climate Ecosystems, Montpellier, July, and the Second German-French Colloquium in September. He was a member of the Advisory Committee for the Australian Journal of Plant Physiology. He was the Editor of Planta. He was also a member of the Australian Committee for International Geosphere-Biosphere Programme, a member of the International Photosynthesis Committee and a member of the editorial board of Functional Ecology (British Ecological Society).

ECOSYSTEM DYNAMICS

Dr Ian Noble is a Member of the Australian National Committee for the Man and the Biosphere Programme. He is also a member of the National Committee for Plant Sciences, Australian Academy of Science and a member of the Australian Organising Committee for the IUBS 1988 General Assembly. He is a member of the editorial Board, UNESCO/MAB Book Series, the editorial board, Australian Journal of Ecology and the Editorial Board, Environmental Software. He is a consultant to the Australian National Parks and Wildlife Service on fire management. He is also a consultant to the UK Department of Environment and the Institute for Terrestial Ecology on application of expert systems to managing changing land use. He gave seminars at University of East Anglia, Cambridge University and Imperial College. Dr Noble is a Member of the Research Committee of the Centre for Resource and Environmental Studies, ANU and a member of the Subcommittee on University Computing Requirements, ANU.

Dr Tom Smith gave seminars at the University of Virginia and Oak Ridge National Laboratory

Dr Bruce Wellington is Book Review Editor, *Australian Journal of Ecology* (to May). He was a guest lecturer, School of Horticulture, Riverina College of Advanced Education, Wagga

PUBLICATIONS

SYMBOLS

In this section symbols are used to indicate when authors are not members of the School. The symbols are:

\# visiting research worker
\+ not a member of this University
* former member
† member of another part of the University
§ former visiting research worker

DIRECTOR'S UNIT

Published

Slatyer, R.O. UNESCO programs over the years. UNESCO Review No. 15, 14–17.

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DEVELOPMENTAL NEUROBIOLOGY

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Dr Jim Fullard, University of Toronto
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VISUAL SCIENCES

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Dr Les Philip Davies, Dept of Community Services & Health, ACT
Dr Wolfgang Kirchner, Zool. Inst. der Univ., West Germany
Prof Bob Pinter, University of Washington, USA
Dr Miriam Lehrer, University Zurich, Switzerland
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MOLECULAR GENETICS

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Patrick Skelly, BSc, MSc (Dublin) PhD (ANU) (from April)

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Chris Hardy, BSc
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Adam Marchant, BSc
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Lun-Quan Sun (Anhai University), MSc (The Fourth Military College, PRC) (until June)

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Allan Lindsay Freeth, BSc(Cant),PhD

Queen Elizabeth II Fellow
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Dr Rudi Appels, CSIRO Divison of Plant Industry, Canberra(until Dec)
Dr Peter Luykx, University of Miami, Florida (until June)
Dr Edna Watson, (until Dec)

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Janette Norman (jointly with Dept of Zoology)(until Dec)

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Susan Maynes, DipAnimal Care (NSWIT)

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David Alan Willcocks, DipAppSc(Biol)(CCAE) (until Dec)

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Russell Cameron (until Dec)
Thi Huiynh Anh Cao, BLet(Saigon)
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Graham Carl von Schill, (until Sep)

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PLANT CELL BIOLOGY

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Lok Man Singh Palni, MSc (Gorak), PhD (Wales) (until August)
Jacek Plazinski, MSc, PhD (Krakow)

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David McCurdy, BSc, PhD (La Trobe)

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Dr Jane Badenoch-Jones
Dr Claudine Franche, Orstom Institute, Paris
Dr Franz Grolig, Justus Liebig Universitat, Giessen (from April)
Dr Yoshinobu Mineyuki, University of Tokyo (until Sep)
Professor Murdoch Mitchison FRS, University of Edinburgh
Dr Lok Man Singh Palni (from Aug)
Dr Sally Stowe (until Jun)
Dr Pamela Warren Wilson
Dr Ren Zhang, Academia Sinica, Beijing (from Mar)

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Ann Cleary, BSc (Monash)
Arthur Davis, BSc, MSc (Guelph) (from Sep)
Moira Galway, BSc (Car)
Janet Gorst, MSc (NE) (until Mar)
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Santokh Singh, BSc (Puchan), MSc (PAU)
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John Wicks BRTC (jointly with Plant Environmental Biology Group)

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Ursula Hurley, BSc (Natal)
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Frank Sek, BApSc (CCAE)

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PLANT MOLECULAR BIOLOGY

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Jacek Plazinski, MSc. PhD, (Krakow)
Brett Tyler, BSc (Monash), PhD (Melb)
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Layne Huiet, BSc (Duke) PhD (Georgia) (from June)
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Jeremy Weinman, BSc, PhD

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Dr A.A. Brunt, Glasshouse Crops Research Institute, Littlehampton, U.K. (Jan)
Dr. M. Damanakis, Biology Department, University of Crete (Sept–Oct)
Dr Miriam Fisher, Zoology, Faculty of Science, ANU
Shizhen Huang, Fugian Academy of Agricultural Sciences, China
Dr Claudine Franche, ORSTOM Instit. Paris, (until May)
Dr Elizabeth Zimmer, Louisiana State University, USA—Nov.

Visitors
Alan Richardson, Univ of Melb (until Sept)
Petra Gross, MSc (Goetinger) (from Nov)
Xue-juan You (Beijing) (Feb–Aug)

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Yuxin Mao, BSc (Zhejiany Agricultural University)(from July)
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Louise Currie
Jennifer Howe, BSc (from Sept)
Anne Moten, BSc (Adel) BA
Fiona Oliver (Until May)
Lynette Preston, BAppSc
Susan Perry, Dip AppCs (CCAE)
Craig Stanton

Secretary
Louise Booth (from March)

PLANT ENVIRONMENTAL BIOLOGY

Professor and Group Leader
Ian Roy Cowan, MSc (Lond), PhD (Nott), FAA

Professor
Charles Barry Osmond, MSc (NE), PhD (Adel), FAA, FRS

Senior Fellow
Graham Douglas Farquhar, BSc (Qld), BSc, PhD

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)
Suan Chin Wong, MSc (Nanyang), PhD

Postdoctoral Fellows
Graeme Dean Price, BSc, PhD (National Research Fellow)
Ichiro Terashima, BSc, DSc (Tokyo)
Matthew Kennedy Morell, BSc, PhD (Syd) (National Research Fellow) (from May)

Visiting Fellows
Dr T. John Andrews, Australian Institute of Marine Science (on secondment)
Dr Enrico Brugnoli, Istituto per l'Agroselvicoltura, Porano (to June)
Emeritus Professor Denis J. Carr
Mrs S.G. Maisie Carr
Dr Christoph Giersch, Universitat Dusseldorf (to March)
Mr Lin Ke Huang, Rice Research Institute, Guangzhou (to July)
Dr Richard Leegood, University of Sheffield (Apr–May)
Dr Heino Moldau, Estonian Academy of Sciences (Feb–May)
Professor David Walker, University of Sheffield (from Nov)

Research Students
William W. Adams, III MS (Kansas) (to July)
David Bagnall, BSc (UNSW), MA
Anthony Gerard Condon, MSc (Syd) (to July)
Daryl Edmondson, MSc (Auck)
Sally Henderson (from Feb)
Lin-Ke Huang (from July)
Jian-Wei Yu, MSc (Guangzhou)

Research Officer
O. Choon Wong, MSc, PhD (W'gong) (jointly with Plant Cell Biology Group)

Senior Technical Officers
Win S. Coupland
Anne Gallagher, BRTC
Derek Millar
John Wicks, BRTC (jointly with Plant Cell Biology)

Technical Officers
Peter Groeneveld, BSc (For)
Prue Kell, BRTC
Veronica Ross, BA, LittB (from March)

Laboratory Technicians
Henrietta Ficker (jointly with CSIRO) (to Jan)
Frank Fox, BSc (cas)
Wesley Keys
Sue Kirby (from March)
Guy Lederbauer (cas)
Sue K. Wood

Laboratory Attendant
Jean E. Hardy (part-time)

Secretaries
E. Jane Vickers (part-time)
Leonie Hoorweg (cas)

ECOSYSTEM DYNAMICS

Fellow and Group Leader
Ian Roy Noble, BSc, PhD (Adel)

Research Fellow
Thomas M. Smith BSc (WVa) PhD (Tennessee)
Alan Bruce Wellington, BSc (Monash), PhD

Visiting Fellows
Dr Michael P. Austin, CSIRO Division of Wildlife and Rangelands
Dr Jill Landsberg, CSIRO Division of Forest Research (from May)

Research Students
Michael Hodda, MSc
Heather Keith, BSc (NSW)
Jennifer Jill Landsberg, BPharm, DipEd BSc (Qld) (to April)
Andrew Moore, BSc (Adel)
Susanne Prober BSc Agr (Syd)
Michael Strasser, BSc (Monash) (part-time from Feb)
Jann Williams, BSc (Melb)

Head Technical Officer
Peter Cochrane, BSc

Assistant Programmer
Michael Strasser, BSc (part-time from Feb)

Laboratory Technicians
Penny Butcher, BNatRes (UNE)
Graham von Schill (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
Carol Barmin
Margaret Mitchell
Heather Morgan
Diane Price
Sandra Ottey (to October)
Tania Felton (Temp)
Tania Hoffmann (Trainee)
Tea Assistant
Ivy Grace Wind (to June)
Audrey Coupland (from July)

Security and Cleaning
Head Watchman/Janitor
Terence James Durrant
Watchman/Janitors
Alexander King Kyle
William Kyle
John Nelson
Stanley Kelly
Robert Payne
John O'Rourke (to August)
Cleaners
Cveta Bodrozic
Eva Versegi
Slavica Skrobot
Ruza Skrtic
Marica Peric
David O'Rourke
Liza Robregado

Store
Chief Storeman
Werner Gunther Friedrich
Senior Storeman
Robin George Mark Hassall
Clerk
Annemarie Thaller
Storeman Driver
Nenad Vidovic (to November)
George Roussidis (fm November)

Laboratory Preparation
Laboratory Attendants
Jeane Atkinson
Elizabeth Cipe
Jean Hardy

Workshop
Head Technical Officer
Walter Pfluger
Senior Technical Officers
Douglas Crawford
Kerry Richens
Reginald Dwyer
Technical Officers
Mark Buckley
Doug Turnbull
Senior Laboratory Craftsmen
Godfried Aschenberger
Leonard Palmer
Michael Gerstenbuehler
Tad Rudzcuk
Greg Jackson (from July)
Gian Franko Foppoli
Paul Larsen
Malcolm Andrew Lamond
Jan Reyn
Alfred Lee (from June)
Paul Cairns (to May
Stan Ruzinski (to June)
Steve Fulham (Temp)
Senior Adult Storeman
Graham Edwards
Apprentices
Dan Brian Grant
Daniel John Clayton
Paul Melis
Laboratory Technician
Martyn Smith (to November)

Computer
Programmer
David Sandilands
David Smith (to October)
Assistant Programmer
Steven Ball (fm October)

Gas Chromatograph/Mass Spectrometer
Research Officer
Onn Choon Wong, PhD (W'gong)

Photography and Illustration
Senior Technical Officer
Maureen Whittaker
Technical Officer
Garry Stephen Hanson
Illustrator
Garry Brown
Laboratory Technicians
James Whitehead (fm June)
Maocan Cai (Temp)
Simon Carter (to June)

Plant and Animal Culture
Senior Technical Officer
Paul Thomas Puttifoot
Technical Officers
Ronald Colin Dencio
Peter Hank Fokker
Laboratory Technician
David Jones Ferguson (to January)
Labourer
Debra Kay Rankin
Paul Smider (Casual)

ELECTRON MICROSCOPE UNIT

The School houses a University facility, the Electron Microscope 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 heavilly used and is much appreciated, by RSBS researchers.

Head Technical Officer
George Hunter Weston
Senior Technical Officers
David James Llewellyn
Sally Stowe
Technical Officer
Ian Andrew Duff
Laboratory Technicians
Katherine Lorna Asmussen
Alison Margaret McLean

STUDENTS' THESES SUBMITTED AND EXAMINED DURING 1987

DEVELOPMENTAL NEUROBIOLOGY

Doctor of Philosophy

Comans, P.E.
Thesis: Development of motoneurons in the lumber spinal cord of the wallaby.

Guppy, A.
Thesis: Comparative acoustical and physiological studies of hearing and directionality in vertebrates.

Trowell, S.C.
Thesis: The role of phosphatase enzymes in invertebrate photoreceptors.

Master of Science

Flett, D.
Thesis: Topography of retinal projections to the colliculus and geniculate in the wallaby (*Macropus eugenii*).

MOLECULAR GENETICS

Doctor of Philosophy

Decruz, E.E.
Thesis: Molecular characterization of the novel gene *nbl* in normal and tumour cells.

Miyahara, K.
Thesis: Molecular Topological plasticity of a dual promoter gene: The *Drosophila Melanogaster* Adh gene.

POPULATION GENETICS

Doctor of Philosophy

Freeth, A.L.
Thesis: Studies on alcohol dehydrogenase null alleles from natural populations *Drosophila melanogaster*

McIntyre, C.L.
Thesis: Evolutionary relationships among species of the *Triticeae*

Rowell, D.M.
Thesis: Population genetics of the huntsman spider *Delena cancerides* Sparassidae: Arachnida).

Smith, A.M.A.
Thesis: The sex and survivorship of embryos and hatchlings of the Australian freshwater crocodile *Crocodylus johnstoni*

PLANT CELL BIOLOGY

Doctor of Philosophy

Gorst, J.R.
Thesis: Studies of cell proliferation and somatic embryogenesis in suspension cultures of *Daucus carota*.

Zhang, R.
Thesis: Cytokinin metabolism and translocation in relation to leaf senescence and fruit development of leguminous plants.

Master of Science

Busby, C.H.
Thesis: Development of the meiotic cytoskeleton in Bryophytes.

PLANT MOLECULAR BIOLOGY

Doctor of Philosophy

Chen, H.
Thesis: Studies on the role of exopolysaccharides in *Rhizobium* infection of plants.

Djordjevic, S.P.
Thesis: A chemical and genetic analysis of the role of *Rhizobium* exopolysaccharides in the infection of legume species.

Prendergast, H.D.V.
Thesis: Structural, biochemical and geographical relationships in Australian C_4 grasses (Poaceae).

Weinman, J.J.
Thesis: The molecular genetics of nitrogen fixation in the Bradyrhizobium sp. (Parasponia) strain ANU 289. (Jointly enrolled with Department of Botany, Faculty of Science.)

Cell Biology Honours
(This is a fourth year honours program run by the School in association with the Faculty of Science.)

Arioli, T. A molecular analysis of an exopolysaccharide overproducing mutant of *Rhizobium* strain NGR234.

Osorio-Keese, M. (Graduate Diploma) Sequence analysis of the genomic RNA of two tymoviruses: eggplant mosaic virus and Andean potato latent virus.

Stanton, J. Isolation and characterization of the *nod*LMN genes in *Bradyrhizobium parasponia* strain ANU289.

PLANT ENVIRONMENTAL BIOLOGY

Doctor of Philosophy

Adams III, W.W.
Thesis: Photosynthetic acclimation and photoinhibition of CAM plants in response to different light environments.

Condon, A.G.
Thesis: The use of carbon isotope discrimination in screening wheat genotypes for efficient use of water.

Master of Science

Ariffin, Z.
Thesis: Regulation of protein synthesis of abscisic acid and phaseic acid in barley aleurone layers.

ECOSYSTEM DYNAMICS

Doctor of Philosophy

Landsberg, J.J.
Thesis: Dieback of Rural Eucalypts: Dietary Quality of Foliage and Insect Herbivory.