ChE at the

University of Melbourne

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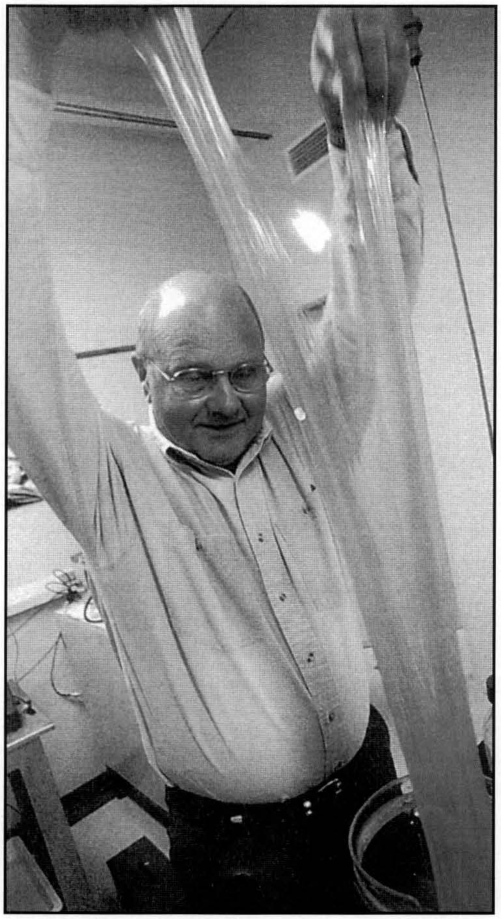
The University of Melbourne has a reputation as being Australia's leading research university, attracting more competitive research funds than any other university in the country. Likewise, the Chemical Engineering Department at Melbourne is recognized as one of Australia's leading departments in terms of both its research and its teaching.

The city of Melbourne, with a population of some three million people and located in the southeastern corner of Australia, was founded in 1835 by settlers who moved there from the first settlement in Sydney. It prospered when gold was discovered some 110 km to the west in the 1850s, and by 1861 it had become the largest city in the country as a result of the influx of immigrants eager to try their luck in the goldfields. In 1901, Melbourne became the temporary capital of the newly independent country of Australia and it soon became the manufacturing base of Australia. Following World War II, European immigrants brought diverse cultures to the city, and in 1956, it became known around the world as the home of the Olympics. Decades later, a second wave of immigrants, mainly from neighboring Asian countries, again enhanced the culture of the city. Home to major sporting events and superb restaurants, Melbourne has repeatedly won accolades as being the "World's Most Livable City."

The University of Melbourne became Australia's second university when it was founded in 1853. The University's motto, *"Postera crescam laude"* is often rendered as "Growing in the esteem of future generations." Its mission is to make the University of Melbourne one of the finest universities in the world. It is located just one kilometer north of the downtown area and is a broad-based university with faculties of architecture and planning, arts, economics and commerce, education, engineering, law, medicine, music, science, and veterinary science. The university has over 34,000 enrolled students, including over 9,000 graduate students, and over 2,100 academic staff members. It is a founding member of the Universitas 21 international consortium of universities.



Professor David Boger's work with non-Newtonian fluids has defined a new class of fluid behavior.

The first engineering degree was awarded in 1883. Since then, the University has played a leading role in the education of generations of professional engineers in Australia. In more recent times, the University has established a reputation for excellence in the Asia-Pacific region, attracting increasing numbers of international students to its various engineering disciplines. The university offers degree programs in chemical engineering, civil engineering, computer engineering, computer science, electrical engineering, electronic engineering, environmental engineering, geomatics, manufacturing engineering, mechanical engineering, mechatronics, and software engineering.

The Chemical Engineering Department is one of the largest in Australia, with more than 600 undergraduate students currently enrolled in its courses. In addition, more than 80 students are presently enrolled in its postgraduate programs. Women represent nearly half of the undergraduate population, one of the highest proportions of any engineering department in Australia.

THE UNDERGRADUATE PROGRAM—THE MELBOURNE PARADIGM

Flexibility is the key word that describes the undergraduate chemical engineering program at Melbourne. It is this flexibility that allows the majority of the students in the Department to enroll in not one, but two, undergraduate degree programs.

Until the late 1980s, the four-year structure of the chemical engineering degree was very rigid. The subjects and the sequence in which they were to be studied were prescribed. Students studied the basic sciences of mathematics, chemistry, and physics. In their first year they also received general engineering education across the other major engineering disciplines, and over the last three years of the course they undertook studies in chemical engineering science, practice, and design. They also studied process economics, management, and engineering law.

Occasionally, permission was given for students to take one or two non-engineering subjects, allowing them to pursue some other interest. These subjects were taken either in addition to their normal study loads (*i.e.,* as an overload) or in lieu of certain specified subjects. If the student wished to complete two degrees, then there was no alternative but to pursue them consecutively. Usually some credit was given toward the second degree for work performed in the first degree. For example, a student who had completed a three-year Bachelor of Science (BSc) degree might be given one year of credit toward a four-year Engineering (BE) degree. This would reduce the total time taken to obtain both undergraduate degrees from seven years to six years.

Beginning in the late 1980s, students were permitted to pursue two degrees simultaneously. By taking extra subjects in each semester and by spreading the content of both degrees over the entire time, it became possible to achieve a reduction in the time required to complete the requirements of both degrees. For example, instead of taking seven years to complete studies toward undergraduate degrees in engineering and commerce, it became possible to gain both degrees in only five years. The workload required to accomplish this feat, however, was very heavy, with overloads required in every semester. Only students with demonstrated abilities were permitted to enroll in concurrent degrees.

In 1990, the first combined-degree program involving chemical engineering was introduced when the combined Bachelor of Engineering/Bachelor of Science (BE/BSc) program was offered. Its structure made it possible for a student to meet the requirements of both degrees in just five years. The reduction in the time required to complete two degrees is achieved by the existence of material common to both degrees, *e.g.,* chemistry and mathematics. It should be noted, however, that it is not possible to obtain a BSc degree by simply studying for an additional year after completing the BE degree. Study for the two degrees must be integrated from the moment the student enters the University.

The Bachelor of Engineering/Bachelor of Arts (BE/BA) combined degree program was introduced in 1992, allowing students to pursue an interest in a language, history, or other arts major while undertaking the engineering degree. Like the Bachelor of Engineering/Bachelor of Commerce (BE/BCom) degree introduced later, the BE/BA degree requires five years of study. The combined Engineering and Law (BE/LLB) degree requires six years of full-time study.

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Since their introduction, the popularity of the combined-degree programs has increased to the point where students enrolled in them now make up the majority of chemical engineering students. Prior to 1990, about three students each year began studying concurrent degrees, and the number of students entering the chemical engineering undergraduate program was steady at between 60 and 70 students. Following the introduction of the first combined-degree programs, enrollments began to increase, initially at the expense of the single-degree program. By 1994, the number enrolling in the chemical engineering programs had almost doubled, peaking at over 140.

While such combined-degree programs are available at most Australian universities, the University of Melbourne has the highest proportion of combined-degree students in the country. Currently, 70% of the students in the Department are enrolled in combined degrees. Since its introduction, the BE/BSc program has been the most popular of all combined-degree programs. Not surprisingly, chemistry has proven to be the most popular science major among the students, as many see it as the natural complement to their chemical engineering studies. After chemistry, the next most popular science majors are the biological-based sciences, biochemistry, and microbiology. In more recent years, the study of pharmacology and genetics has become popular with the BE/BSc students. Other science disciplines that combined-degree students have enrolled in include biology, botany, computer science, geology, psychology, and zoology.

Of the BE/BA students enrolling over the same period, more than 80% have undertaken a language as their Arts major. Other majors include criminology, fine arts, history, linguistics, politics, psychology, and women's studies. The diverse nature of studies chosen by the students is indicative of the flexibility of these programs.

BE/BCom students are able to enroll in commerce subjects ranging from microeconomics to accounting and from personnel management to international trade. BE/LLB students often choose to complement their chemical engineering studies with subjects such as corporate law, corporate governance, and international law.

In a recent survey of the future directions for chemical engineering education, James Wei suggested that it was time for chemical engineering educators to seek a new paradigm. He suggested several possibilities that would empower engineering graduates to meet the challenges of the new century. Should chemical engineering become more oriented toward perceived societal needs such as environmental protection, manufacturing efficiency, and sustainability? Should it move to embrace developing disciplines as exemplified by information technology, nanomaterials, and tissue engineering? Should the educational processes focus more on people, teamwork, leadership, and communication skills? Should it broaden to more hybrid degrees of financial engineering? Or should chemical engineering education focus not so much on the design of new processes, but more on the development of new products?

As in any industry, chemical engineering educators must also consider the demands of their clients, namely their students, the processing industries, and the chemical engineering profession. In the last two decades of the 20th century, the petrochemical industries, traditional employers of chemical engineering graduates, cut back their graduate recruitment programs. In order to find employment, graduates began to consider the opportunities in non-traditional industries such as food, finance, and pharmaceuticals. Can the search for Wei's new paradigm and the changing requirements of the clients be answered in a single development?

At the University of Melbourne, we believe that our extensive combined-degree program is possibly the new paradigm. While no single engineering program can produce chemical engineering graduates at home in all the emerging areas from tissue engineering to intelligent processes, the chemical engineering graduates take with them into the work place understanding and expertise in a range of disciplines. This is the Melbourne paradigm.

The Department also has an excellent record in teaching. Every year the Graduate Council of Australia surveys graduates from all universities across all technical and non-technical disciplines. Using the responses to twenty-four questions, each teaching department in the country is given a score for several different categories. The survey of 1998 graduates showed that Melbourne's Chemical Engineering Department was one of the top departments in its discipline. It ranked second among the ten Australian chemical engineering departments on the *Good Teaching* and *Clear Goal* scales and in terms of overall satisfaction with the course.

International exchange is also a feature of the undergraduate program. As a member of the Universitas 21 consortium, the Department has a number of undergraduate exchange programs in place with leading universities around the world. These programs generally permit our students to spend up to twelve months at a foreign institution, usually in their third year. Each year the Department also has a number of study-abroad students from around the world who come to the university for a single semester. These students are always welcome.

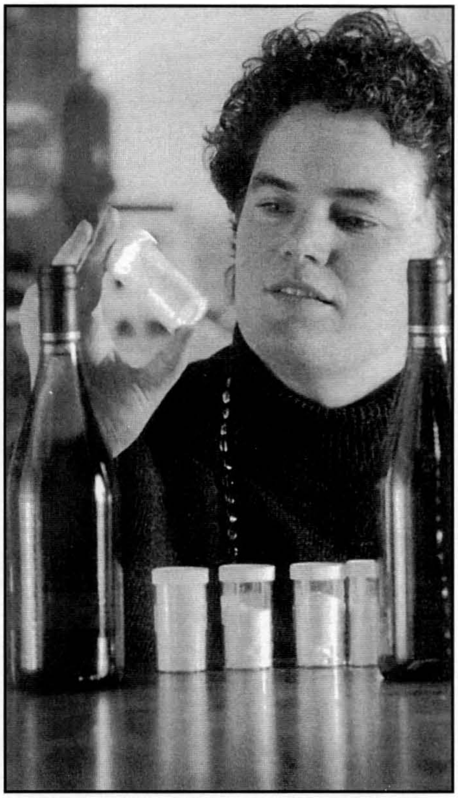
RESEARCH

The Department is one of Australia's leading chemical engineering departments in terms of research. In 1998 it had the highest competitive-grant research income of any Australian chemical engineering department (with an income of more than $217,000 per full-time equivalent staff member) and published more papers per government-funded staff member than any other Australian chemical engineering department. The research activities of the Department are diverse and are focused principally around the three research centers

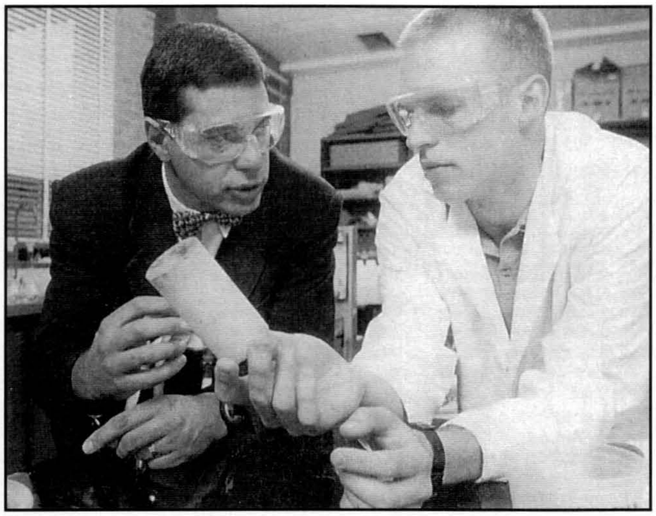
- *The G.K. Williams Cooperative Research Centre for Extractive Metallurgy*
- *The Particulate Fluid Processing Centre, a Special Research Centre of the Australian Research Council*
- *The Cooperative Research Centre for Bio Products*

The centers are at the forefront of international research and are the outward face of the Department's research expertise. Supporting the centres is a fundamental research infrastructure comprising: non-Newtonian fluid mechanics, high-temperature thermodynamics, separation processes, and computational fluid dynamics. Other research areas of significance are biochemical engineering, environmental engineering, fluoride process engineering, development technologies, pulp and paper, and, more recently, polymer science and mineral processing.

The G.K. Williams CRC for Extractive Metallurgy creates new, technically competitive advantages for the Australian smelting industry based on enhanced smelting proficiency.



Dr. Andrea O'Connor's work with mesoporous silica has potential applications in the Australian wine industry.



Professor Jannie van Deventer and graduate student Johan van Jaarsveld with a geopolymer test cylinder.

Professor Geoff Stevens and recent graduate Dr. Brenda Hutton setting up an experiment with supercritical carbon dioxide.

It was established in 1991 as a joint venture between the Commonwealth Scientific Industrial Research Organization (CSIRO) and the University of Melbourne. Research is focused on high-temperature processes involving both fundamental and applied research, with world-class research capability in measurement and modeling of thermodynamic and transport properties of solids and melts at high temperature, physical modeling of high-temperature operations, flow visualization, and laser flow diagnostics and computational fluid dynamics of multi-phase complex flows. Many research achievements have resulted in improved technical and economic performance for industry, including a licensing agreement with major international companies to commercialize a new patented concept and design of composite refractory cooling systems.

The Particulate Fluids Processing Centre (PFPC) develops key science for the processing of particulate fluids of all kinds, concentrating on systems involving solid and liquid particles where the dispersed phase is colloidal in nature. Through the coordination of proven international strengths in surface chemistry, continuum mechanics, and non-Newtonian fluid mechanics, the PFPC effectively solves particulate fluid processing problems experienced by the agricultural, chemical, food, inkjet printing, mineral, water treatment, waste management, ceramic, and pigment industries.

The Cooperative Research Centre (CRC) for Bio Products is a collaborative venture with three participants: The University of Melbourne (Botany School and Chemical Engineering Department), CSIRO, and industry. Professor David Boger leads the Department's participation and heads the Fundamental Testing and Hydrocolloids node of the CRC. The main goal is to "establish the science and technology underpinning the manufacture of plant biopolymers for the food and other industries." Research of the group is focused toward understanding the fundamental structure-function relationships of biological molecules directed at applications. The key fundamental research areas are understanding the adsorption to and stabilization of the oil-water interface using biopolymers and the rheology and gel behavior of these systems. Fundamental programs include rheological characterization of novel gelling biopolymers for new material

ACADEMIC STAFF

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■ Professors

- **David Boger** is Laureate Professor of Chemical Engineering and Director of the Particulate Fluids Processing Centre. He is also a Program Leader in the Cooperative Research Centre for Bio Products. His research is primarily in non-Newtonian fluid mechanics, with interests ranging from basic polymer and particulate fluid mechanics to applications in the minerals, coal, oil, food, and polymer industries. The winner of many international awards, he has published nearly 300 papers and consults widely around the world.
- **Geoff Stevens** is Professor and Head of the Department. He has an international reputation in solvent extraction, interfacial phenomena, and emulsion stability and is presently Secretary General of the International Solvent Extraction Committee. His research is primarily in the hydrometallurgical field, but also covers aspects of food, pharmaceutical processing, and environmental or waste-water processing.
- **Jannie van Deventer** is Professor of Mineral and Process Engineering. He is the leader of the Mineral Processing Group. His research interests include diagnostic leaching of gold ores, extraction of gold by activated carbon, modeling of simultaneous leaching and adsorption processes, image analysis of flotation froth, transport processes in froth flotation, geopolymerization of waste materials, immobilization of toxic waste, and simulation of ill-defined processes using artificial intelligence.
- **David Wood** is Dean of the Faculty of Engineering and Professor of Engineering. He is the immediate Past Chair of the Institution of Chemical Engineers in Australia and a former Vice-President of the Institution of Chemical Engineers (UK). Over the last thirty years his research has ranged widely, but in more recent years it has focused on fluoride processes. He is presently Chair of the Sixth World Congress of Chemical Engineering, which will be held in Melbourne in September 2001.

■ Professorial Fellow

- **David Solomon** is a Professorial Fellow within the Department. He leads the Polymer Science Group and is best known in Australia as the leader of the research team that developed the plastic bank note, currently in circulation throughout Australia.

■ Readers and Associate Professors

- **Malcolm Davidson** is a Reader within the Department. Trained as an applied mathematician, his research interests include computational fluid dynamics in process engineering. Much of his current work is associated with the G.K. Williams Cooperative Research Centre for Extractive Metallurgy.
- **Neil Gray** is a Reader within the Department. After spending several years with BHP Central Research at Newcastle, New South Wales, he has continued his main research interest in the area of physical and mathematical modeling of rate phenomena in metallurgical processes. He is currently Program Leader in the G.K. Williams Cooperative Research Centre for Extractive Metallurgy. In conjunction with WMC Resources Ltd, a licensing agreement has recently been signed with major international companies to commercialize a new patented concept and design of composite refractory cooling systems.
- **Peter Scales** is a Reader in the Department. His research activities include understanding the measurement and application of compressional dewatering of solid materials and the rheological and electrokinetic characterization of concentrated suspensions of particles. Unit operations of interest include clarification, thickening, and filtration and an aim is to be able to predict and optimize these operations from first principles on the basis of laboratory measurements. Interests in the area of characterization of suspensions include the use of electroacoustics and the failure of concentrated flocculated suspensions of particles in shear.
- **Neville Pamment** is an Associate Professor of Chemical Engineering and leads the Biochemical Engineering activities in the Department. He is a Commissioner of the International Yeast Commission. His research interests range from ethanol production from lignocellulose using recombinant bacteria to the kinetics and physiology of product inhibition in microbial fermentations.
- **David Shallcross** is an Associate Professor and Universitas Fellow in the Department. His research interests include ion exchange and enhanced oil recovery. The author of two books, he is active in the secondary school community, developing teaching material aimed at raising the profile of the engineering profession among school students. He is also Chair of the Program Committee for the Sixth World Congress of Chemical Engineering and is Associate Dean (International) for the Faculty of Engineering.

■ Lecturers

- **Mike Conner** is Senior Lecturer and Deputy Head of the Department, responsible for all undergraduate matters. He is also a Deputy Director of the University's Office of Environmental Programs. His research interests lie mainly in the areas of environmental engineering and policy and thermochemical biomass conversion.
- **Geoff Covey** is Senior Lecturer and is responsible for supervising the final-year design project. After a career in the pulp and paper industry spanning twenty years, he continues his research interest in this area. His other areas of interests include process development and economics and pan pelletizers. He is also a member of the fluoride research group.
- **David Dunstan** is Senior Lecturer and is a physical chemist by training who leads a team in the Cooperative Research Centre for Industrial Plant Biopolymers. His key research areas are understanding the adsorption to and stabilization of the oil-water interface using biopolymers and the rheology and gel behavior of these systems. Fundamental programs include rheological characterization of novel gelling biopolymers for new material design.
- **Leong Yeow** is a Senior Lecturer and his research interests include non-Newtonian fluid mechanics, inverse problems in rheology, and hydrodynamic stability.
- **Andrea O'Conner** is a Lecturer whose research focuses on surfactant behavior and separation processes, particularly those for the food and pharmaceutical industries and for waste-water treatment. Mesoporous molecular sieves are synthesized and tailored for selective separations by adsorption via size exclusion and targeted surface chemistry. The current focus of this work is on the development of these materials for purification of high-value biological molecules.
- **Sandra Kentish** is a Lecturer and joined the Department in early 2000. She has a strong industrial background, with experience in the petrochemical, photographic, and paper industries, as well as in chemical-hazard management. She is developing research interests in a number of areas, including biopolymer processing, biofouling, solvent and supercritical extraction, carbon dioxide absorption from flue gases, and the use of ultrasonics in industry. Molecular dynamics simulation is another area of more fundamental interest.

design. Rheooptic, time-resolved fluorescence, and light-scattering measurements aimed at developing understanding of solution flow behavior are also studied.

Other research groups are also very active within the Department. The **Separation Processes Group** investigates rate phenomena involved in separation processes with particular reference to hydrometallurgy, waste treatment, and biochemical separations. A major focus is on gaining a better understanding of the interplay between diffusion, hydrodynamics, and the interfacial reactions occurring in solvent-extraction systems. In particular, novel techniques have been developed based on attenuated total internal reflectance spectrophotometry and, more recently, atomic force microscopy to study interfacial phenomena and reactions occurring at the interface. Mechanistic models for axial dispersion in pulsed sieve plate columns have been developed. In addition, the group has been active in liquid membrane processes, coalescence processes, diffusion in liquid systems, and in ion exchange. Biochemical separation processes being studied involve a range of operating and potential technologies for the food, pharmaceutical, and water-treatment industries. These include adsorption using specifically tailored adsorbent materials, electrophoresis, supercritical extraction, and ultrafiltration. Surfactant aggregation phenomena and their applications are also under investigation. Novel ion exchange processes presently being studied include ion exchange in radial flow and ion exchange equilibria in dual exchanger systems. Much of the work is in collaboration with others in the University, with the CSIRO Division of Chemical and Polymers, Tsinghua University Beijing, Massachusetts Institute of Technology, and with industry.

The **Mineral Processing Group** focuses on reactions at the fluid-solid interface. Electrochemical and mineralogical aspects of the extraction of metals from ores are studied at both laboratory and plant levels. Significant advances have been made in understanding the kinetics and equilibrium of the interaction between reacting and dissolving solids and the presence of adsorbents such as activated carbon and ion exchange resins. Various features of artificial intelligence have been integrated with systems of differential equations to describe the dynamics of operating plants, especially for cases where fundamental models are lacking. The transformation of reactive alumino-silicate wastes into useful construction materials is being investigated extensively at both laboratory and pilot-plant scale. Emphasis is placed on interfacial phenomena and the evolution of microstructure during the formation of geopolymers. This group succeeds in integrating fundamental research with the needs of operating plants.

The **Polymer Science Group** has interests in a diverse range of macromolecular related projects that combine the disciplines of polymer science and chemical engineering. The span of research includes phenolic resins and their composites; minimal shrinking monomers for specialty applications; novel multifunctional monomers for controlled network formation; grafting studies of polyolefins; development of living radical polymerization for the generation of predetermined macromolecular properties; and the determination of kinetics of propagation.

The **Fluoride Process Engineering Group** has special expertise in fluoride chemistry. Its work involves the treatment of minerals with fluoridating agents to produce pure products. It is also developing processes for the treatment of carbonaceous materials such as coal and spent pot-lining from aluminium smelting to produce commercial products. While some government support has been obtained, the group almost totally interacts with industry, both large and small, Australian and overseas. Currently it has three major projects: a new process for production of titanium oxide pigments; a process for the production of ultra-clean coal; and a process for the recovery of spent pot-lining.

The **Computational Fluid Dynamics Group** investigates fluid dynamics and transport phenomena in single and multiphase flows in process engineering. A major theme is the fundamental study of dispersed multiphase flows and two-fluid flows with deforming interfaces. Current topics include the dispersion of solids in metallurgical melts, molten slag foaming, droplet breakup, heat and mass transfer in soils, drop impact on solid surfaces and liquid films, slumping of yield stress materials, mass transfer at deforming interfaces, and self-sustained oscillations of confined jets.

The **Biochemical Engineering and Fermentation Technology Group** works on the application of microorganisms and enzymes to chemical processing. A major focus is on the use of recombinant bacteria to produce fuel ethanol from lignocellulosic materials such as wood and straw. The group also has an international reputation for its fundamental research on the factors affecting product inhibition in fermentations, the focus being most recently on the key role of acetaldehyde as an inhibitor or stimulant of yeast and bacterial alcohol fermentations, depending on the concentration of this metabolite.

THE FUTURE

The Department is one of the strongest research departments in the University. As its activities and student numbers have grown over the last two decades, it has gradually spread out from its original building built in the 1960s. In 2001, construction will begin on extensions to the existing building that will allow the Department much needed research space for expansion.

It is the success of the Department's graduates that continues to illustrate its success in chemical engineering education and research. In its ranks of graduates, the Department boasts three Rhodes Scholars and the current Australian Chief Scientist. Its future is assured by the continued success of its graduates. ❒