Knowledge Management and Continuing Change in CSIRO

Revised version of a paper presented to the Conference "Knowledge Creation Management in Asia" National University of Singapore, 6-7 March 1998

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1 Introduction

Established in 1926, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) is Australia's largest public research agency. It conducts strategic research in a wide range of areas including agriculture, minerals and energy, manufacturing, construction, communications, and the environment. It operates an annual research budget of approximately US$500M of which some 65% is direct government funding, the remainder coming from other, external sources.

This paper looks at the contribution Knowledge Management can make to understanding and guiding ongoing change within CSIRO, notably toward a greater commercial focus, against a backdrop of internationalisation of the Australian economy.

Public research agencies around the world face common challenges as they adjust to meet the demands posed by the globalisation of the world's economies, and rapid technological change. In particular they need to ensure that strategic research directly interfaces with, and supports, growth in national welfare. This requires increased focus on the transfer of research outcomes to industry and on the processes of commercialisation. Since the late 1980s CSIRO has changed significantly in developing a stronger commercial orientation across the range of its research.

The tools and concepts emerging in the Knowledge Management field are useful in understanding and guiding these ongoing processes of change. Subsequent sections look at:

- the international setting
- scientific research and innovation
- commercial knowledge management, and
- organisational change

2 The New Economic Setting

The globalisation of the world's markets has far-reaching implications for us all. It puts added emphasis on the international competitiveness of countries' industries and their exports, be they commodity-based or manufactures.

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It is clear that innovation - the creation of new or better products and services or new ways of producing or supplying them – is a major contributor to economic growth and critical to maintaining a competitive edge in the production of goods and services.

The emerging literature and thinking on Knowledge Management emphasises the role of knowledge as a key competitive resource which underlies organisations' ability to innovate and to maintain competitive advantage.

It also helps interpret and analyse the impact on organisations of rapid change in information and communications technologies, eg in relation to:

- increased diversity, complexity and amount of available information
- a frequent sense of "information overload" – the gap between the volume of information and the tools we have to make sense of it
- the explosion in **connectivity**. With new technology (eg the Internet and organisational Intranets) in place, it is possible to communicate with practically anybody with zero cost.[4]

> *The rapid emergence of universal technical standards for communication, allowing everybody to communicate with everybody else at essentially zero cost, is a sea change.*
> P Evans and T Wurster, Harvard Business Review, September, 1997

These changes have wide implications. New technologies make it simpler and less costly for information to be unbundled from its carrier and for new specialist, intermediate businesses to arise. This has already happened in the international financial market as major packages are unbundled and shared by specialist financial service providers. In addition the relative value of intangible assets such as knowledge grows more important, with implications for the valuation and treatment of "intellectual capital" embodied in organisations and people.[5]

Moreover these changes are continuing. Boundaries that have previously existed have been demolished by the emergence of information technology, and the way we create and manage knowledge seems destined to become increasingly important as a major determinant in international trade and economic growth.

Approaches to Knowledge Management

The growing literature in Knowledge Management[6] has generated a number of concepts and ideas that respond to the new environment. The challenge is to identify those of greatest use to particular organisations.

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[4] See eg Frances Cairncross, *The Death of Distance*, Economist Publications, London, 1997.
[5] Thomas Stewart, *Intellectual Capital:The New Wealth of Organizations*, Currency-Doubleday, New York, 1997.
[6] As well as some cynics - eg. "Knowledge management remains an infuriatingly vague subject to write about – let alone sell" *(The Economist*, 31 May, p.77, 1997)

A common theme in the literature has been the need for a broad-based approach, including management of data and information, which encompasses social as well as technology aspects. Technology by itself will not change attitudes to documenting, sharing and using ideas. What is needed is not changes in procedures or technologies alone (ie not just a "technical fix") but also changes in the behaviour and the culture of organisations.

Nonaka and Takeuchi[7] provide an insightful analysis of organisational knowledge creation within firms and the ability of companies, notably, large Japanese companies *"to create new knowledge, disseminate it throughout the organisation and embody it in products, services and systems"* -with emphasis on the human "soft" side of organisations rather than the technical "hard side". They see the process as critically dependent on the sharing and articulation of tacit knowledge and involving four steps: (a) sharing of tacit knowledge (know-how embedded in individual experience, and associated mental models, beliefs and perceptions); (b) conversion of tacit knowledge to explicit knowledge (formalised and formulated expression); (c) new combinations of explicit knowledge and (d) internalisation of new knowledge into tacit knowledge (the "knowledge creation spiral").

The creation of new, shared, tacit knowledge is also critical to innovation, *"a highly individual process of personal and organisational renewal"* by which the world is recreated *"according to a particular ideal or vision"*. Under this view *"to create new knowledge means quite literally to recreate the company and everyone in it in an ongoing process of personal and organisational self renewal"*. In particular, Nonaka and Takeuchi show the power of managers in developing powerful metaphors and analogies to stimulate and foster the process.

This focus on the processes and socio-cultural conditions leading to knowledge creation, raises important issues that need to be explored and raises questions of applicability in other countries and cultures. It is also distinct from other work in the knowledge management field that is primarily concerned with the processing of knowledge or its valuation.

Davenport and Prusak[8] offer a useful overview emerging from an inter-organisational program on information and knowledge management. In particular they identify three components in knowledge management:

- Knowledge generation: Includes external generation of knowledge - by acquisition or hiring in of experts - or internal generation by "fusion" of different knowledge sets. (The latter concept overlaps with the Nonaka and Takeuchi concepts of "requisite variety" and "redundancy" of inputs.)

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[7] Ikujiro Nonaka and Hirotaka Takeuchi, *The Knowledge Creating Company*, Oxford University Press, 1995

[8] Thomas H Davenport and Laurence Prusak, *Working Knowledge: How Organisations Manage What They Know*, Harvard Business School Press, Boston, 1998.

- Knowledge codification: Putting organisational knowledge in a form available to those who need it. The mapping, classification and encoding of knowledge requires judgement as to what is important, and to the appropriate level of structure. Just as there are different kinds of knowledge so are different systems needed to capture these.

- Knowledge transfer: The successful transfer of knowledge requires both transmission and reception. Clearly it is not simply a matter of getting the "hard" aspects right – the technology to capture, store and distribute, and provide access to knowledge. The "soft" aspects - notably knowledge sharing and a culture built on trust - are also important if what is transmitted is to be received and used. Davenport and Prusak note that, alone, *"Lotus Notes will not change a knowledge-hoarding culture into a knowledge-sharing culture"*

> *Innovation occurs at the boundaries between mindsets, not within the provincial territory of one knowledge and skill base*
> D Leonard-Barton, *Wellsprings of Knowledge*, Harvard Business School Press, Boston, 1995
>
> *Conversations are the way knowledge workers discover what they know, share it with colleagues and in the process create new knowledge for the organisation*
> AM Weber, Harvard Business Review, January, 1993.

McDermott[9] puts the case for the creation and maintenance of professional communities, both disciplinary and interdisciplinary, as a way of leveraging knowledge, that is extending knowledge available in an organisation beyond the limits of personal experience. This requires the rethinking of knowledge as a shared asset within an organisation rather than an individual asset stored in systems unavailable to others, and the responsibilities of professionals who focus, filter and organise information for each other. Successful leverage means access to the right information, at the right time and at the right level of detail.

Of particular interest in this regard are the knowledge management systems established at a number of large consulting and accounting firms to provide a shared firm-wide asset of structured knowledge, and the experience with "virtual teams" which draw together members from multiple locations for generation of solutions and of breakthrough thinking. [10]

3. Innovation and CSIRO

The Australian Setting

CSIRO is undergoing a period of continuing change as it adjusts its role as research provider. Origins of this change lie in global economic changes and actions by the

[9] Richard McDermott, *Leveraging Professional Knowledge (Working Draft)*, Silver Creek Associates, 1997.
[10] Steven Prokesch, Unleashing the Power of Learning: Interview with British Petroleum's John Browne, Harvard Business Review, September 1997.

Australian Government in recent years, notably to lower tariffs and to facilitate an increased international role for Australian industry.

Broadly its challenge has been to promote innovation and increased competitiveness of Australian industry, notably in areas of economic strength such as minerals and energy, agribusiness and other industries *"stemming from a century of high living standards, and the occupation of a very large land area by a scattered population"*. [11]

As a medium-sized country Australia has a relatively high output of quality science and accounts for 2.5% of the world's scientific literature.[12] At the same time the challenge is to maintain access, links and awareness of the other 98% of the world's science to capitalise on innovation opportunities that arise.

Total R&D undertaken in Australia in 1994/95 amounted to *ca.* US$5.5 billion (1.61% of GDP) which, although sizeable, is not large on a world scale. CSIRO accounted for about 9% of the national total,[13] notably longer-term **strategic research.** Private sector R&D, on the other hand, is heavily weighted toward **experimental development.** Other important players in Australia's innovation system are the universities and recently introduced CRCs (Cooperative Research Centres).

Linking Strategic Research and the Market

CSIRO's role in innovation is based on its research capabilities in a wide, but not comprehensive, range of research. Figure 1 provides a descriptive model of the way commercial application can be linked to core strategic research capabilities.[14] These core capabilities are characterised by:

- **people** - world-class research teams of "critical mass"
- **equipment** – equipment, support and facilities to match research teams in similar fields elsewhere in the world
- **intellectual property** – development of a strong intellectual property position
- **international networking** – relationships with other public and private sector research teams around the world

Examples of core capabilities are computational fluid dynamics, protein crystallography, remote sensing in mineral exploration, climate modelling, vaccine development, gene mapping, food quality & safety, packaging technologies, and biotechnology for agriculture. These capabilities are not fixed but evolve over time in the light of scientific developments and market opportunities. CSIRO's broad research base enables cross-

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[11] Business Council of Australia, *Australia 2010*, BCA, Melbourne, 1993 These include a wide range of manufacturing industries, health & medical technology and services, educational services, civil aviation and transport, financial infrastructure & services, telecommunications, construction, urban development & management, and arts, sport, leisure & hospitality industries

[12] *Australia Science and Technology at a Glance, 1997,* AGPS, Canberra, 1997, based on the ISI and OECD data for the period 1989-1994.

[13] CSIRO total research, as a percentage of GERD+BERD (respectively government and business expenditure on R&D)

[14] See for example, Garrett Upstill, *Creating Wealth for Australia: CSIRO and the Manufacturing Sector,* CSIRO, Canberra, 1995.

disciplinary teams to be formed in response to new opportunities, drawing on a wide range of disciplines and skills.

Figure 1 shows the link between strategic research and support for wealth creation by industry and how intellectual property can be used and renewed for national benefit. A core capability may underlie collaboration with a number of different companies for several different applications.

A specific example concerns a core capability in machine vision. Current applications include traffic monitoring systems, food packaging and remote identification and management systems, all licensed to different customers. Through retention of intellectual property rights, it is possible to maintain and reinforce capabilities (people, equipment and intellectual property) while working on specific applications.

This strategy could be called "keeping ahead of the game" whereby CSIRO is able to transfer its generic technology and research results initially to a number of Australian industry sectors, providing the basis for competitive advantage. Once a competitive advantage has been achieved, successive improvements can be introduced locally, while transferring technology to the global marketplace. Of course, this is, in the main, an issue of timing and market strategy.

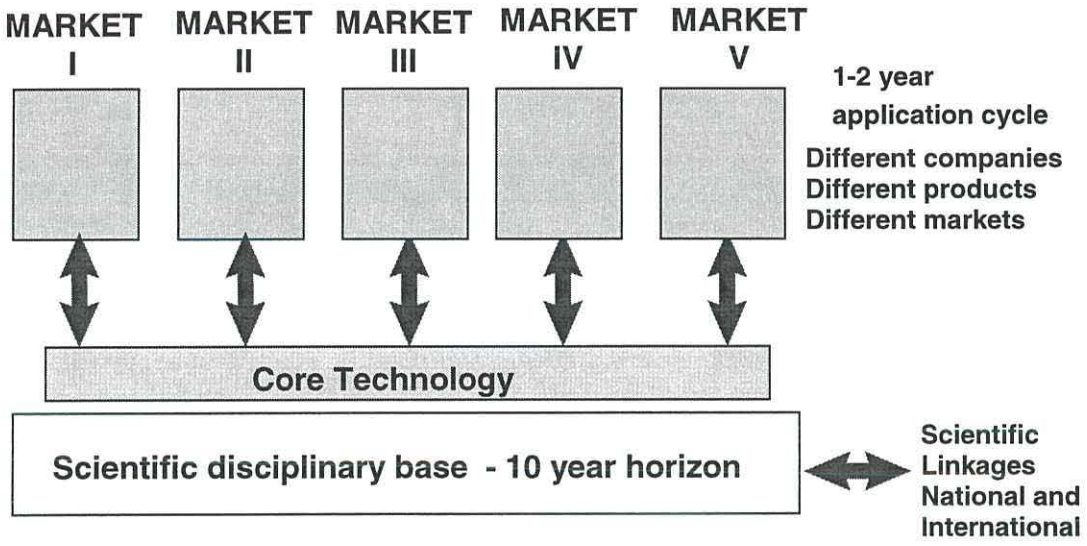

Figure 1: Core Research Capabilities and the Market

The key factors set out above – people, equipment, networking and IP management – have underlain a number of successes posted by CSIRO in recent years (see Box 1). The challenge now is to build on experiences and both to maintain and strengthen its cross-disciplinary science base and to ensure scientific knowledge is effectively linked to significant commercial outcomes. Current developments in Knowledge Management may assist this process.

Box 1: Recent CSIRO Achievements[15]

Cotton

Australia's cotton crop of about US$1.2 billion p.a. is primarily due to a CSIRO research program launched in the mid-1970s. Over 93% of the current national crop is grown from seed types tailored by CSIRO to deliver high yield and fibre quality in local conditions, while resisting pests and diseases. Seeds of these varieties are also now being sold internationally. In 1997, the first gene-enhanced cotton crop was harvested, carrying a gene that made it unpalatable to heliothis, cotton's principal pest. This allowed farmers to cut insecticide use by nearly two thirds.

Influenza

A new anti-influenza drug has its origins in work within CSIRO on the 3D structure of the neuraminidase protein on the flu virus, and the identification of a site on the surface of the virus that did not mutate. This provided a target for synthesis of a drug that locks onto this site and blocks the virus from leaving a cell. The development of the drug was backed by the Australian company Biota, who licensed it to the multi-national pharmaceutical company, Glaxo-Wellcome. The drug is in Phase III clinical trials which, if successful, could see a commercial launch by the turn of the century. The annual market is estimated at over US$1B.

Gold

The discovery of the Plutonic and Bronzewing deposits in Western Australia, which have a combined resource of 10 million ounces of gold, and are valued at over US$2 billion, owe their origins to a technique of laterite geochemistry, developed within CSIRO. Traces of valuable minerals migrate from buried ore bodies into the overlying, weathered rubble and soils known as laterites and can form a halo over a buried deposit. The new exploration technique is now well established in Australia for a wide range of commodities, including diamonds, and in appropriate terrain overseas.

Magnesium

Early in 1997 Queensland Metals and Normandy Mining, together with Ford Motor Corporation, announced a process leading to construction of a magnesium smelter beginning in 1999 with the capacity to supply up to one quarter of world magnesium demand. This will make Australia a major world supplier of magnesium. The announcement is the culmination of extended collaborative research involving CSIRO, which solved a number of processing technology issues. Work is continuing to assist development of magnesium alloy fabrication aimed towards supply of high performance lightweight parts to the international automotive and aerospace industries.

Power

An Australian power industry consortium established to exploit work by CSIRO is a world leader in solid oxide fuel cells and recently successfully demonstrated a 5kW working cell. The cells marry the properties of modern ceramics with the principles of fuel cell technology, which uses the heat released in chemical reactions to generate electricity. They are highly efficient, modular and environmentally friendly. They are also compact - a 5kW fuel stack is only the size of a shoebox, yet can meet the needs of several households. The successful operation of the 5KW system allows the company to proceed with fabrication and testing of larger demonstration systems which will lead to commercialisation of the technology.

Radioastronomy

Australia is in the forefront of radioastronomy, due in part to CSIRO's Australia Telescope which has been in operation for most of the past decade. Designed and built in Australia with a high content of locally built components, it is an array of eight antennas located at three different sites in New South Wales forming a baseline array, 320km long. A source of leading edge international research, it is also in strong demand from overseas researchers.

Bay Management

Port Phillip Bay is one of Australia's most important bodies of water. It is the entrance to Australia's busiest port, and has over 3.2 million people living around its shores. CSIRO recently completed a detailed multidisciplinary environmental study of the bay's ecology, physical processes, and nutrient and toxicant levels. Water quality was linked to inputs from land activities, such as nutrients from sewage and industrial plants, run-off from agricultural land, and surface run offs from cities. The environmental study identified the sources, concentrations and dispersal of pollutants and the critical nutrient load which can be tolerated. It has provided decision makers with unprecedented predictive power over the impact of future development around the Bay.

[15] From *Beyond Science: Managing Projects for Success*, CSIRO, Canberra, 1998.

4. Production of Scientific Knowledge

The way scientific knowledge is created and managed has evolved over a long period of time. It is primarily discipline-based, practised by professionals with extended academic training and reliant on well-established peer and professional networks. Nonetheless, this process is influenced by changes such as:

- information and communications technology developments
- importance of larger, often interdisciplinary team in addressing major issues
- changing attitudes to the publication and management of commercially relevant information

Indeed these may be contributing to fundamental change. Gibbons *et al.*[16] argue that the nature of knowledge production is changing in science and technology. From traditional approaches by which knowledge is created in a disciplinary, primarily cognitive context, now a variety of forces is leading to a new form of knowledge production. Modes 1 and 2 are terms invented to describe the polar differences in the ideas, methods, values and norms associated with differences in the production, legitimisation and diffusion of knowledge. Specifically:

> *In Mode 1 problems are set and solved in a context governed by the, largely academic, interests of a specific community. By contrast mode 2 knowledge is carried out in a context of application. Mode 1 is disciplinary while Mode 2 is transdiciplinary. Mode 1 is characterised by homogeneity, Mode 2 by heterogeneity. Organisationally, Mode 1 is hierarchical and tends to preserve its form, while Mode 2 is more hierarchical and transient, each employs a different type of quality control. In comparison with Mode 1, Mode 2 is more socially accountable and reflexive. It includes a wider, more temporary and heterogeneous set of practitioners, collaborating on a problem defined in a specific and localised context.*[17]

Gibbons *et al.* argue that the second mode is supplementing, if not supplanting the first in a number of applications, and notably in production of knowledge "useful" to Government, industry or society more generally. The issue warrants further consideration and research.

5. Management of Commercial Knowledge

Traditionally commercial management has been seen as separate from science management in organisations such as CSIRO. Despite notable achievements in transfer of technology and knowledge, these have been often seen as important but secondary to the underlying research. In recent years there has been an emerging awareness that the two are inextricably linked; that indeed the value of the science is found in the value to end-users and society more generally.

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[16] Michael Gibbons, Camille Limoges, Helga Nowotny, Simon Schwatzman, Peter Scott and Martin Trow *The New Production of Knowledge*, Sage Publications, London, 1994.
[17] Gibbons *et al*. p.3

While research can lead to valuable knowledge and a range of potential outcomes, this new knowledge *per se* does not lead to a competitive advantage. It is how an industry or nation values and uses knowledge that determines whether a competitive advantage can be derived through the application of knowledge.

Within CSIRO there have been structural changes as well as to changes in the commercial operations to strengthen the technology transfer process. Recently the Organisation transformed its operations from a divisional to a sector-based focus whereby the 25 essentially discipline-based divisions deliver to 22 industry sectors. This has promoted much closer scientific interactions, a process made easier by electronic communication and enabling the creation of cross-national and international research teams. The new arrangements have also provided a better interface with industry representatives *via* sector advisory committees and the opportunity for industry to help set directions for CSIRO's strategic research.[18]

At an operational level there has also been change. Four phases can be identified in the evolution of the process of commercialisation within CSIRO, namely:

* ***science push*** The approach prevailing till the early 1980s was one which focused on the science; when discrete innovations emerged with commercial potential they were licensed to industry;
* ***arms length management*** The next phase until the early 1990s was via a separate in-house body charged with the commercialisation of research. It sought commercial opportunities for in-house inventions and other intellectual property and identified applications for research services;
* ***specialist management*** A concern to improve linkages between research and its applications led to the replacement of the arms-length relationships by new senior commercial specialists operating across the organisational structure;
* ***devolved management*** More recently, with the new structural arrangements and rising commercial skills, the responsibilities for commercialisation have been devolved, with research managers frequently playing a role in commercial negotiations alongside specialists.

A similar evolution in approach – namely increased devolution of commercial responsibility – may be seen in other public sector research organisations around the world.

The transfer and commercial exploitation of technology is integral to CSIRO's legislated role in facilitating the application of its research. It may take a variety of forms. These include:

- technical advice and services
- licensing – exclusive or non exclusive of rights to use technology
- contract research – outcomes generally well defined in advance and usually conducted on a full-cost recovery basis
- collaborative research – longer term in character with outcomes that are not precisely defined and in which the firm shares costs, risks and expected benefits.

In addition technology is transferred through technical education, movement of people, through informal contacts and via spin-off companies

[18] The linkage of R&D to corporate strategy is well covered in Philip A Roussel, Kamal N Saad and Tamara J Erickson, *Third Generation R&D*, HBS Press, Boston, 1991.

Successful commercial transfer of research knowledge depends on four broad factors:[19]

- the quality and relevance of the R&D undertaken and hence of the knowledge generated
- the quality of the delivery mechanisms, both technical and human, used to deliver the knowledge to industry
- the cost of delivering the knowledge at a given level of quality
- the adoption of the knowledge by the end-user and its integration in the industry's value chain and culture.

For public research agencies, having assured themselves the activities are appropriate to their charter, the principal questions are of **effectiveness** in transfer of commercial knowledge and **efficiency** in its management.

For CSIRO the **effectiveness** is measured by the economic impact of research, as revealed in ongoing cost-benefit analyses, and by other measures of impact such as generation of spin-off companies,[20] secondments to and from industry, involvement in venture capital activities, as well as informal knowledge transfer outside formal contractual arrangements. These processes are being augmented by increased use of "account management" principles in dealing with customers.

Personal contacts and conversation are important to these developments, and group meetings, special courses and "knowledge fairs" involving both CSIRO scientists and industry representatives have been widely used to good effect. Informal channels represent, in economic terms, a significant "knowledge spill-over benefit" that is not captured by normal evaluation and reporting procedures. A study conducted in 1995[21] showed that well established research groups within CSIRO were involved in upward of 300 contacts per year, notably from Small-Medium Enterprises (SMEs), and that individual senior scientists were involved in up to 100 informal contacts per year. Contacts were for the provision of technical advice (65%), referral to other expert sources (20%) and discussion of R&D opportunities (15%). Moreover, these often-overlooked informal contacts provide information and feedback beneficial to both parties.

Box 2 The Asian Context

The predicted population growth in the Asian region is likely to mean a population explosion in a number of major cities over the next three decades. These "Megacities" are likely to become the focus for trade and services with the global economy. Clearly, demographic changes of this type will require technologies to enable these cities and networks of cities to conduct their business efficiently and effectively. Innovation in information technology, food processing and safety, health and the environment will be important to ensuring growth with high quality of life.

[19] Stephan Wellink, *Technology Sales and Information Sharing,* Keynote address to Australian Sugar Convention, Brisbane, 1997.

[20] Defined as when a staff member leaves and builds a company based on CSIRO technology, under an agreement with CSIRO; over the past decade this has involved 50 companies; these (plus their 31 subsidiaries) have a total annual income of some US$130M pa and employ over 900 people.

[21] CSIRO Industrial Technologies, *Putting a Value on Informal Industry Contacts with CSIRO*, Canberra, 1995.

CSIRO was engaged in some 300 science & technology projects in ten Asian countries in 1997.

Indonesia – Over 70 projects involve Indonesia. The largest of these is a $7 million World Bank management-systems-strengthening project at the Indonesian Institute of Sciences (LIPI) which involves three CSIRO staff based in Jakarta and an Australia-based visiting team. This, and other Indonesian projects, is supported by an informal electronic network which has proved an effective means of linking those with a professional interest in Indonesia, eg through exchange of information on meetings, contacts and opportunities that arise.

Japan
The first example dates back to the early 1990s, when CSIRO conducted a project that focused on identifying food preferences of Japanese consumers; the project utilised expertise in sensory evaluation of foods. Data was gathered from a wide range of foods and a consumer profile was developed based on parameters that included taste, smell, appearance and texture. The knowledge gained from this initiative has benefited a number of Australian food companies in their approaches to the Japanese market.

A second example is the placement, of a senior CSIRO commercial manager at the Tokyo headquarters of the Itochu Corporation, a large Japanese trading house. The objectives are to gain knowledge concerning the conduct of business in Japan, to identify commercial opportunities and to determine whether Japan can provide a gateway for CSIRO and its partner companies to other countries in Asia. The relationship is progressing well with several commercial opportunities in negotiation. The knowledge gained through this initiative is documented and is shared widely across the Organisation.

The **efficiency** of commercial knowledge management is primarily internal to the organisation. CSIRO's system has evolved over a number of years in response to prevailing circumstances and opportunities. It involves a complex mix of elements such as market research, industry analysis, commercial practices and procedures, intellectual property and contract management, and information on potential, current and past customers. Improved efficiency will depend on factors such as stronger networking, streamlined databases, better project management and upgraded commercial expertise.

6. Knowledge Management and Organisational Change

A primary target for applying Knowledge Management approaches to CSIRO is in relation to commercial knowledge processing.

Figure 2 sets out a model of the current commercial knowledge system within CSIRO[22] and showsthe flows of commercial data, information and knowledge within the Organisation. It shows staff in four distinct groups, each of which interfaces to a different extent with the external market and with the commercial information and knowledge structures. These are the research scientists (*ca.* 60% of staff), line managers involved in marketing and commercial decisions (8%), other administrative support (31%), and commercial professionals (about 1%).

[22] After diagram in Rhys Francis, Michael Kenyon, Garrett Upstill & Stephan Wellink, *Working report on Commercial Knowledge Management in CSIRO*, 1997

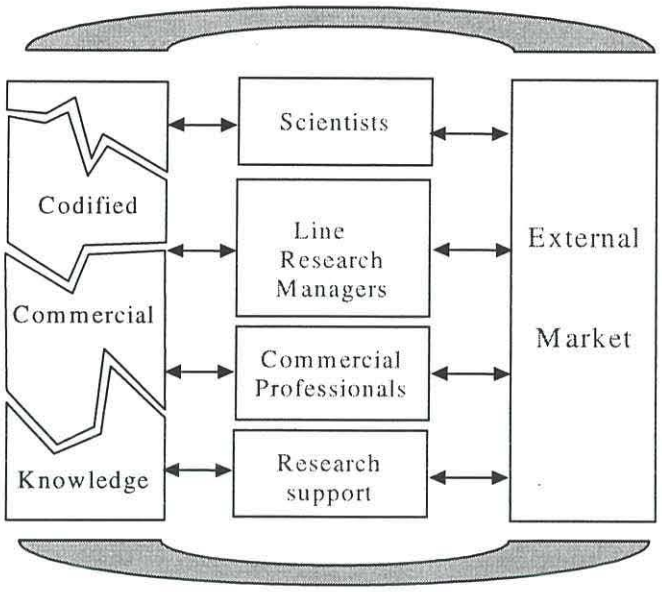

Figure 2: Model of Commercial Knowledge Flows

Each of the groups shown may be a source of commercial information, not the Commercial professionals alone. Scientists can be important primary sources of data or market information, for example through initial or occasional contacts with clients. We note that problems in accessing information and leveraging knowledge are common to many organisations, eg even in an innovative company like 3M. McDermott[23] notes that: *"A 1994 survey found that 80% of all the company's electronic information was stored on the personal computers of its professional staff, essentially unavailable to others working on the same issue."*

Both technical and "cultural" issues are involved in improving commercial knowledge flows to, from and between each of these groups, to provide a coherent and accessible knowledge base within the organisation, and finally to encourage behaviours to improve commercial knowledge management.

The primary task, which is being addressed, is to establish marketing and related electronic databases and information "banks" which are integrated, user-friendly. The risk is systems which are serviced, but poorly used – so-called "information junkyards". Davenport and Prusak[24] point to the need for different kinds of databases eg. for:

- external knowledge (eg. competitive intelligence)
- structured internal knowledge (eg. reports, marketing materials and methods)
- informal internal knowledge (eg. discussion databases including know-how and "lessons learned")

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[23] Richard McDermott, *Leveraging Professional Knowledge (Working Draft)* , Silver Creek Associates, 1997

[24] Thomas H Davenport and Laurence Prusak, *Working Knowledge: How Organisations Manage what they Know*, Harvard Business School Press, Boston, 1998, p.146.

These changes need to be accompanied by measures to ensure a supportive organisational environment for recording, interpreting and passing on commercial data, information and knowledge. One aspect here is emphasis on the promotion and rewarding of knowledge sharing and management, even as a key performance indicator. Another is raising the awareness of staff, notably scientists, as to broader corporate responsibilities in relation to commercial management via inputs and access commercial information and knowledge systems. A third aspect is the opportunity to extend the community of those concerned with commercial activities beyond commercial professionals and line managers to include other parts of the organisation, with science placed within a "value in use" context.

Related to the above are efforts underway to instil an organisation-wide adoption of client management and key account relationships ("gateways" rather than "gate keepers") with major research users. The approach introduces organisation-wide responsibilities and requires efficient and expert management of relevant commercial knowledge; it offers a number of benefits:

- a consistent approach to customers
- ability to maintain a whole-of-organisation view
- knowledge of one's own and one's client's business "inside out" with a clear understanding of the business objectives of both parties
- avoiding duplication of effort.

7. Conclusions

There are no ends or beginnings, only middles
– Robert Lowell

Managing in a fast changing world is a challenge for all organisations. For CSIRO the challenge is to build on a tradition of excellence in strategic science, and a number of achievements in transfer of technology, as well as a strong organisational *esprit de corps*, to meet the demands of the changing international environment and changes generated by new information and communication technogies.

CSIRO has changed considerably in recent years as it seeks to work more closely with the marketplace. This need continues as pressures for research agencies and industries to remain globally competitive increases.

An aspect of change has been an increasing devolution of commercial awareness and responsibility within the organisation. This paper argues this will continue, influenced by two factors. One is the changing nature of scientific knowledge production (described by Gibbons[16]) involving a shift to a new perspective which sees the value of science in a new context of application and use. The other is the opportunity provided through new technologies to access and share information and knowledge quickly and at low cost. Increasingly commercialisation and technology transfer are likely to depend not on

commercial specialists or agencies alone, but on the active involvement of research managers and researchers.

These changes point to the need for improved systems to allow sharing and use of knowledge – notably knowledge linked to the use and uptake of scientific research - in a way which maximises the value of research outcomes. Recent developments in the field of Knowledge Management provide a valuable input into how this should be done, and into consideration of the broader issue of knowledge creation in a multidisciplinary public research agency like CSIRO.

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