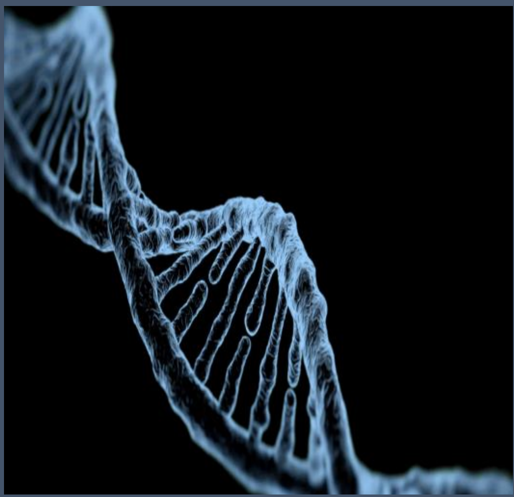

Science is the Business Frontier

Future directions for Scientific Research in New Zealand

Dr James D. Watson

Science is the Business Frontier

SUMMARY

"We are beginning to realize that the gross GDP of a nation can measure the intangibles that are core to the wellness of a nation. These are people, capital, education, acquisition of new knowledge". Katsuya Takii

- Science and innovation are the foundation of the New Zealand economy. And science requires patient, long-term investment.

- Many of our top scientists do their best work in other countries. New Zealand's reputation as a science hub should be viewed as a place where careers take off, not where they fade.

- The quality of New Zealand's research is extremely high and it is often the pioneering nature of that research which sets it apart. It has a distinctive character which is robust and resourceful, often multi-disciplinary, breaks boundaries, challenges preconceptions and tackles traditional problems in innovative ways.

- Reputation is fickle. In the past, science and science institutions were highly regarded, this can no longer be taken for granted.

- For a successful and prosperous society, science and innovation must underpin the economy. Renewal of the country's faith in the ability of its scientists to lift its international performance is required. Focusing on a set of key priorities, and addressing them in an appropriate and timely fashion, can achieve this.

- New Zealand needs a national framework to address strategic issues around research, funding, core science capability, professional development and knowledge transfer.

- Too few high-calibre young people are entering careers in our science system and far too many experienced people are leaving science or taking science overseas. Without a continual stream of well-trained scientists entering our overall science system, no matter how credible that may seem to be in isolated instances, *its success will be limited.*

- No science strategy can work unless it is led by a partnership between leading scientists and government. A science-driven model of policy setting, in which scientists are involved from the very beginning, must be developed.

- The primary scientific institutions in NZ are the Universities and Crown Research Institutes (CRIs). The CRI model is essentially sound, but implementation of the model, involving multiple layers of policy and management and incompatible profit-driving instructions, has created problems of purpose.

- CRIs are required to carry debt and to recover a high proportion of the cost of their capital. While this encourages a disciplined approach to management decision-making, it fails to consider the realities of public good science – and distorts and compromises scientific output.

- Earlier leaders had the vision to build the nation's knowledge capacity by establishing the New Zealand University Act of 1874, and in 1926, to establish the Department of Scientific and Industrial Research (DSIR), to build science that supported industry and economic development.

- Thus in 1874 and again in 1926 – during tough economic times for our nation – public investment in research and development was recognized as the foundation for economic growth and increasing productivity per capita.

- Science has long been the backbone of New Zealand's economy, which is built on agriculture and horticulture. New Zealand today however lacks a systematic plan for the country.

- Smart information technology is now required.

- The OECD in 2017, reported that we rank 26 out of 41 countries with regard to Research and Development (R&D) spending.

- Denmark, Ireland, Norway, Finland and now Singapore are all examples of small nations who have successfully invested much more in science systems and this is reflected in the growth of their economies relative to the OECD mean. New Zealand invests 1.3% of our GDP to R&D in comparison to 2.3% for the first four countries (2017 figures).

- Strategic planning is required as opposed to allowing the system to meander wherever the funding takes it - no science strategy can work unless it is led by a partnership between the leading scientists and government. A science-driven model of policy setting, in which scientists are involved from the very beginning, must be developed.

- Science is a common good, and it is in the national interest that the country’s capability be better directed, maintained and utilised in support of national economic, environmental and social goals.

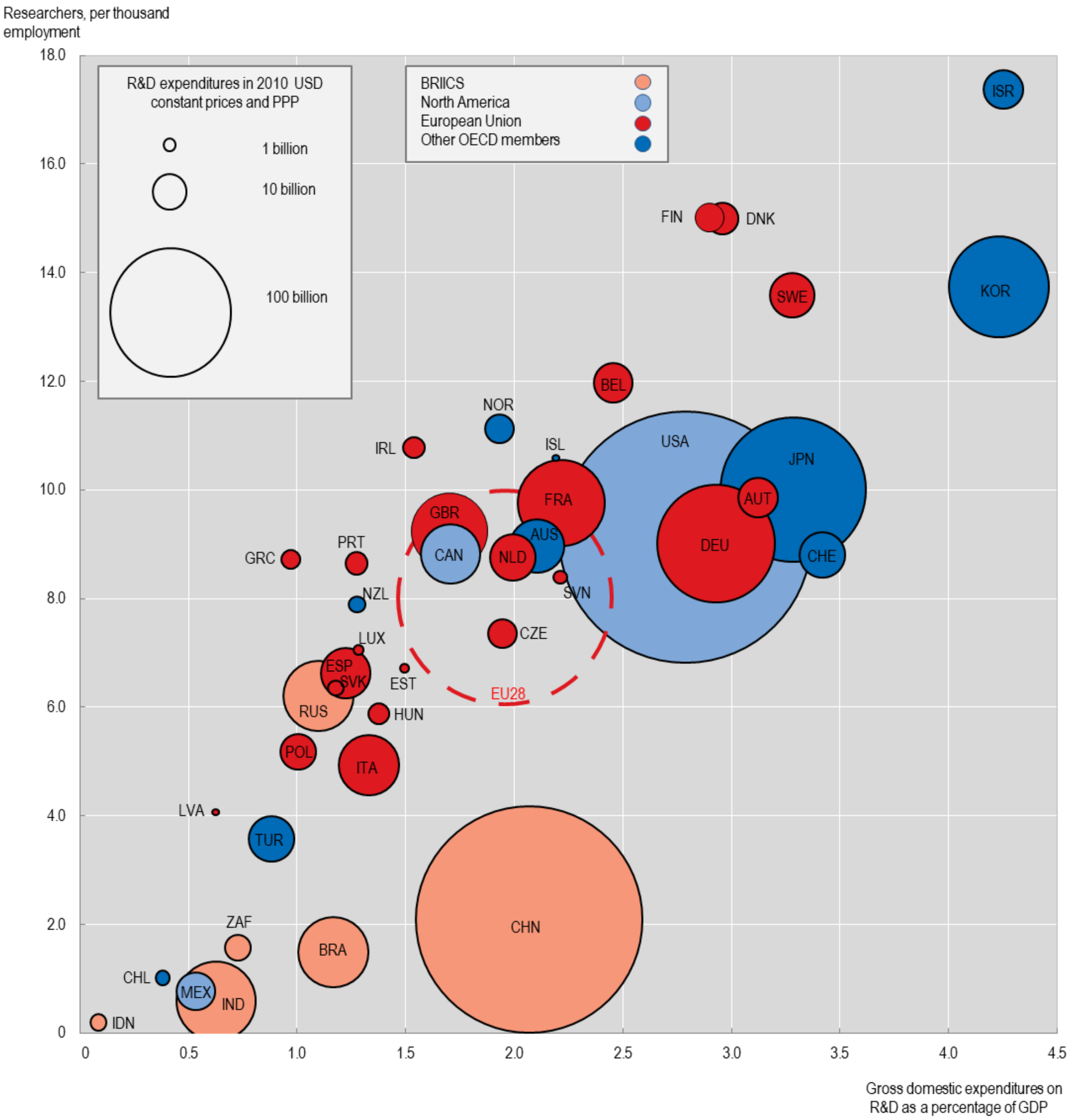

Figure 1: R&D in OECD and key partner countries, November 2017.

Introduction

In 1990, the United States government launched the most ambitious biology project ever conceived when it commissioned the sequencing of the complete human genome. On the 26th June 2000, Craig Venter announced that his team had completed a draft of the human genome. It was out of this sequencing project that a new technology was born: genomics, the study and interpretation of the genetic code, written in DNA, that all life forms contain. As a technology, genomics is transforming life science industries and providing researchers with novel insights into living systems, health and disease.

One result of the human genome sequencing initiative is the identification of genes associated with specific disorders. This has led to an unprecedented increase in diagnosis, drug development and the advance of molecular medicine.

Patients have benefited from advances in molecular medicine through early detection of genetic predisposition to disease, monitoring treatment, rational drug design and treatment of genetic defects by gene therapy. While the health industry today is clearly at the forefront of the genomics revolution, it has also invested and gained the most.

Genomic applications are not limited to the health industry. The knowledge that plants and higher organisms, like humans, share similar genes as well as biological systems is the basis for the expansion of biotechnology into other life science industries. These close parallels may not only yield useful drugs but may also expand the way drugs are produced and delivered. Some pharmaceutical companies have already expanded into plant biotechnology to develop plants that protect against human diseases like diarrhoea, tetanus, hepatitis B and cholera, by carrying vaccine components. Despite huge public opposition, agribusiness is also investing heavily in the development and distribution of seeds from genetically-engineered plants which are insect and drought-resistant and require few or no herbicides. These products are beneficial to the environment because the use of fertilisers, insecticides and herbicides is reduced, and soil quality can be improved. Plants are already used to clean soils contaminated with high levels of salts and toxic pesticides.

While modern biotechnology is of relatively recent origin, its fundamental concepts and concerns have played a prominent role in this nation's economy for more than a century, as we built our agricultural industries. For much of that time what we now call biotechnology went under different names –

animal and plant breeding and husbandry, plant physiology, clonal forest trees. Today these are all part of the biotechnology industry.

The biotechnology industry is a new one, but it holds the key to the next great advances in medicine, plant technologies, computation and communications. It brings new meaning to the term sustainability as applied to solutions to environmental issues, business development and the evolution of new companies. It is evolving rapidly, more so than any technology-based industry that has come before. We are only beginning to analyse the impact of people capital and skills, education and the new knowledge generating capacity, and realise the impact of these factors on GDP growth.

The development of New Zealand's biotechnology economy has been a core theme of national and regional economic development strategies since the publication of *"Growing an Innovative New Zealand"* (2002), which then became known as the Growth and Innovation Framework. Using the 2007/08 statistics, I would say that the New Zealand biotechnology sector is only in the early stages of development. At that time, the New Zealand biotechnology sector was estimated to be made up of 126 private and public-sector organisations with estimated total revenues of $811 million (of which the private sector accounts for 63%). Approximately 40% of biotechnology sector research and development is concentrated in agricultural applications which build on New Zealand's globally competitive position in sectors such as dairy, forestry, and horticulture. Medical devices and diagnostics account for 23% of expenditure; and 28% of investment is in human health applications which vary from biopharmaceuticals to a broad array of nutraceuticals and functional foods. Reflecting the early stage of sector development and typically long product development-cycle times, 67% of NZ biotechnology firms were in the research and development stage.

Internationally, this has become an enormous area of scientific exploration as companies are formed to develop products ranging from pharmaceuticals to new plants, foods and industrial processes and compete directly with the older pharmaceutical and agri-industries.

While the heart of biotechnology is biological science, the forces that drive it lie in interdependent areas. First are the entrepreneurs, who push the frontiers of knowledge because they see how to make a difference. Then there are the talented people whose scientific skills solve problems, shift boundaries and transform entire industries. Third are the investors, who see opportunity for large financial returns. Finally, there are business leaders who see that science can be a business. In order to succeed, all these forces must be harnessed under a common vision.

As a technology, genomics is transforming life science industries and providing researchers with novel insights into living systems, health and disease.

How is the current health of the NZ science system?

We can boast about our three Nobel laureates, but that does not cement our international reputation. In fact, it rather underpins the notion that our top scientists do their best work in other countries. What is essential to enhancing New Zealand's reputation as a science hub is to be viewed as a place where careers take off, not where they fade. Without that reputation, our environment and lifestyle, with all their charms, are not sufficiently compelling to persuade top science people to build their careers here.

Measured against international benchmarks, the quality of our research is extremely high. But it is often the pioneering character of that research that really sets it apart. Some of the very best research conducted here has a distinctive character. It is robust and resourceful. It is often inherently multi-disciplinary in character. It breaks boundaries. It challenges preconceptions. It tackles traditional problems in innovative ways. This character may be the result of our distance from world centres, with the unique mix of freedoms and constraints that distance brings. It may result from learning to make do with the relatively few resources that we have. It may reflect our creative responses to chronic under-funding or the can-do attitude that is inevitable in a small society. And because our research is carried out in what are, by world standards, relatively small institutions, it has a certain practical intimacy to it. It is inspired science, not the science of technocrats. It is not Big Science; it is science on a human scale.

I believe that New Zealand has been, and can be again, a great place to do inspired science. It is important that others share this view as to be great, we must be seen as a place where leading international scientists want to come and work, and where new scientists emerge and thrive.

Reputation is a highly dynamic phenomenon: it is generated as a result of complex interactions and it is subject to change, especially as the result of errors, erosion, corruption or deception. Reputation is fickle. Once, our science and our science institutions were highly regarded, we can no longer take that for granted.

As New Zealanders, we have a proud science heritage and each generation must carry the obligation to add to this heritage. But it's more than that. While our icons, from Rutherford to MacDiarmid did most of their great work overseas, our obligation today is to ensure that the many benefits resulting from local science and science done overseas, are used to improve the economic, social and environmental needs of New Zealand. The challenges that face the well-being of all New Zealanders require the use of science.

If we are to enjoy a successful and prosperous society, science and innovation must underpin the economy. We need to renew our country's faith in the ability of its scientists to lift its international performance by focusing on a set of key priorities and addressing them.

New Zealand needs a national framework to address strategic issues around research, funding, core science capability, professional development and knowledge transfer. We must institute plans to maintain and develop our long-term research capability in areas where New Zealand already has a natural comparative research advantage or a reputation for research excellence. We also need to retain and support sound research capability where national interest makes it essential that we maintain core skills.

Innovative funding packages, designed to support the work of the best of our emerging scientists and kick start their careers, are needed as a way of investing in our nation's future.

We can debate this; we can argue about relative levels of funding; we can discuss the merits of various administrative processes all we like. However, what we simply cannot avoid is that too few, high-calibre young people are entering careers in our science system and that far too many experienced people are leaving science or taking science overseas. Without a continual stream of well-trained scientists entering our overall science system, no matter how credible it may seem to be in isolated instances, *its success will be limited.* It is not simple; notably, increasing investment is important to transforming our science system only if it is accompanied by a corresponding set of comprehensive changes that rebuild the fundamentals of our system.

Ultimately, no science strategy can work unless it is led by a partnership between leading scientists and government. We must develop a science-driven model of policy setting, in which scientists are involved from the very beginning.

Science is a common good, and it is in the national interest that our capability be better directed, maintained and utilised in support of national economic, environmental and social goals.

The New Zealand economy, in particular, is founded on science and innovation. And science requires patient, long-term investment.

New Zealanders pride themselves on their innovation, yet paradoxically we struggle to develop and execute a coherent policy for encouraging innovation, and often our most promising innovations fail to negotiate the hurdles to commercialisation. Some are constrained by the lack of business investment in R&D, reflecting our thin industrial base and opportunistic approach to global market development. Some are unable to secure appropriate levels of external funding at the relevant stages.

Universities and Crown Research Institutes

Our primary scientific institutions are our Universities and Crown Research Institutes (CRI). CRIs are beginning a new era of growth in real scientific capacity. The CRI model is essentially sound, but implementation of the model, involving multiple layers of policy and management and incompatible profit-driving instructions, has created problems of purpose.

CRIs are required to carry debt and to recover a high proportion of the cost of their capital. While this encourages a disciplined approach to management decision-making, it fails to consider the realities of public good science – science that benefits the common good, which is non-exclusive and non-competitive.

The pool of people who have both the scientific and business skills required, is small. As a consequence, our efforts at commercialisation are often ill conceived, under-funded and poorly managed. That is not to denigrate commercialisation: it simply recognises that it is too important to leave in the hands of scientists and institutions without the necessary commercial skills and training.

Quite by chance, I was fortunate early in 2009 to listen to the very inspiring speech President Obama gave to the National Academy of Sciences. I am reminded of Lincoln, a man who during a Civil War found the time to start the Trans American railway, to make the land grants which now form the basis of the State University system of the United States and allocated funding to establish the National Academy of Sciences. Thus, I am reminded also of our own leaders who had the vision to establish the New Zealand University Act of 1874 to build the nation's knowledge capacity, and in 1926, to establish the Department of Scientific and Industrial Research (DSIR) to build science that supported industry and economic development. The DSIR surveyed, identified and classified the country's animal, vegetable and mineral resources; worked on ways to increase the utilisation of natural resources and reduce the risks of natural disasters; bred better plant varieties; developed better pest and disease control methods for agriculture and horticulture; provided advice for industrial developments; standards for commerce and industry; and data for the maintenance of public health.

How else was our nation built? How else do we build the science capital for the 21st Century and empower future generations to make the discoveries that drive our Information Technology, improve our public health system, act as watch dog for diseases that follow swine flu, take our agriculture and horticulture to new heights, continue to produce knowledge about ourselves and both our physical and social environments?

So, let us look at the challenges that face scientists and the science system.

We need to address four quite fundamental issues:

1. How should New Zealand invest in science?
2. How can we achieve more with the available funds – and what would further funding address/achieve?
3. What are the challenges we face as a nation in the 21st Century?
4. How do we remodel the science system?

How should we invest in science?

We all take for granted the everyday science that touches all aspects of our lives – our homes, our food, our welfare, our children's development, our health, our environment and our jobs. We and our treasury, or Ministry of Finance, readily identify with the fact that any improvements we hope to make to our economy, environment, infrastructure, health, energy supply, communications, entertainment and the operation of the many institutions on which a civil society depends, all need strong science components.

Thanks to the wisdom of our forebears, science has long been the backbone of New Zealand's economy, built on agriculture and horticulture. New Zealand today however lacks a systematic plan for the country. Currently our system is one of government intervention mixed with the private sector, which then occasionally stumbles its way towards more commercial activity – but no one is specifically looking at the issue strategically. This lack of structure makes it even more crucial that New Zealand uses its best available scientific talents to provide input into government's wider policy and legislation processes. Otherwise initiatives are misdirected, and resources wasted.

All these concerns have also been objectively identified in the 2007 OECD report on our innovation system, which recognised that New Zealand lags seriously behind global competitors in Research, Science and Technology (RS&T) investment. The Government's allocation for RS&T in 2009 was around $760 million. Denmark, Ireland, Norway, Finland and now Singapore are all examples of small nations who have successfully invested much more in science systems and this is reflected in the growth of their economies relative to the OECD mean.

How can we achieve more with the available funds?

Our universities and research institutes do have their successes in their laboratories, and a few New Zealand companies have enjoyed spectacular success on the international stage. The common ingredient is research and innovation. But, in our impatience to translate these results into comparable prosperity we forget that we cannot predict when and how our scientific capital will be used for commercial gain.

In 1874, and again in 1926 – tough economic times for our nation - public investment in research and development was recognised as the foundation for economic growth and increasing productivity per capita.

What are the challenges we face as a nation in the 21st Century?

We require smart information technology – the knowledge factor, health of our people, clean energy technology, food, land use and environmental security, and changing social behaviours to name a few.

How do we remodel the science system?

In the absence of strategic planning we tend to allow the system to meander wherever the funding takes us. This puts pressure on science culture, the institutions and commercialisation.

In 1989, the government requested research institutes (including the DSIR, Ministry of Agriculture and Technology, Research Division of the New Zealand Meteorological Service, and others) separate out their funding allocations and place these in the Public Good Science Fund (PGSF) which was held by the Ministry of Research Science and Technology (MoRST). Funding allocated from bidding was to go to the Foundation of Research, Science and Technology (FRST). To the then Minister of Science's dismay,

"I argued for 40% core funding (of CRIs) at the outset. I got 10%. In one surreal exchange, a Treasury official helpfully suggested that perhaps having a single purchaser was a risk and that we should have competing purchasers

as well. In the flood tide of theory that engulfed public sector reform in the late 80s and early 90s, no idea was too outlandish. Fortunately, this one didn't have a life belt and sank without trace. So, we entered a world of contestability that progressively wore everyone out."

Simon Upton, Parliamentary Commissioner for the Environment, November 2017

In 1993, universities gained open access to the entire Public Good Science Fund (PGSF) for just $10 million. At the time, this caused resentment in both the CRIs and the universities. Assurances were given that the PGSF was scheduled to grow sufficiently rapidly to off-set severe competition and that the move would stimulate appropriate co-location of CRI facilities on university campuses. What happened since is well known; the PGSF did not grow, competition became even more severe and co-operation between the major institutions of the science system effectively collapsed. The overheads required to administer the MoRST and FRST bureaucracies, where funding allocations were decided by 'managers' rather than scientists, had a significant burden on the meagre New Zealand public science funds.

Performance Based Research Funding (PBRF) was introduced into universities in 2000 and encouraged university researchers towards an academic pathway favouring publication. From the university's point of view, it generated a focus on research quality which is important. It makes universities hire, develop and retain people in different ways that actually has a spin-off for commercialisation.

There are no such performance-based incentives for CRI scientists. As a result, they are simply forced to chase the funding for their salaries and research with little thought as to the science involved, the impact of solving a real problem, or simply being a key part of the quest for real knowledge gain – whether academic or commercial. Our science crisis has arisen in large part because scientists simply must chase money, are unwisely micromanaged, and all to speed up imaginary commercial gain. We must also go on to ask why students are steering away from science as a career. It is not because they lack passion, or ability. Indeed, our secondary school pupils top their global peers for science literacy.

Commercialisation

The original expectation was that Intellectual Property should be transferred from CRIs to the aligned industry and that this value should be captured as long-term revenue gains and economic growth. Industry alignment in New Zealand is a particular problem. We are a nation of many small to medium enterprises, and the CRI sector alignment is breaking down because they do not appear to rely on any particular one, other than Fonterra. As a result, CRIs need to have functioning networks with the whole industry, because they need to be able to work with anyone and everyone at any one time.

We need to address commercialisation with a fresh kiwi face. What is the real focus of the CRIs? Are they the commercial guardians of our future or do we need to take that role away and build a new national commercialisation vehicle? We cannot hope to succeed if we continue with the present process.

Concluding thoughts

As a scientist, I close with some thoughts:

I believe our principal task in life is to find out what you really like and what you are really good at.

To paraphrase Arnold H. Glasgow, *"the bright flame of success is seldom a result of spontaneous combustion. You must set yourself on fire. You cannot rely on anyone else to undertake that service for you."* Or, as Mahatma Ghandi said *"we must be the change we wish in the world."* And that is the lesson scientists need to remember.

Ultimately, no science strategy can work unless it is led by a partnership between the leading scientists and government. We must develop a science-driven model of policy setting, in which scientists are involved from the very beginning.

Science is a common good, and it is in the national interest that our capability be better directed, maintained and utilised in support of national economic, environmental and social goals.

About the author

Dr James (Jim) Watson (CNZM) (3.11.1943-13.02.2017) was the founder of New Zealand's first biotech company, Genesis Research and Development, and cancer research institute Caldera. Jim was a passionate advocate for science in New Zealand and received his Companion of the New Zealand Order of Merit for services to scientific and medical research in 2006. He was a member of the New Zealand government's Innovation and Advisory Board from 2001 to 2003, President of the Royal Society of New Zealand from 2003-2006 and founder of the Department of Molecular Medicine at the Auckland University Medical School. Jim faithfully served the NZ science community for most of his adult life.

Although he grew up in rural New Zealand (Te Teko) his foundations in science were developed largely in the United States where he began with a post-doc at the Syntex Research Institute followed by a Research Associate position at the prestigious Salk Institute in La Jolla, California. Here he met and/or worked with the great geneticists and biochemists of the time, including his namesake James Watson and colleague Francis Crick (Nobel Prize winners who uncovered the double helix structure of DNA) and Jonas Salk – the discoverer and developer of the polio vaccine. It was the era of extraordinary discovery in the application and structure of DNA and Jim's first major immunological discovery was the chemical messenger: interleukin 2. This was the gene system which put him on the scientific map and launched his career. He moved from the Salk Institute in 1975 to the Department of Microbiology in the College of Medicine at the University of California at Irvine, where he was promoted to full professor in 1979.

Jim's first NZ company, Genesis, had many successful discoveries and later formed two subsidiary companies - BioJoule and Lanzatech - which evolved out of the work of Genesis staff. Jim's final company, Caldera, investigates not only the biological basis of hormonal cancers, but also examines lifestyle practices and the effects of medication. After Jim's cancer diagnosis he took on the writing of three books, a family genealogy, a personal history of his career (*A Walk on the Science Side* – from which this excerpt is taken) and finally, *Evolution and Energy in Cancer Cells*.

One of the most frequent and striking things that people say when talking about Jim, is what an amazing teacher and mentor he was, and how greatly he inspired them and changed their lives. His contribution to the substance and direction of NZ science was, and still remains, enormous.