WHITHER TRANSLATIONAL SCIENCE IN ACADEMIA: RISKS AND OPPORTUNITIES

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CHANGING A WORD : DID WE MEAN THIS ?

WHITHER APPLIED SCIENCE IN ACADEMIA: RISKS AND OPPORTUNITIES

WORDS INDEED CLOTHE US IN RESPECTABILITY !

WE ARE STILL GRAPPLING WITH SEMANTICS

- Basic research
- Fundamental research
- Blue sky research
- Curiosity driven research
- Directed basic research
- Use inspired basic research
- Translational research
- Socially relevant research
- Applied research
- Development

The lack of precision in our language is symptomatic of the lack of clarity on the nature of our enterprise

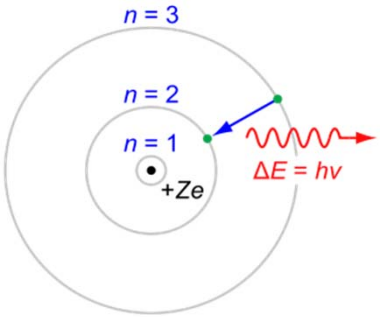
BASIC AND APPLIED SCIENCE : ARE THEY DIFFERENT ?

Metaphor: Buckets of paint vs a painting

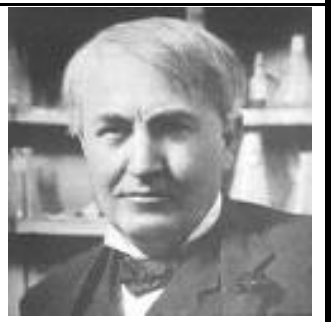
There is science and the applications of science :
Louis Pasteur

Pasteur's Quadrant

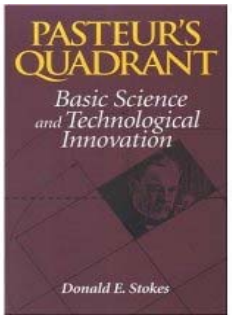
Bohr



Pasteur



Edison



1997

Fundamental Research
Knowledge quotient

Use Inspired Research
Application quotient

BASIC RESEARCH IN TIMES OF CHANGE IN SOCIAL CONTRACT BETWEEN SCIENCE AND SOCIETY

Do basic research

(and someone will solve societal problems)

OR

Solve societal problems

(and, by the way, if you want to do some fundamental research, that's OK

The emergence of concept of use inspired science. It means using basic science for a purpose and practical problems as stimulus to curiosity driven research (G.W. Whitesides and J, Deutch, Nature 460, 21 (2011)

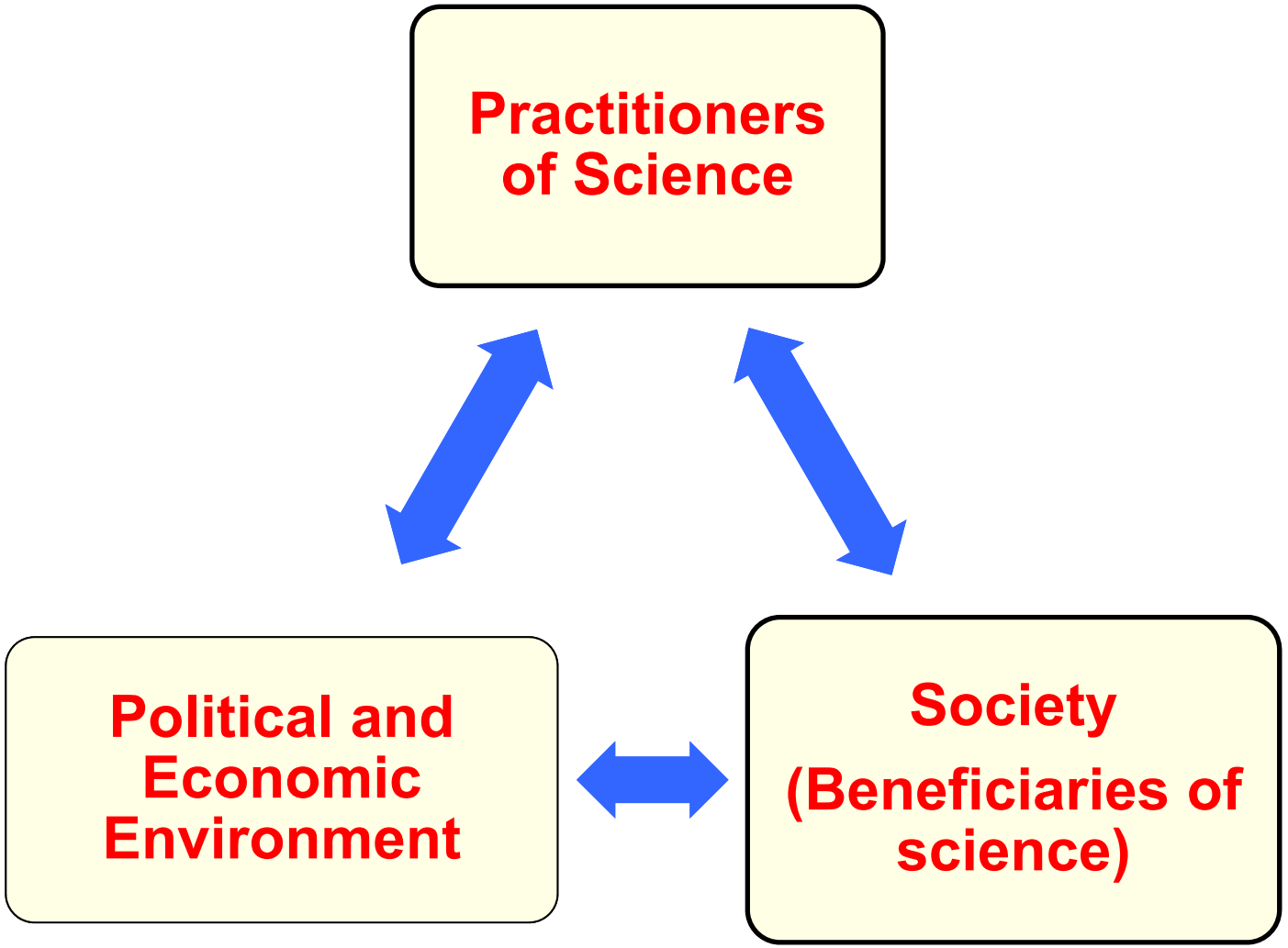
WHY ARE WE IN THIS DILEMMA ?

Answer

- A scientific order, philosophy and public policy that served us for over seventy five years is now broken; there is a need to construct a new public policy framework that will defend future science

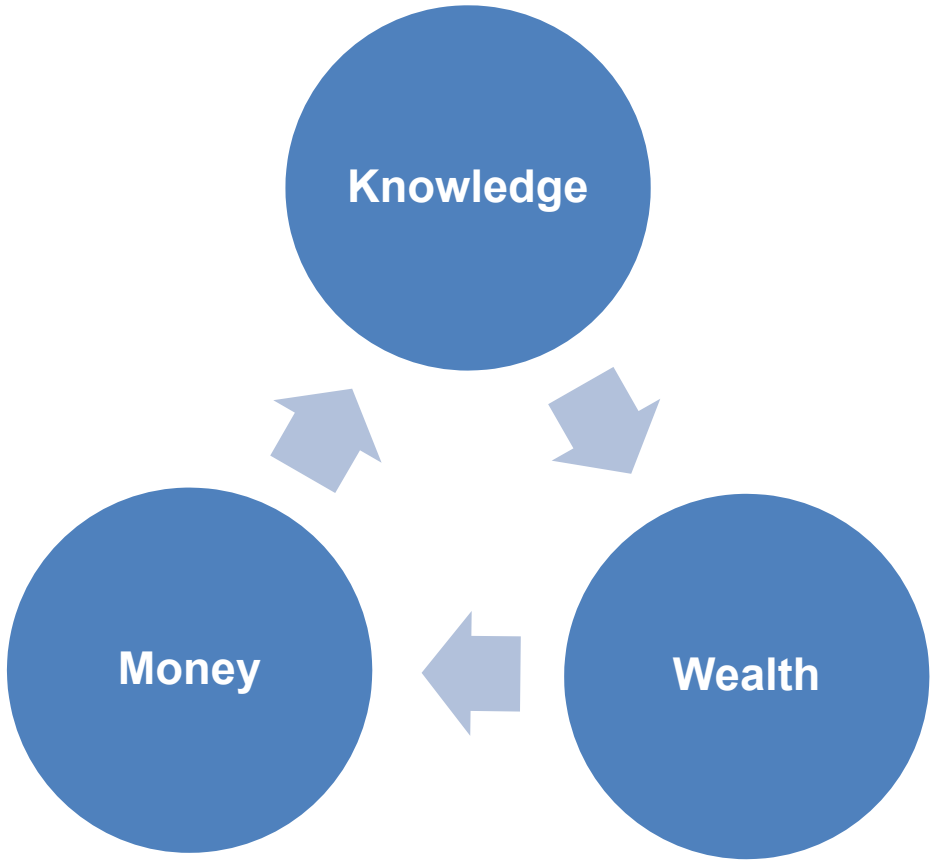
- The social contact that defined scientific enterprise is no longer relevant

SCIENCE AS A SOCIAL CONTRACT



PRACTITIONERS OF SCIENCE

- Faculties, scientists, students, individuals as well as S&T professionals in industry universities, research laboratories, society, industry, etc.
- To create a virtuous cycle of wealth creation from knowledge



THE SOCIETY

- The human race in the early part of 21st century is living in an unprecedented period of peace and prosperity. More people in the world have been lifted out of penury in the last half a century, people are healthier, living better and longer. Many basic human needs have been fulfilled; So it is no wonder an average citizen's interest in science and technology has also waned. He is no longer looking for "miracles of science"

- This does not mean the world has no problems; environment, energy, global warming, climate change, water etc, are issues that are threatening the long term survival of this planet. However, an average human mind cannot grasp issues that do not impact him in his own life time. To make a case for science for solutions that are needed in a distant future is no easy task !

THE POLITICAL AND ECONOMIC ENVIRONMENT

- Shrinking global economy and an aging population is putting severe pressures on Governments discretionary expenditures
- Public policies in science demand quick return on investments implying relevance and importance to national objectives
- While current national objectives may be momentarily worthy, decisions based solely on this premise may ultimately diminish our capacity to produce any kind of science
- What is considered good science and find support today may fall from favor tomorrow

The greatest folly in public support for science is the belief that science can provide solutions to technological problems in the time frame which defines Government longevity and election cycles

SCIENCE AND SOCIETY

- In reality, practical importance of scientific discoveries are often overestimated and hyped, purely for selfish interests.
- Have you wondered how many cures for cancer have been announced in the last two or three decades ?
- Often, discoveries which initially appear irrelevant turn out to be of great practical value
- Consequently, the credibility of science driven solutions to problems faced by the society has suffered damage.
- Common man is more interested in short term solutions that will make his life better in his life time !

This has led to more and more demand for short term focus

NEWS

Trump's cabinet picks worry science community

Selections prompt fears of roll-back on environmental research and mass reorganisation of science agencies

President Trump's choices for cabinet positions and agency director posts have increased tensions between the incoming administration and America's scientific community. Many researchers, science policy experts and environmental groups have sounded the alarm in response to Trump's nominees to head the Environmental Protection Agency (EPA) as well as the Departments of State and Energy, among others.

Last year, Trump revealed that he will nominate Oklahoma attorney general Scott Pruitt – whose website says he is 'a leading advocate against the EPA's activist agenda' – to be the next administrator of the EPA. Pruitt has repeatedly sued what is set to become his agency to roll back regulations like President Obama's Clean Power Plan that aims to cut emissions from coal-fired power plants and has often publicly disparaged the science behind global warming and its connection to human activity.

Trump's cabinet picks require Senate approval before they can take up their posts, but it is controlled by the Republicans so there may be relatively weak opposition. Confirmation hearings were underway as *Chemistry World* went to print.

During a Senate hearing on 18 January, Pruitt said he does not believe that global warming is a hoax, as Trump has tweeted. While Pruitt acknowledged that the climate is changing, he said the precise impact of human activity on those changes is subject to 'continuing debate and dialogue'.

Pruitt also indicated that he 'absolutely' supports full implementation of the new Toxic Substances Control Act (TSCA), which governs US chemicals policy. The 40-year-old law was finally updated with bipartisan support in June last year, and Pruitt applauded the fact that the EPA now has the ability to order safety testing for chemicals coming onto the market.

Campaign contributions data indicate that Pruitt has received more than $300,000 (£240,000) from the fossil fuel industry since 2002. The American Coalition for Clean Coal Electricity (ACCCE) endorsed him as the EPA's new chief. '[Attorney] general Pruitt will be a strong advocate for sensible policies that are good for our environment, as well as mindful of the need for affordable and reliable electricity,' said Paul Bailey, the ACCCE's senior vice president for policy.

'Dangerously irresponsible'

However, the American Association for the Advancement of Science (AAAS) is troubled by Pruitt's attitude to the EPA, and his claims that the science of climate change is unsettled. 'If a person jumped off a building because he said gravitation is only a theory, one would say he is delusional,' said AAAS chief executive Rush Holt, a physicist and former congressman. 'So too, any policymaker who would base national policy on denial of climate science because there is "debate" would be called dangerously irresponsible.'

One person extremely qualified to comment on the choice of Pruitt to lead the EPA is Christine Todd Whitman, who served as the agency's administrator under former Republican president George W Bush, and she is extremely apprehensive. 'Pruitt doesn't seem to have much faith in science, period – much less the agency's science,' Whitman tells *Chemistry World*. 'There seems to be a general attitude in the incoming administration that they don't trust the science,' she continues.

'Science, it seems to me, is going to take a hit if everything they say is true – how would they fill that gap, except for finding some of the 3% of scientists that don't believe in climate change,' Whitman asks. Studies have revealed that at least 97% of active climate scientists agree that human activity is responsible for current warming.

Phillip Williamson, an environmental scientist at the University of East Anglia in the UK who also serves as science coordinator for the UK government's Natural Environment Research Council, fears for the future. He worries that US participation in the Intergovernmental Panel

> **There seems to be a general attitude in the incoming administration that they don't trust the science**

on Climate Change – the international body charged with assessing climate change research – might now 'come to an abrupt and shattering halt' in the Trump administration. 'If US scientists aren't funded to participate, or if the nominations to such meetings are individuals who have got a climate denial background, then that could be very disruptive.'

Stopping sledgehammers

Nina Fedoroff, a molecular geneticist at Pennsylvania State University who was science and technology adviser to the Secretaries of State during the Obama and George W Bush administrations, acknowledges that there are aspects of EPA regulations that need improvement. However, she says that taking 'a sledgehammer to the agency is clearly not constructive'.

Although it is unclear what Pruitt will do at the helm of the EPA, Fedoroff says his repeated attacks on the agency's regulations provide insight. 'Presumably, if he behaves consistently with his record, that will certainly affect the nature of the research that is supported, or perhaps decrease the support for climate research,' Fedoroff states.

Beyond Pruitt, Trump's choice to head the Department of Energy (DOE) – former Texas governor Rick Perry, who once vowed to abolish the agency and has called climate change a 'contrived, phony mess' – is also causing consternation.

Under Perry's tenure as Texas governor, the state's oil and natural gas production boomed. Indeed, Perry's second largest contributor when he ran for president in 2012 was Murray Energy – the largest privately owned coal company in the US – with donations of over $115,000.

Perry disavows Trump request

During his Senate confirmation hearing, Perry expressed his desire to maintain US scientific leadership and support basic research. He also distanced himself from a questionnaire the Trump camp sent to the DOE apparently seeking to identify employees involved in the agency's climate change research programme.

Perry said that survey went out before Trump selected him to be the next DOE director. 'I didn't approve it, I don't approve of it,' he stated. Many saw the questionnaire as an attempt to

TRUMP'S SCIENCE AGENDA

Budget Cuts Fiscal 2017

Agency	% cut
DOE-ARPA	51
EPA	10
NIST	50
NIH	4*
NSF	5

** Budget Cut for NIH recommended for 2018 : 15 %*

Obama's initiative on Precision Medicine, Cancer Moonshot and Clean Energy unlikely to be funded

SCIENCE IN UNCERTAIN TIMES

NEWS ANALYSIS

Funding impasse hits Illinois chemists

Political divisions create huge budget shortfalls

Chemistry departments in Illinois, US, are entering perhaps their toughest semester ever, facing budget shortfalls arising from a second year of stopgap state-level educational funding. Universities are among those caught in the crossfire, with politicians' inability to agree on expenditure hitting those with few other funding avenues hardest.

Chicago State University (CSU) has seen 'massive layoffs of administration, support personnel and faculty', says Edmundo Garcia, chair of CSU's department of chemistry, physics and engineering. CSU gets around 40% of its budget from the state, while income from tuition fees is also falling. This is partly because state subsidies for those in financial need went unfunded for several months, but also because students are worried and looking elsewhere. Undergraduate enrolment at CSU for 2016–2017 is currently down 50% compared with 2015–2016.

'We lived from 1 July 2015 until April 2016 without 40% of the money we need to run the school,' Garcia says. 'We let go almost all of our part-time faculty and full-time lecturers. We're in survival mode until this is resolved.'

The crisis began in June 2015 when Republican governor Bruce Rauner vetoed a state budget devised by the Democrat-controlled Illinois government. Rauner said the budget would add $4 billion (£3 billion) to Illinois' existing debt, estimated to be around $100–$300 billion. In April 2016 the opposing sides agreed a $600 million stopgap package for higher education, whereas the Democrat budget originally earmarked $1.7 billion. In June, the opposing sides agreed another $1 billion for higher education through to June 2017.

Eastern Illinois University (EIU) in Charleston, is fractionally better off than CSU, relying on state funding for a third of its budget. It has laid off many support staff, and 25 EIU faculty on previously recurring annual contracts have been lost in the past two years. Meanwhile, the chemistry department is questioning the affordability of using silver nitrate in gravimetric analysis teaching experiments, says Jonathan Blitz, an analytical chemist and president of the faculty union at EIU.

The University of Illinois has suffered less thanks to a greater diversity of funding sources. Gi Girolami, head of the Urbana–Champaign campus's chemistr department, says that research and teaching has been unaffect although faculty and non-unior staff have had no salary increas over the last two years.

Hopes that the situation will be resolved in the November U elections are tenuous. Rauner i up for re-election, but the entir Illinois House of Representativ and most of the State Senate is. Together, the House and Senat can override Rauner's veto.

'The House is a couple of votes short,' Blitz highlights, and if t Democrats gain seats, they cou force their budgets through. Ill income taxes may be raised aft the election, says Girolami, wh 'would certainly help'.

Andy Extance

Economic woes squeeze Brazil science

Money earmarked for research held up by cuts

As economic woes grip Brazil, the country's scientific enterprise has been hit hard. The Brazilian economy is expected to contract 3.5% this year following a 3.8% contraction in 2015, marking its worst economic downturn in a quarter of a century. Science funding has taken a knock, despite arguments that such investment is exactly what's needed to pull Brazil out of its slump.

The budget for Brazil's Ministry of Science, Technology and Innovation (MCTI) has been slashed by almost 20% and sits now at about BRL4.3 billion (£875 million). The ministry also faced a significant reduction in 2015, and overall about one-third of its budget was lost from 2014 to 2016.

'There is a huge crisis in Brazilian science,' warns Helena Nader, president of the Brazilian

Funding for Brazil's popular international exchange scheme has been slashed

and entrepreneurship.

There was a call to create

them is available for release later this year. The rest of the

Without Borders, which was created by Brazilian President Dilma Rousseff, who is currently fighting impeachment, in 2011 to improve the nation's competitiveness in science and technology. The initiative is supported both by the Ministry and Education and the MCTI, through the respective funding agencies Coordinating Office for the Advancement of Higher Education (CAPES) and the National Council of Scientific and Technological Development (CNPq).

In its first four years of operation, Science Without Borders funded roughly 101,000 scholarships to enable the international exchange of Brazilian researchers, undergraduates and postgraduates. In 2015, about BRL3.7 billion was provided to the programme by CAPES and BRL1.1 billion by CNPq. This year, those amounts were slashed to BRL1.46 billion and BRL500 million, respectively.

Brexit storm shakes European Research Council

Europe's premier science council's mission at risk

Pierre Bourguignon, president of the ERC.

But June's referendum result casts doubt on the UK's future eligibility. The loss of the UK and Switzerland would 'be a big blow to European science', warns Athene Donald,

the ERC itself of the ERC, i was following US model, fo and imaginati general acade McConnell s

(£43 million) to €1.8 2017, its first increas Switzerland has p

Worst may still be to come for Spanish science

Effects of budget cuts from the financial crisis are still in

Nazario Martin, president of the Confederation of Spanish Scientific

the financial he blame for untries, such as Italy and the UK, ding on R&D n. 'The problem ticians consider stead of an n says. countries invest

model based on knowledge, and unfortunately the economic recovery hasn't reached our R&D system,' says Jorge Barrero, chief executive of COTEC. The shortfall in public R&D investment in Spain hasn't been made up for by the private sector either. According to COTEC, 47% of R&D was privately funded in Spain, while the private sector in other countries such as Germany, France and the UK covers around

dominated by SMEs, which constitute over 99% of companies and contribute over 65% of GDP – behind only Greece and the Baltic countries. 'These [small] companies already have trouble surviving, and they don't usually conceive research as something useful,' Martin says.

The funding shortfall and other problems, such as a brain drain, haven't affected productivity yet, however. According to CRUE's yearly report, scientific output has remained static. However, Gómez said that the worst is still to come. 'I think we have a good system, which is weathering the crisis quite well, but we must not relax. We are going to see the real effects in a few years.'

Science chief sounds alarm on funding

Calls for US research spending to exceed 3% of GDP

White House science adviser John Holdren and the leaders of three key US science agencies have warned that the nation must up its commitment to science and innovation to ensure it isn't outstripped by its competitors. Holdren expressed disappointment that the Obama administration has fallen short of the president's goal to increase spending on R&D to more than 3% of GDP.

'We haven't quite got there, we are still just under 3%,' Holdren

significant concern that the US's R&D intensity is decreasing relative to other nations.

It has always been a challenge to answer how much R&D investment is sufficient, but empirical evidence shows that the US is making an inadequate investment in science, technology and innovation, he said. The National Institutes of Health (NIH) is only able to fund about 16 or 17% of the grant proposals it receives, he added, when it is estimated that about 50% of the applications submitted have merit.

As another example, Franklin

White House science adviser John Holdren calls for the US to increase

within a dozen years of their PhD, is 'much, much lower' at her agency and elsewhere. 'We are very worried,' Cordova said. 'The other consequence of this is that we are losing people to science because they are getting discouraged by not getting their grant accepted.'

Despite its failure to achieve the 3% of GDP target, science and technology fared better under President Obama's budgets than almost any other sector of the government. 'That was a result of the president's understanding of how and why science and technology

SCIENCE IN UNCERTAIN TIMES

NEWS AND ANALYSIS

Australian science base eroded by cuts

FUNDING
Scientists decry decisions as 'politicised'

Australia's research community is reeling from what have been described as short-sighted and politically motivated cuts, outlined in the new conservative government's first budget.

Only medical research emerges as a real winner, with the creation of a A$20 billion (£11 billion) fund by 2023. But 'overall there will simply be less science research in Australia in three years time', according to Lee Field, science policy secretary at the Australian Academy of Science. Field says the government 'failed to realise that medical research needs underlying expertise in the chemical and physical sciences, and that support is being eroded'.

'It's an easy headline grabber,' says Michael Borgas, secretary of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) union, talking about the medical fund, but he argues it 'politicises' research as it will be built up through a new A$7 consultation fee for seeing a doctor. The money will be ploughed into medical research once the fund reaches its A$20 billion goal.

'There is no thought as to how to use the money they don't have any understanding of the science system,' says Borgas. CSIRO – the largest government research organisation – faces cuts of A$114 million. It will lose 420–500 staff in the next year. Coming on top of 300 previously announced redundancies, this means the organisation will shrink by around 20% in just two years. There was further bad news for CSIRO with reports that eight research facilities will also be closed.

Sleight of hand

Both Field and Borgas welcome an additional year's funding for big infrastructure projects, such as the Australian Synchrotron and the Square Kilometer Array's supercomputer. But a feature of the budget will see science funding redirected from one programme to another, as although CSIRO budgets will be supporting infrastructure, there will be less money for its scientists to use the facilities. Field bemoans the short-term approach the government is taking: 'One has to weigh out what infrastructure you need and how to support it – and that transcends the lifetime of a government.'

Environment, climate change and renewable energy are all big casualties of the budget – most notably the intended abolition of the Renewable Energy Agency that will save A$1.3 billion, and the A$10 billion Clean Energy Finance Corporation. A$162.9 million will be cut from the carbon capture and storage flagship, and a commitment to 1 million solar roofs has been withdrawn.

Abandoning carbon pricing will cost the Australian treasury A$30 billion, while raising corporations will get A$13 billion in subsidies through diesel fuel rebates, accelerated depreciation rules and offsetting the costs of exploration, says Victoria McKenzie-McHarg, climate campaign manager at the Australian Conservation Foundation. 'Billions of dollars have been cut from clean energy programmes which were delivering jobs on the ground.' She argues these were positive Australia to take advantage of its natural resources. 'A great opportunity to change our economy has been squandered – the question is whether through wilful ignorance or a fundamental misunderstandin

Fees quandary

From 2016, the university fundi model is changing so that universities will be able to decid their own course fees. Universiti will have to cover an 8.5% drop i funding compared with what wa promised in last year's budget – and one which already included stringent cutbacks. Changes to t higher education loan program mean interest rates payable by students taking out the loans wi be set at the higher 10-year bond rate, rather than inflation.

Universities are still trying to unpack the consequences of undergraduate fees, and trying to work out what the market will bear,' says Field. Nor do universities yet know the impac of new fees for PhD and master students. 'Government support for science undergraduates has been hit hard, so universities wi have to work harder to recover more money from science students,' he says, 'so it's going to cost more to study science f… and that may mean people choc shorter degrees.'

The Australian Research Council will have to find almost A$75 million in efficiency saving over the next three years, and A$92 million of its funding will be redirected towards research into tropical health and medicin dementia and the Antarctic.

As the main agency which supports science other than heal and medicine, the success of gra applications is already just 20% says Field. Its settlement 'will put Australia into a zone where funding for chemical research, f example, may not be available.' *Angela Stehta*

THE BUDGET IN NUMBERS

Winners

- A$20 billion for a medical research fund
- A$140 million to continue mid-career fellowships
- A$90 million for the National Collaborative Research Infrastructure Strategy for 2023–16

Losers

- CSIRO funding cut by A$114 million
- Clean technology programme axed saving A$43 million
- Innovation and commercialisation programmes cut by A$850m
- Carbon capture and storage flagship cut by A$62.9 million

Tony Abbott's government is backing a new A$20 billion medical fund

NEWS AND ANALYSIS

Portuguese chemistry faces disaster

FUNDING
A third of academic chemistry labs could close

Scientific research centres across Portugal are facing dramatic funding cuts following a large-scale review carried out by the country's Foundation for Science and Technology (FCT). The chemical sciences have fared particularly badly, with more than a third of chemistry departments evaluated set to receive no or minimal funding over the next five years, putting them at significant risk of closure.

The decision is part of the 2013 evaluation of R&D units carried out by the FCT, the main government organisation responsible for funding research in Portugal. During the first stage of the evaluation, research centres are reviewed and graded by panels of experts appointed by the European Science Foundation, based on several criteria including scientific merit, productivity and strategic plans.

Only those deemed 'very good', 'excellent' or 'exceptional' will move on to the next stage of the review, which will decide how much funding each department will get. Those given a 'poor' or 'fair' rating will get nothing for the duration of the 2015–2020 funding period, starting in January 2015. Those rated 'good' will receive only core funding, ranging from €5000 (£3960) for the smallest labs up to €40,000.

Across all research areas, 22% of all centres evaluated were given a poor or fair rating and will get no funding at all. Of the 36 chemistry research centres evaluated, six failed to receive a high enough rating to proceed to the next round. Some of these centres received a very good or excellent rating in previous reviews, and are suddenly facing a severe loss of income.

'FCT funding is vital for chemistry research in Portugal,' explains Anthony Burke, a chemistry professor at the University of Evora's chemistry department, which is one of the groups affected. 'Besides EU funding, the FCT is the principal source of funding for chemical research, including PhD and postdoc scholarships. There is virtually no industrial funding.'

The Portuguese Chemical Society (SPQ) said it is 'deeply concerned' by the review's outcome, and urged the FCT to look again at its evaluation processes.

'Several chemistry research centres have not passed the second stage of the evaluation process, which essentially condemns them to extinction,' they said in a statement. 'Some of these research centres have significant indicators of scientific productivity, based on the fact that they mostly received "excellent" or "very good" ratings in previous reviews.'

SPQ secretary general S Seixas de Melo tells *Chem World* that the society can out its own bibliographic based on data provided b Elsevier. 'We found that t research fields some of th most productive [centres] excluded from the second he says. 'Something defin went wrong in this evalua procedure.'

But the FCT strongly d that its assessment meth were in any way flawed. It a statement saying it had confidence in the robustn of the ongoing review' an it was being carried out w 'total transparency, rigou independence and in line with the highest internati standards'.

Research centres can ap the FCT's decision, and s have already begun this p *Emma Stoye*

NEWS AND ANALYSIS

Scientists unsure about Modi

POLITICS
New Indian government must address underfunding

India may have dispatched a mission to Mars recently, but no Indian citizen has won a science Nobel prize since the country gained independence in 1947. As a new government takes centre stage in the world's largest democracy, the scientific community is demanding a renewed focus on science.

The new prime minister, Narendra Modi, has appointed endocrinologist Jitendra Singh as the new science and technology minister. Singh is a newcomer to politics and had not run for election until this year. Most of the ministers who are given this portfolio are low profile, and it's unfair to speculate on how he will perform based on his political experience,' says Mathai Joseph, a software R&D consultant and a former professor of computer science at the University of Warwick, UK. 'He has a background in science. I'm optimistic.'

Will Modi's government deliver for India on science?

Same old problems

The new government faces a set of problems that have plagued Indian science for years. 'Former Indian Prime Minister Manmohan Singh spoke of increasing the science and technology budget to 2% of GDP for donkey's years, but nothing happened,' says N Raghuram, associate professor of functional genomics and molecular biology at Guru Gobind Singh Indraprastha University, and former secretary of the independent scientific community-watchdog Society for Scientific Values. India's current public spending on research and development is around 0.9% of GDP, which is lower than other rapidly developing countries, with China and Brazil spending 1.8% and 1.3% of their GDP on science, respectively. Moreover, India's contribution to global spending on research and development is a mere 2.7%, compared with China's 15.3%.

According to an analysis by the Blankstack Centre for Public Policy Research, India's science budget was cut by 1.62% in 2013–13, compared with the previous year. However, it did see a year-on-year increase of 11% in 2013–14.

The last government earmarked just Rs823 billion (£829 million) for the ministry of science and technology, which is compared with Rs297 billion for the atomic energy and space departments in 2013–14.

Thomson Reuters data shows that while India's research output grew substantially from 2003 to 2012 – at nearly three times the rate of the global average – its percentage of highly cited papers remained low, hovering around 0.7% in 2011. Joseph blames this on a lack of money for universities. 'Universities are blamed for not creating enough PhDs,' Joseph says. 'But they do not have sufficient funding to create enough PhDs, to produce manpower for the research institutes and generate quality papers.'

Most scientific research in India is publicly funded, with the money controlled by government agencies. Joseph advocates creating an independent agency along the lines of the National Science Foundation in the US or the European Research Council to dispense science money. 'Creating independent agencies expedites the process of approvals for research,' he notes.

Ajay Lele, a research fellow at the Indian Institute for Defence Studies and Analyses, says the major tenets outlined in the science and innovation policy unveiled by the government in 2013 should be continued by the new one. 'Attracting private investments in R&D, for example, could be one fruitful area,' Lele says.

Environmental concerns

Meanwhile, the Modi government has removed the environment ministry to include climate change in its title. 'It is a good move, symbolically, to include climate change under the portfolio of the environment ministry,' says Chandra Bhushan, deputy director general of the non-profit Centre for Science and Environment. 'This shows that this government is putting a little more emphasis on climate change than the previous one.'

However, Vinatta Gopal, Greenpeace India's climate and energy head, is sceptical about the government's commitment to protect the environment. 'In the first few days of governance, they've indicated how they're going to fast-track green clearances,' says Gopal. 'While the environment minister, Prakash Javadekar, keeps indicating that development will not be favoured over the environment, the message they're really sending out to the industry is that clearances would not be held up.'

Dinsa Sachan

IN THE PAPERS

Rothko restored
Rothko's *Black on Maroon*, painting that hasn't put bac on display in the US's Tate Modern gallery following months of restoration afte was vandalised with inde ink. Conservators used a mixture of benzyl alcohol ethyl lactate, applied unde a microscope using a very fine brush, to dissolve the ink bit by bit, removing th graffiti without damagin painting itself.
The Guardian, 14 May 201

Tomato pill for heart health
A daily 'tomato pill' contai the antioxidant lycopene the red pigment that gives tomatoes and peppers the colour – may help prevent heart disease. Researcher found that tomato pills improved the functioning blood vessels in a group 72 adults, when compared a placebo.
BBC News, 6 June 2014

Brushing back enamel
Unilever has launched a toothpaste that they claim restores and whitens damag teeth by regenerating 82% enamel in just three days. The toothpaste contai calcium silicate and sodium phosphate, which provide building blocks for a fresh of enamel to clean prep
The Daily Mail, 15 June 20

Boost bracelet
An ankle bracelet that can tell if the wearer has been drinking by detecting alc in their sweat will be trial in the UK for monitoring criminals convicted of rel related offences. The 'sobr bracelet', which has been successful in the US, cont a fuel cell that works in a similar way to a breathaly generating a current when alcohol is present.
The Times, 14 May 2014

NEWS

Fears for fundamental science after India's latest budget

India's scientific ambition not backed up by funding

For the third year running, science funding has remained static under Narendra Modi's government, following India's latest budget. The news has caused disquiet among scientists, who are worried about the fate of basic research.

The key departments engaged in scientific research, including the Ministry of Science and Technology, will receive INR348 billion (£3 billion) – an 11% hike in funding over the previous year. Yet critics point out that this rise will mean science spending will only just keep pace with inflation. 'This year not only follows the same trend of the past, but with more disillusionment,' says Krishna Ganesh, director of the Indian Institute of Science Education and Research (IISER), Pune. This budgeted allocation is at odds with prime minister Modi's announcement at the Indian Science Congress in January that India will become a global power in science by 2022.

Unveiling the budget, finance minister Arun Jaitley said: 'Emphasis will be given on science education and flexibility in the curriculum to promote creativity through local innovative content.' However, no new ideas were proposed in the budget as to how to go about this. Jaitley also spoke of higher education reform, but funding increases (of around 60%) were only announced for the Indian Institutes of Technology (IITs) – the country's premier research institutes.

Only two departments in the science ministry, biotechnology and space, received substantial increases – 22% and 21% respectively – signalling support for their ambitious programmes. The department of biotechnology launched a national strategy at the end of 2015, which aims to raise India's biotech turnover from $7 billion (£5.3 billion) to $100 billion by 2025. 'We plan to launch our new programmes in marine science research, and drugs and pharmaceuticals, besides supporting basic research,' Department of Biotechnology secretary Krishnaswamy VijayRaghavan tells *Chemistry World*.

Meanwhile, in 2017 the department of space will launch further remote sensing and communication satellites, and prepare for its second moon mission scheduled for 2018. The science and technology department received a relatively meagre 7.7% hike, compared with previous years when it received heftier rises and saw the launch of 16 new programmes.

Not good enough

This is the third consecutive year that Modi's government has disappointed the science community's hopes of a major funding boost. In recent years the budget for basic science appears to be increasing in real terms, but 'the actual percent increase every year is decreasing', points out Ganesh. 'This is no good.'

While India has opened up a large number of IISERs, IITs, central universities and a host of R&D institutes, attracting an estimated 600–700 young, talented scientists back to the country, 'the amount of research funds to support such a large number of scientists has not gone up by the same proportion. The increase is paltry – to take care of inflationary trends,' says Ganesh.

India's investment in basic science has been hovering around 0.9% of GDP for the last decade, compared with advanced countries that invest about 2% of their GDP. Gautam Desiraju, professor of chemistry at the Indian Institute of Science, Bangalore, says this figure 'is too low and needs to go up'.

'Successive governments including the present one, in general, might have tended to shy away from heavy funding of projects, fearing that it may not all be spent in the required timeframe or could be misused,' Desiraju adds. 'Accountability of the use of funds is largely absent.'

The Indian government also tends to allot significant funding to a few well-known researchers, Desiraju notes. 'Whereas, the country should fund a large number of smaller researchers and investigators with smaller grants, so that more innovative research ideas are pursued. The concept of big funds for a few projects is justified in mission-oriented research such as, say, the Mars mission, but not basic research funding.' ■

T V Padma

Government funding of science under stress; No nation is today immune to this trend.

IN DEFENCE OF BASIC RESEARCH

- Should scientists be restricted by shortsighted timelines and narrowly defined objectives ?
- Curiosity driven research is under pressure to justify itself; It is endangered and has become vulnerable
- Today's prevailing policy is to measure the value of research solely on whether it is useful, whether the research addresses a social problem or whether it is possible to deliver a marketable product in the foreseeable future, preferably within a few years

On the Usefulness of Useless Knowledge
Nature Reviews, Chemistry, 11 January 2017
Doi:10.1038/S41570-016-0001

THE CONUNDRUM

Why is it that the society is willing to support an activity as abstract and altruistic as basic scientific research and an enterprise as large and practical as the research and development enterprise ?

UTILITARIAN AND ROMANTIC VIEW OF SCIENCE: BERNAL Vs POLANYI

- Utility is the central objective of the scientific enterprise
- Central role of state in supporting / promoting science
- The rationale for organized science, government funded or directed science

- Individual scientists pursuing truth leads to the most efficient social outcomes

The Social Function of Science, J.D. Bernal, George Rutledge and Sons, 1939.
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THE ROMANTIC VIEW OF SCIENCE

" Scientific research has to do only with the respect with which we regard one another, the dignity of men, our love of culture. It has to do with : are we good painters, good sculptors, great poets? I mean all the things we really venerate in our country and are patriotic about. ***It has nothing to do directly with defending our country except to make our country worth defending"***

Robert Wilson, arguing for support from the US Congress for building the Fermi National Accelerator, 1969
Source: Scientific Temperament: Three Lives in Contemporary Science, P. J.Hilts, Holiday House, 1984

IN DEFENCE OF BASIC RESEARCH : USELESS KNOWLEDGE

Intellectual Freedom in Academic Scientific Research under Threat

*John Meurig Thomas**

Sir John Meurig Thomas

"Research at the institute is primarily curiosity driven, which is reflected in the five sections comprising this Review" (on the oxidation of carbon monoxide). So wrote H.-J. Freund, G. Meijer, M. Scheffler, R. Schlögl, and M. Wolf in a Review in the special issue of *Angewandte Chemie* to mark the centenary of the Fritz Haber Institute (FHI) of the Max Planck Society (*Angew. Chem. Int. Ed.* **2011**, *50*, 10064). These words were music to my ears. The philosophy that animates research at the FHI also prevailed in almost all universities of the United Kingdom in former times. But this is no longer so: indeed, such has been the transformation in the attitudes of policy makers and funding bodies that it has prompted many leading academics in this country to establish a Council for the Defence of British Universities (CDBU) so as to reinstate an ethos that is still pervasive at the FHI and doubtless at many other Max Planck Institutes. Four former Presidents of both the Royal Society and the British Academy, along with the present holders of those prestigious posts, two former UK Government Cabinet Ministers, and numerous leading academics representing the sciences and the humanities are among the founders of the CDBU.

Ever since the days of Isaac Newton, university teachers have cherished the freedom to investigate any aspect of the natural world irrespective of the need to justify the possible practical importance of their discoveries. In the early 1850s, for example, the young James Clerk Maxwell became fascinated by the experimental discoveries of Michael Faraday, especially the observation that light could be "manipulated" by a magnetic field. So intrigued was Maxwell by Faraday's work that he decided to write a treatise on "Faraday's Lines of Force" as his Research Fellowship submission to Trinity College, Cambridge. The outcome of Maxwell's work led to the mathematical foundation of the phenomenon of electromagnetism. One of the consequences of the Maxwell–Faraday work is the realization that every ray of light has a magnetic and electrical component. If this were not so, it would be impossible to explain the transmission and reception of radiowaves or to account for the mode of action of devices such as televisions and telephones. Newton's Laws do not help us one iota in understanding the mechanisms of these and the other electronic gadgets now in popular use. It was Faraday's question of a possible relation between magnetism and electricity that led him to discover electromagnetic induction, which gave us the dynamo, the transformer, and the means of generating continuous electricity now used worldwide in power stations.

In the 1920s, young Paul Dirac, stimulated by the work of Heisenberg, Born, and Jordan in Germany, undertook his quantum-mechanical studies, which were motivated by sheer intellectual curiosity and the desire to incorporate relativistic features into the Schrödinger equation. Dirac's mathematical formulations led him to propose, in 1927, the existence of the positron, the first-ever suggestion that antimatter was a reality. It took another four years before the experimental proof of the positron's existence was established by Carl Anderson at the California Institute of Technology. For many decades thereafter, the positron was regarded as a novelty with little prospect of it ever being harnessed for practical purposes. Now, however, almost every major hospital in the industrialized countries uses positron-emission tomography (PET). Its many uses include charting cerebral activity and identifying stages in the growth of tumors.

It was pure curiosity that led scientists in the late 1940s to discover NMR spectroscopy; a few decades later, another noninvasive medical technique based on it, magnetic resonance imaging (MRI), was invented. In the 1950s, at Columbia University, Charles Townes became intrigued by the possibility that the population of electrons in simple molecules could be inverted. When he proposed this experiment, he was told that he was wasting his time by several notable physicists. But Townes stubbornly persevered and so discovered the maser, the forerunner of the laser. This has changed our world comprehensively. In addition, it duly led to the discovery that our nearby galaxies shine maser light upon us.

There have been many other transformational discoveries, the practical importance of which could not have been readily foreseen: X-rays, nuclear fission, antibiotics, antibodies, immunosuppressive drugs (that make spare-part surgery feasible), and the structure of DNA, to name but a few. Scientific researchers know that discoveries cannot be planned: they pop up, like Puck, in unexpected corners.

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COMMENT

On the usefulness of useless knowledge

Helmut Schwarz[1,2]

Basic research may or may not lead to new technologies. Our safest bet in this gamble is to give our brightest minds the funding and freedom to dream big.

> Individuals need space, freedom and trust to be able to develop to their full potential. Only then will they have the courage to take the risks that make discoveries possible

Most breakthroughs in research are not and could not be planned. Rather, they appear, like Puck, in entirely unexpected corners. Because it is the passion of individuals that sparks major discoveries or inventions, choosing outstanding people and providing intellectual freedom and generous funding are key to the success of academic institutions.

Abraham Flexner, the founding Secretary General of the Institute for Advanced Study in Princeton, penned in November 1939 a most readable essay on fundamental research[1]. *The Usefulness of Useless Knowledge* described, in Flexner's fluid prose, how apparently random experimentation eventually leads to the most important discoveries. He argued vehemently against the need for utility in the promotion of research and the allocation of funding. Instead, Flexner delivered a rousing plea for the "freeing of the human spirit". His article is an eloquent discourse on the benefits and virtues of freedom in fundamental research. Flexner's words are music to the ears of scientists who pursue science because they are curious and, in the venerable words of Friedrich Schiller, do not live off science but, above all, for science. Although Flexner's essay appeared more than 75 years ago, it is still one of the most compelling pieces on the vital role of fundamental research — extolling not only its cultural value, but also its benefit to mankind in general.

The role of individuals

Fundamental research itself thrives on the desire of scientists to explore new territory — *terra incognita* — to discover the truly unknown, and to investigate and explain and, perhaps, to apply it. This is usually a protracted process fraught with setbacks. It turns out, time and again, that breakthroughs in research cannot be planned and that their value and usefulness are initially unknown or difficult to assess. Although science, like a mosaic, is made of the contributions of many, crucial breakthroughs are nearly always based on the achievements and passion of individuals, contingent on a combination of creativity, intelligence, curiosity, perseverance and serendipity. These individuals need space, freedom and trust to be able to develop to their full potential. Only then will they have the courage to take the risks that make discoveries possible. To foster the development of researchers, they should not be restricted by shortsighted timelines and narrowly defined objectives, but should instead be provided with funding continuity. This is indeed the demand at the heart of Trust Researchers, a manifesto signed by over 13,000 scientists and submitted to European institutions and parliaments.

Fundamental research

New knowledge is generated when researchers are driven by the desire to understand, a desire that can only be acted on when intellectual pursuit is liberated from the constraints of concrete applications and tightly set targets. "Knowledge ought to precede application," stated Max Planck[2] amidst the depressing atmosphere hovering over Europe in the wake of the First World War, and it has remained the precept on which the Max-Planck-Gesellschaft (MPG) operates to this very day. Along with generous public funding, their focus on basic research, the uncompromising pursuit of excellence and hiring the very best, has put the MPG on par with the best and most prestigious research institutions in the world. No fewer than eighteen Nobel Laureates have emerged from the ranks of its scientific members since 1948. Similar success stories include the Laboratory of Molecular Biology in Cambridge, UK, as well as the AT&T Bell Laboratories and US National Institutes of Health, the latter two having blossomed in the mid-1960s. The common thread is that all of these institutions were based on the principle of excellence.

Although curiosity-driven research is the engine that eventually generates innovation, at the outset such research entails travelling a long and winding road, swimming against the current and overcoming hurdles with no shortcuts in sight. Basic research is time consuming and expensive. It is rarely easy for scientists to explain this to the general public, legislators or ministerial decision makers. Actually, in many countries, basic research has come under pressure to justify itself: it is endangered and has become vulnerable.

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THE USEFULNESS OF USELESS KNOWLEDGE

BY ABRAHAM FLEXNER

Is it not a curious fact that in a world steeped in irrational hatreds which threaten civilization itself, men and women—old and young—detach themselves wholly or partly from the angry current of daily life to devote themselves to the cultivation of beauty, to the extension of knowledge, to the cure of disease, to the amelioration of suffering, just as though fanatics were not simultaneously engaged in spreading pain, ugliness, and suffering? The world has always been a sorry and confused sort of place—yet poets and artists and scientists have ignored the factors that would, if attended to, paralyze them. From a practical point of view, intellectual and spiritual life is, on the surface, a useless form of activity, in which men indulge because they procure for themselves greater satisfactions than are otherwise obtainable. In this paper I shall concern myself with the question of the extent to which the pursuit of these useless satisfactions proves unexpectedly the source from which undreamed-of utility is derived.

We hear it said with tiresome iteration that ours is a materialistic age, the main concern of which should be the wider distribution of material goods and worldly [illegible] are deprived of opportunity and a fair share of worldly goods therefore diverts an increasing number of students from the studies which their fathers pursued to the equally important and no less urgent study of social, economic, and governmental problems. I have no quarrel with this tendency. The world in which we live is the only world about which our senses can testify. Unless it is made a better world, a fairer world, millions will continue to go to their graves silent, saddened, and embittered. I have myself spent many years pleading that our schools should become more acutely aware of the world in which their pupils and students are destined to pass their lives. Now I sometimes wonder whether that current has not become too strong and whether there would be sufficient opportunity for a full life if the world were emptied of some of the useless things that give it spiritual significance; in other words, whether our conception of what is useful may not have become too narrow to be adequate to the roaming and capricious possibilities of the human spirit.

We may look at this question from two points of view: the scientific and the humanistic or spiritual. Let us take the scientific first. I recall a conversation which I had some years ago with Mr. George Eastman on the subject of use. Mr. Eastman, a wise and gentle far-seeing man, gifted with taste in music [illegible] to devote his fortune to the promotion of education in useful subjects. I ventured to ask him whom he regarded as the most useful worker in science in the world. He replied instantaneously: "Marconi." I surprised him by saying, "Whatever pleasure we

A. Flexner, Harpers, issue 179, 544, June-November, 1939

GOVERNMENT (PUBLIC) FUNDED RESEARCH IS OF A RECENT ORIGIN

- State funding of research is a post world War II phenomena

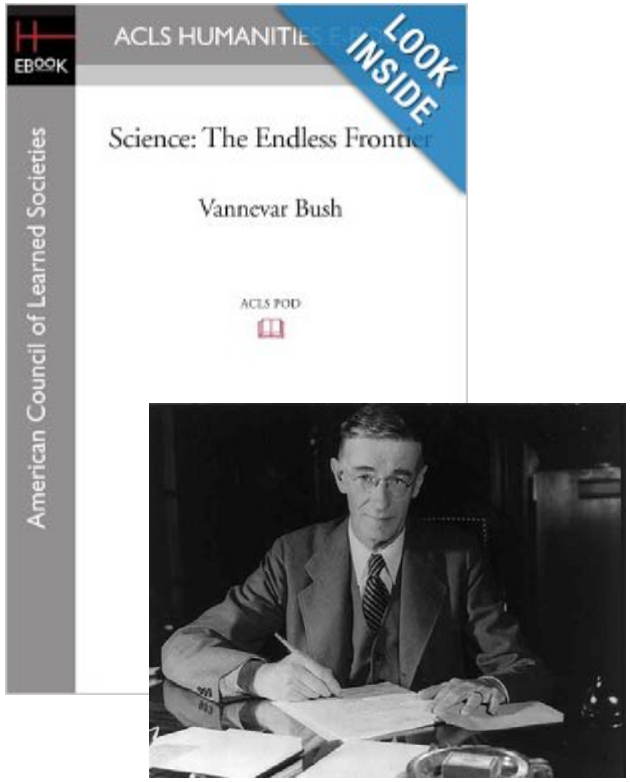
- A large part of nineteenth and twentieth century research and explorations in science were not funded by the state.

- It was the two wars that gave impetus for the state to step in and direct research

No government funded research project on energy technology led to the discovery of steam engine or electricity, nor the discovery of automobiles and airplanes a programmed outcome of a structured approach to transportation technology !

PUBLIC FUNDING OF SCIENCE : THE ORIGINS

- The tenet : investment in “basic research” by a nation ”performed without thought of practical ends” will lead to prosperity for its people.
- More money, more Institutions, more research, more papers and PhD’s will result in greater prosperity and wealth creation in society
- This tenet was implicitly accepted by Governments around the world as an established public policy



1945

The Cold War fuelled large public investment in science driven by the military-industrial complex; with the collapse of the Communism, this rationale was lost

THE RELATIONSHIP BETWEEN SCIENCE AND ECONOMIC DEVELOPMENT

- The integration of Vannevar Bush's tenet with the economic theories of Joseph Schumpeter and Robert Solow in the early fifties led to the identification of technology as a factor of production along with land, labour and capital
- This led to greater justification for Government investment in S&T as all factors of production were under the purview of the Government
- The connection between basic research and macroeconomic growth was based on a linear model that believed that scientific discoveries lead to invention and technology, which in turn leads to new products, industrial growth and job creation

WHY SHOULD GOVERNMENTS (PUBLIC) FUND SCIENCE ?

- Economic growth and prosperity of a nation depends on investments in science
- Science is too delicate, precious or strategic to leave it to non governmental sectors or market forces
- Government intervention is necessary in S&T to prevent free market failures of emerging technologies
- Government and the scientists who get funded have the best collective wisdom on the future strategic directions of science and technology
- Politicians love to fund science; spend small money and take credit for large successes
- It is patriotic to fund science (like defending our borders)
- Our country needs to produce more Noble Prize winners

PUBLIC FUNDING OF SCIENCE

- Most of the arguments on why public Government funding is needed for science have been constructed by the scientific community themselves ; and almost all of them are wrong !
- Public funding of science is looked at as charity; we have lost sight of the economic underpinning of Government investment in science
- Scientists love public / Government funds, because it comes with no obligations other than to their own community; funds from other sources demand far greater accountability

THE APPROPRIABILITY CONUNDRUM

- How well do the rewards flow back to the investor (in this case the Government) who is investing in science and taking the risk?
- The problem is that the returns from basic research are large, but they are not appropriable !
- The nature of basic research is that the results freely flow to the world. The monetization of basic research in terms of patents, products and economic growth may not necessarily occur in the laboratory where the work is originally done or even in the same country.
- Basic research leading to discoveries is a public good with low appropriability

This shifts the emphasis by Governments to more appropriable R&D, that is more "D" and less "R"

PRESIDENTIAL ADDRESS

What's So Special About Science (And How Much Should We Spend on It?)

William H. Press

Scientific research probes the deepest mysteries of the universe and of living things, and it creates applications and technologies that benefit humanity and create wealth. This "Beauty and Benefits of Science" is the theme of this 2013 AAAS Annual Meeting.

The subject of my address is a different kind of mystery, although it is also related to this theme. It is the mystery of why society is willing to support an endeavor as abstract and altruistic as basic scientific research and an enterprise as large and practical as the research and development (R&D) enterprise as a whole. Put differently, it is the mystery that a unified scientific enterprise can be simultaneously the seed corn for economic advance and the confectionary corn syrup of pure, curiosity-driven scientific discovery.

The view that science can be supported as a contribution to the intellectual richness of the world has a distinguished list of adherents. In 1969, Robert Wilson explained what Fermilab would do for the country by saying, "It has nothing to do directly with defending our country except to make it worth defending" (*1*). And, almost two centuries earlier, in his first annual address to Congress, George Washington wrote, "[t]here is nothing which can better deserve your patronage, than the promotion of Science and Literature. Knowledge is in every country the surest basis of publick happiness" (*2*).

Indeed, U.S. taxpayers are, to some extent, willing to pay for activities that enrich American social and cultural capital without having a direct economic benefit. Congress, up to now, has appropriated about $150 million a year for the National Endowment for the Arts (NEA) and about $170 million a year for the National Endowment for the Humanities (NEH) (*3*). However, by contrast, Congress appropriates about $40 billion a year for basic research (*4*). If you plot a bar graph with these three numbers, you can barely see that the NEA and NEH numbers are not zero.

It is evident that society is willing to pay much more for curiosity-driven research in science than for the analogous thought- and beauty-driven practice of the arts and humanities. It is easy to guess the reason: the link, sometimes subtle but repeatedly established over time, between investment in basic research and macroeconomic growth. Discovery leads to technology and invention, which lead to new products, jobs, and industries.

Such is the case that we scientists need to reinforce in the austere times that we face. However, mere repetition is not an effective strategy. In today's lean times, we need to articulate our case more powerfully and in a more sophisticated way than in more prosperous times. A skeptical and stressed Congress is entitled to wonder whether scientists are the geese that lay golden eggs or just another group of pigs at the trough.

More Than a Century of Exponential Growth

Figure 1 shows the growth in U.S. gross domestic product (GDP) per capita over the past 130 years. If we ignore a few bumps with time scales of a decade or so, the curve is surprisingly well fit by a pure exponential. Note that the curve is not plotting GDP, which would grow with population and the overall size of the U.S. economy, but GDP per capita, which reflects something like the average income of each individual. Ameri-

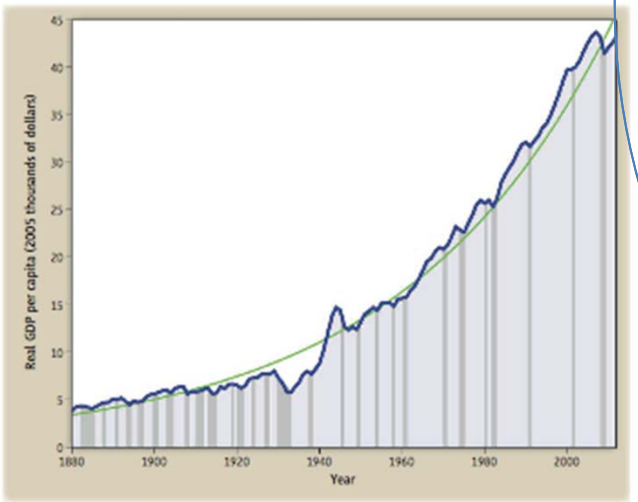


Fig. 1. U.S. GDP per capita, corrected for inflation in 2005 dollars. The smooth green curve is an exponential fit to the data. Shaded date ranges show official periods of recession. On average, an individual's income in the United States has increased by about 2% per year for more than 130 years.

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In today's lean times, we need to articulate our case more powerfully and in a more sophisticated way than in more prosperous times. A skeptical and stressed government is entitled to wonder whether scientists are the geese that lay golden eggs or just another group of pigs at the trough

SPACE Battle of the planets could see a new moon p.392

WORLD VIEW Energy scientists must show their workings p.393

OPTICS Semiconductor camera has eagle-eyed vision p.395

Beyond the science bubble

Research leaders in the United States and elsewhere should address the needs and employment prospects of taxpayers who have seen little benefit from scientific advances.

One question dominated discussions at the annual meeting of the American Association for the Advancement of Science (AAAS) at the weekend. Researchers, journalists and science lobbyists squeezed into conference rooms, perched on recycling bins and sat on the floor between rows of filled chairs as they strained to listen to those who tried to offer a response. The question was phrased in various ways, but the variations all boiled down to: how should science and scientists respond to the administration of President Donald Trump?

The answers were numerous too — from political activism to better communication — and were met with cheers, applause and the odd standing ovation. Many scientists will have left the Boston conference with renewed hope, or at least a sense of combined purpose. They had an answer of sorts to their question.

But it's the wrong question. It is not Trump that scientists must respond to. The real question is what science can do for the people who voted for him. Exactly who did support him, and why, is still being debated by political scientists, but it's clear that many of those who voted Trump are those he canvassed in his campaign and credited in his inauguration speech. It is people who feel left behind by supposed progress and who have suffered a real or perceived collapse in their quality of life.

PERSUADING THE UNCONVINCED

One speaker at the AAAS meeting appropriately sharpened the challenge. There are two types of taxpayer: those who pay up voluntarily because they believe in the public good that the money generates, and those who pay only because they will be put in jail if they don't. How many scientists, he suggested, could confidently say their project was so important to people that those people should be thrown into prison for not supporting it?

Just telling the same old stories won't cut it. The most seductive of these stories — and certainly the one that scientists like to tell themselves and each other — is the simple narrative that investment in research feeds innovation and promotes economic growth. 'It's the economy, stupid', so the saying goes, and as nations become a little less stupid by pushing against the frontiers of knowledge, so the benefits of all this new insight spread from the laboratory to the wider population, as improvements in the standard of living and quality of life.

This comfortable story has all the hallmarks of a bubble waiting to pop. For a start, it always has a happy ending. The hero of various quests, science slays the dragon of childhood disease and retrieves the elixir, if not of everlasting life, then at least of increased lifespan. And, like all good stories, this one comes with a pleasing twist: for when it sets off on its quest, science does not know exactly which good deeds it is planning to perform. Pure of heart and research, it is merely enough to send our science hero out into the world, with its consumables, overheads and a postgraduate squire paid for by donations from a grateful and trusting public.

This narrative is truthful enough to have sustained itself for many decades. From the famous discovery of the apparently useless laser that launched uncountable applications to how Einstein's theories of relativity underpin the Global Positioning System — these stories indeed make a case to Trump and his supporters that continued investment in science will help to create companies and jobs.

But as this journal and others have pointed out, it is also clear that the needs of millions of people in the United States (and billions of people around the world) are not well enough served by the agendas and interests that drive much of modern science. There are plenty of reports that show, for example, how public investment in the Human Genome Project has paid off many times over and created firms and jobs, but rather than trickling down through society, these benefits of discovery science arguably deepen the pools of wealth and privilege already in place — creating expensive new drugs that most people cannot afford.

"The needs of millions of people in the United States are not well enough served by the agendas and interests that drive much of modern science."

It is right that more scientists should tell stories of the good their research can do. But it is more important and urgent than ever that researchers shoul… stories really end — a… of the people they clai… get to live happily ev… should focus more effo… cation and scientific research can help the many… to be displaced by the very inventions that scie…

As they ponder their next move in respo… Trump, science organizations — universities, fu… the rest — should look harder at social proble… and seek ways for science to help.

For example, some universities are incre… climate-change adaptation. There will be employment opportunities in creating companies that help cities and other regional communities to protect themselves from climate change (whatever the sceptics may be saying), stimulated by the readily applicable and intellectually stimulating insights and improved decision-making that research will deliver.

More universities, for example, could follow the example of Michigan State University in East Lansing, in building stronger links with their local communities, and seeking to work with them to tackle research problems that affect their quality of life. These include monitoring soil and water quality, for example, and addressing the challenges of regional demographics, such as the large numbers of elderly people who live alone in some regions and how to deliver health care to them.

There is also a need to tell these stories compellingly — stories that are harder to tell and of less global impact than the hunt for fundamental particles or new materials. And the most important audiences may not be inclined to listen. But those audiences matter. ▪

Do the needs of the people served by the agenda and interests of modern science ?

Stories of impact of science on society is becoming harder to tell; and our stakeholders are increasingly less inclined to listen

Nature, 23 February 2017, p.391

TRANSLATIONAL SCIENCE IN ACADEMIA

- What is translational science ?
- What systemic changes in academia are needed to enable translational science ?
- What are the risks or opportunities ?
- What is the ecosystem needed for translational science?
- Is there a case for a new model for educating and training the future scientists?

Simply put, the "D" in R&D means translation !

TRANSLATIONAL SCIENCE

- Translational research is a way of thought about conducting scientific research to make the results of research applicable to population under study and is practiced in the natural, biological and social sciences (*en.wikipedia.org/wiki/translational-research*)
- A term originally used in biology and medical science by NIH
- Develop, design, engineer and produce/ commercialize: from bench to bedside
- Translation of discoveries to applications was once the exclusive domain of industry
- With industry stepping back, Government through public funding is increasingly stepping in to fill the vacuum, especially in high risk R&D
- Success of translational efforts(defined as commercial success) using public funds still not proven

The belief that public funds invested on needs identified by Government and focused on direct applications is the panacea for our ills goes against the lessons of history; Government picking technology winners is beset with great dangers and risks; exceptions are those solutions which are outside of the market forces

INDIA'S PUBLIC FUNDED S&T FOCUS SHIFTING TO TRANSLATIONAL RESEARCH

- DBT : Commercialize public funded R&D; create TTO's : 150; Technology and Business Incubators : 40
- DST : Promote start ups and high risk as well as industry relevant research
- DST setting up Technology Research Centres at five scientific institutions at an estimated cost of 100 crores
- Funding to technology platforms in areas such as electric mobility, waste management and advanced manufacturing processes upto TRL levels of 6-7

How much does amelioration of society's problems require frontier science and how much clever application of known science ? Should Government only focus on those areas which are not served by the market forces ?

LEARNING TO MANOUVERE THE "VALLEY OF DEATH"

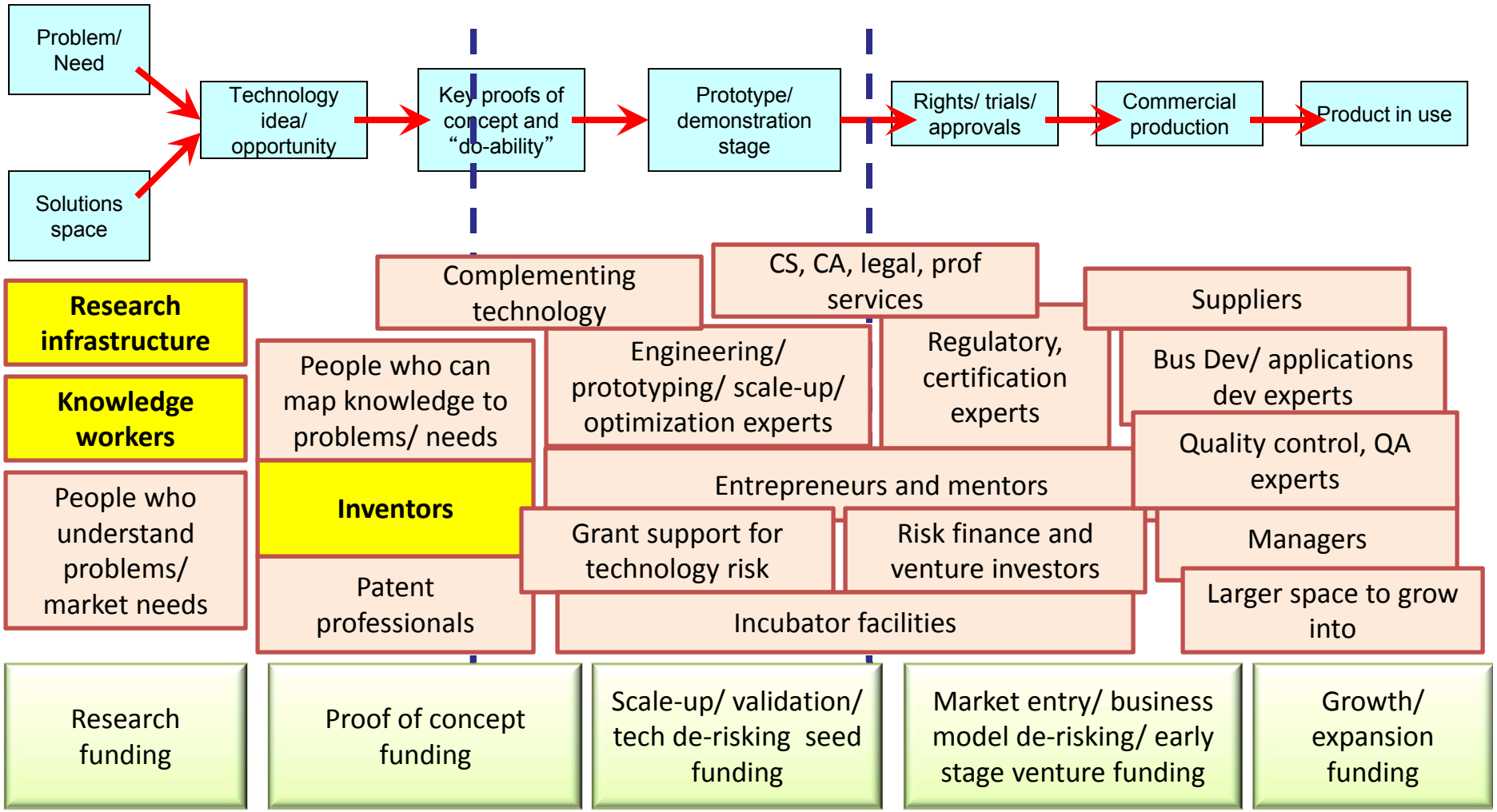
Knowledge
Solutions
Ideas
Low Risk

RISK MITIGATION

Applications
Validation
Markets
High Risk

Too often an obsession with inventing something "totally new" or unique versus extracting value from the creative understanding of what is already known;
Translation and innovation is more about prospecting, refining , mining and adding value; this requires an ecosystem

TRANSLATING SCIENCE – THE ECOSYSTEM



INDUSTRY- ACADEMIA INTERFACE NECESSARY FOR SUCCESSFUL TRANSLATION

Several myths pervade academia–industry interaction

- Industry has to depend on academia for new ideas and concepts
- Cost of performing research in an academic institution is low compared to performing in industry
- The IP generated by academia is undervalued by industry
- Industry's problems do not need cutting edge science
- The reward that industry offers to academic partners is a small fraction of what the industry gains and is often inequitable
- "We can buy any technology that we need"; industry believes it can acquire businesses with technology rather than develop

INDUSTRY- ACADEMIA INTERFACE: REALITIES

- Academia generally overestimates the value of its IP, In the quest for windfall financial returns public institutions demand all encompassing IP rights and subsequent royalty payments from the corporate sector with such vigour that many projects are terminated by the lawyers
- Scientists in public organization vastly underestimate the effort needed to move an idea to a new product or service for which there is a commercial demand. This naivety can make negotiations over IPR and royalty issue an exercise in frustration
- Academia has poor appreciation of market risks of a new technology
- Academia has poor understanding of regulatory and EHS issues

INDUSTRY- ACADEMIA INTERFACE: REALITIES

- Academia has poor understanding of regulatory and environment, health and safety issues
- Academia has a misplaced goal of revenue generation from working with industry ; give us the money and we will work on something related to your interest”
- Scientists are usually looking for support for their own ideas, not tuning their research to suit the needs of the industry
- Timescales in public institutions are much longer than companies can tolerate; companies are generally not in business to fund PhD thesis

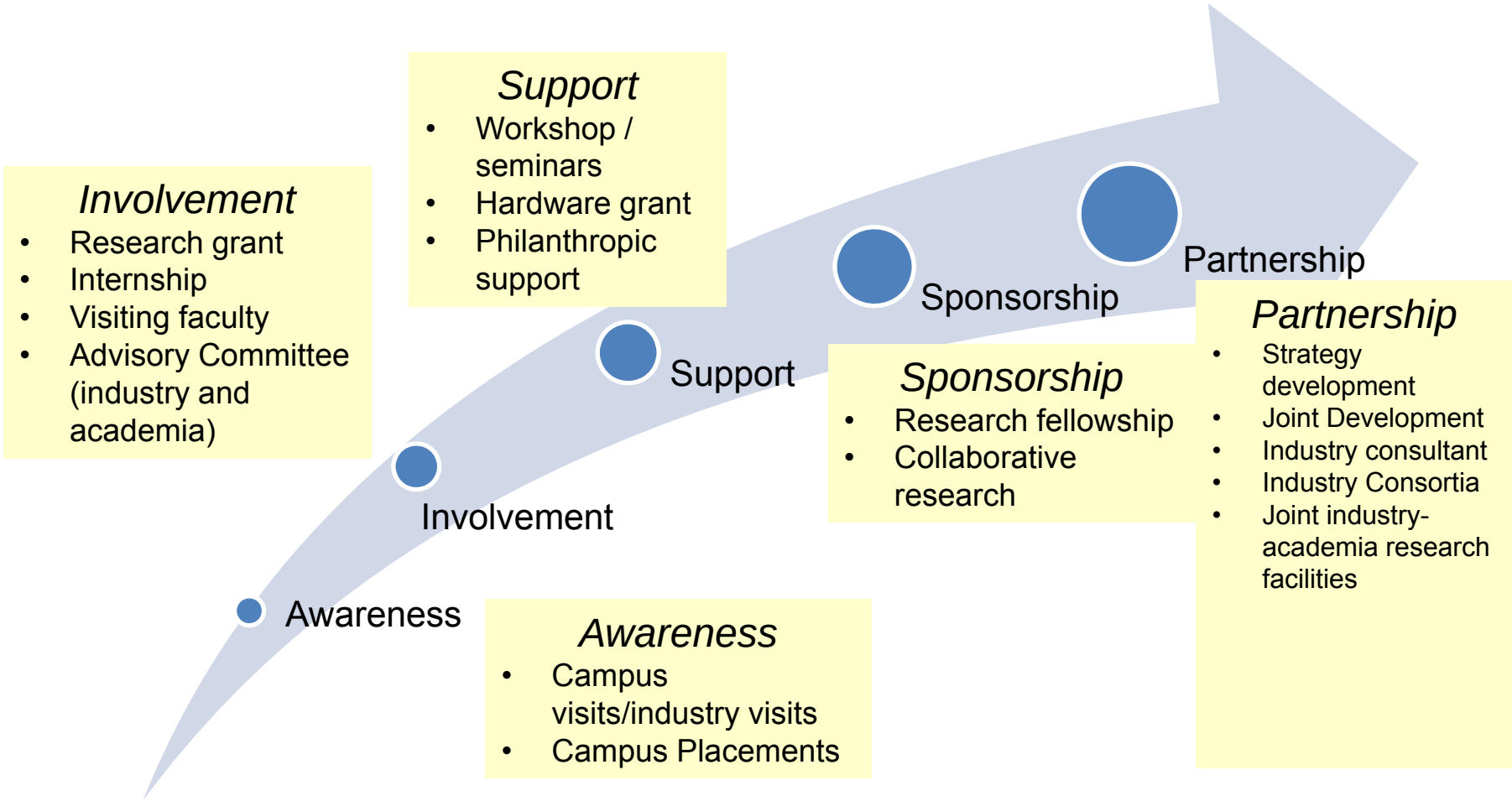
RELATIONSHIP BUILDING KEY TO SUCCESSFUL INDUSTRY ACADEMIA PARTNERSHIP

- Building a relationship in life involves, courtship, engagement, wedding, consummation and learning to live amicably
- When building a relationship with industry we need to go through the same stages, namely, build trust and faith, establish credibility and usefulness, provide confidence that one can stay together and, going far and beyond the written contract and avoid all conflicts of interests
- There is an underlying feeling of suspicion when we have to deal with thecprivate sector; this is a legacy problem

Building a relationship is not a mere contract or transaction; one has to invest enormous time and effort to make it succeed

THE PARTNERSHIP CONTINUUM

(Source: Guiding Principles of University- Industry Endeavors, April 2006)



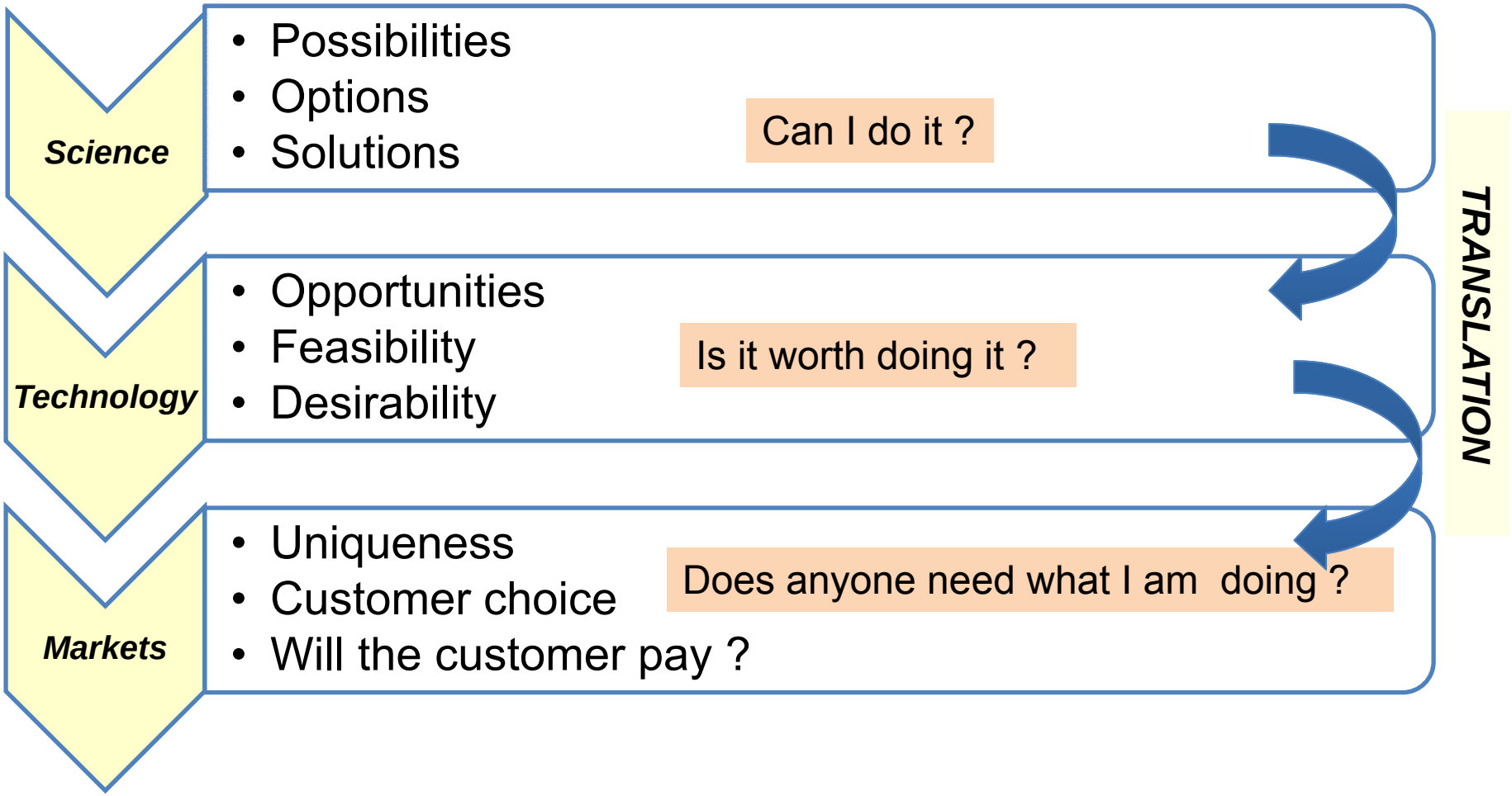
SHOULD ACADEMIA PATENT ?

- Most misunderstood aspect of Indian S&T
- Patents are not mere indicators for defining the vitality of innovation; it must have a strategic and tactical intent
- Global companies have a keen desire to protect discoveries; Indian companies averse since patents are disclosures with little legal protection against infringement in India
- What should be protected and what should not be; where to protect and where not? Skill sets for decision making do not exist in most organizations
- Moral Hazard in decision to patent by academic institution; Institutions and Government pick up the cost of patenting, but do not bear the consequence of that decision

ISSUES IN EXPLOITATION OF ACADEMIC RESEARCH

- One extreme view is that academic research and commercial considerations of results do not mix
- Commercial considerations of research do create conflict in academia between the need to disseminate knowledge and limit access to knowledge
- Public pays twice for the same invention; taxes support university research that yields the invention and the high monopoly prices charged by the provider when the invention reaches the market
- Two high profile cases highlight this dilemma today
    - CRISPR Cas9 : MIT and U of California at Berkeley
    - Zika Virus vaccine and Sanofi

SCIENCE, TECHNOLOGY AND MARKETS



THE BUSINESS OF INNOVATION

- If necessity is the mother of invention, then innovation is its daughter and entrepreneurship its father.
- Cross pollination of invention and entrepreneurship effectively spawns innovation; intersection of invention, innovation and entrepreneurship is necessary for creating wealth
- A scientists or inventor creating fabulous products as a cerebral exercise is never going to impact the world unless that product is is tested, adapted and transformed for mass use and distributed, usually for commercial gain
- An invention may have little or no economic value in spite of having intellectual value.
- Too often an obsession with inventing something “totally new” or unique versus extracting value from the creative understanding of what is already known

STRATEGIES FOR PRODUCT INNOVATION

- Product design for BoP (Frugal Innovation) or ToP application segment
- BoP customer is increasingly demanding higher functionality at lower price
- Value to a customer is defined as the ratio of functionality to price; discerning customers place importance on value rather than price
- Should a new product entry maximize functionality to achieve a niche or high end application or create a low functionality product at a price that is affordable?
- Is it possible to create cutting edge innovation in high technology products focusing only on BoP segment?
- Most successful innovations began as products with high functionalities (at high price) for niche applications. Building scale and learning/experience curve brought the price down and made it affordable to a larger segment of customers
- Most products developed by advanced countries enter application in emerging markets at appropriate price points

THE FUTURE OF SCIENCE

- Science increasingly is interdisciplinary and cross functional
- New paradigms in research funding; public funding increasingly tied to demonstrating measurable benefits to society
- Turbulence on global economy and politics beset with income inequality, low growth, anti-intellectualism and oscillations between globalization and isolationism
- An impatient citizenry, looking for quick solutions and increasingly aspiring for an “ideal” world, which may be beyond our reach

Science, technology and public policy is yet to come to terms with this new reality; we seem to be seeking solutions to future problems using old processes and methods

SCIENCE IN THE 21st CENTURY

- Scientific, technological and social trends are rapidly transforming the way we live and work
- Technology is ubiquitous in the world we inhabit today; yet an average citizen has far little understanding of science and technology today than in the past
- Public policy discourse has also tended to become biased, opinionated with selective dissemination of information
- We all realize that science and technology have to provide answers to many critical problems that we face today; yet we do not have a coherent and shared vision of how we will accomplish this goal

It is very hard to bring a new material to market. Unfortunately the rules of the game are not set by the rules of scientific knowledge, but by the rules of economic and development……. Where money goes is not always where the best technology is.

K. Novoselov, Nobel Laureate, 2010
University of Manchester

THANK YOU

for your patient listening