THE EVOLUTION OF INDIA’S SCIENCE, TECHNOLOGY AND PUBLIC POLICY:

Lupin Science Park
Science Day
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OUTLINE

• The epochal events of February 28
• Science in pre-independent India
• Origins of modern scientific enterprise
• Science in the 21st century
• Science in Independent India: Evolution of public policies
• Science in contemporary India
The epochal events of February 28
“We have got a young student with fine intellect, doing research in our laboratory. A side issue of his work has been published in Nature (24 Oct, 1907). The prophecy of the great man (MLS) is now going to be fulfilled. If circumstances do not go against us, Raman will be the brightest ornament of IACS.”

A.L Sarkar, son of Mahendra Lal Sarkar, founder of IACS, 21 November 1907

“Indian mind is not inferior; what we lack is courage and a spirit of victory. If that indomitable spirit were to arise, nothing can hold us from achieving our rightful destiny.”
Raman was supremely confident of winning the Nobel Prize in Physics. He was disappointed when the Nobel Prize went to Richardson in 1928 and de Broglie in 1929. He was so confident of winning the prize in 1930 that he booked tickets in July, even though the awards were to be announced in November, and would scan each day’s newspaper for the announcement, tossing it away if it did not carry the news. He did eventually win the 1930 Nobel Prize in Physics “for his work on the scattering of light and for the discovery of the effect named after him”. He was the first Asian and first non-white to get a Nobel Prize in the sciences.
“I admire the courage and spirit with which Raman exchanged a lucrative official appointment for a university professorship. This instance encourages me to entertain the hope that there will be no lack of seekers of truth in the Temple of Knowledge which it is our ambition to erect.”

“Sir Asutosh ventured to ask an young and unknown official to devote himself to the pursuit of knowledge under the aegis of the Calcutta University. This, on his part, was an act of courage. But for the action of Sir Asutosh, my scientific career would long ago suffered an abrupt termination.”

C. V. Raman
"This structure has novel features which are of considerable biological interest“........It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material"

Watson and Crick in Nature, April 25, 1953
“Three profoundly destabilizing scientific ideas ricochet through the twentieth century, trisecting it into three unequal parts: the atom, the byte, the gene. Each begins its life as a rather abstract scientific concept, but grows to invade multiple human discourses- thereby transforming culture, society, politics and language. But the most crucial parallel between the three ideas is conceptual: each represents the irreducible unit-the building block, the base organizational unit- of a larger whole: the atom of matter; the byte of digitized information and the gene, of heredity and biological information”
Science in pre-independent India
By the thirteenth century the free spirit of the western mind was adapting to hypothesis driven and evidence based scientific methods for exploring our physical and material world; however, the Indian mind had been enslaved by successive conquests by alien cultures. The age of reason and enlightenment bypassed us, both materially and literally.

**India’s awakening**

*Long years ago we made a tryst with destiny, and now that time comes when we shall redeem our pledge, not wholly or in full measure, but very substantially. At the stroke of the midnight hour, when the world sleeps, India will awake to life and freedom. A moment comes, which comes but rarely in history, when we step out from the old to new, when an age ends, and when the soul of a nation, long suppressed, finds utterance.*

Jawaharlal Nehru, Midnight August 14, 2017
“The sole function will be science-learning and science-teaching. We should carry on unaided by the (British) Government or more properly speaking, without seeking its aid. I want freedom for the institution. I want it to be solely native and purely National.”

“I reiterate my conviction that if our country is to advance at all and take rank with civilized nations, it can only be by means of science. To this end, I have given the best portion of my life, but I am sorry to leave this world with the impression that my labours have not met with the success it deserves.” (Last letter, Nov. 1903)

*Indian science was born by a deep sense of nationalism; to contribute to science was considered as a national service*
PROFESSOR NIL RATAN DHAR: ANOTHER STAUNCH NATIONALIST

• Mentored by Acharya P. C. Ray, 1909
• Founder of the discipline of Physical Chemistry in India
• A staunch nationalist who believed in the power of evidence based science and science as a tool for nation building

“I sincerely believe that sound progress of our nation depends essentially on science and its applications and I have preached this gospel for over 40 years. I am extremely keen on seeing Indian scientists taking up this matter of national regeneration through science with hard labour, great fortitude, devotion and sacrifice.”
Asutosh Mukherjee (1864-1924)
First Indian to publish a paper (1881)

J. C. Bose (1858-1937)
- Microwave communication, semiconductor
- Missed the 1902 Nobel (Marconi)
- “Satyagraha”: Salary boycott

P. C. Ray (1861-1944)
First to do research in Chemistry
- Established Bengal Chemical and Pharmaceuticals (1901)

S. Ramanujan (1887-1920)
- FA fail (1908), First paper 1911, FRS (1918)
JEWELS OF INDIAN SCIENCE IN PRE INDEPENDENCE PERIOD

- C V Raman
- S Ramanujan
- Sir K S Krishnan
- S N Bose
- Sir M Visvesvaraya
- J C Bose
- Birbal Sahni
- P C Ray
- M N Saha
NEHRUVIAN GRAND VISION OF SCIENCE

“ I realized that science was not only a pleasant diversion and abstraction, but was of the very texture of life, without which our modern world would vanish away……..It was science alone that could solve these problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by starving people.”

Indian Science Congress, Calcutta, 1938
Origins of modern scientific enterprise
THE ORIGINS OF MODERN SCIENCE

- Scientific modernity began around 1700 with the publication of Isaac Newton’s publication of “Opticks”
- This was the forerunner to the Age of Reason and the emergence of Enlightenment
- Enlightenment provided an exalted view of human rationality and claimed that all individuals have the right as well as the power to shape their own destinies
- This led to the emergence of rational scientific inquiry processes resulting in epoch making discoveries and eventually to the industrial revolution
MAN IN CONTROL OF HIS OWN DESTINY

• I think; therefore, I am : Rene Descartes (1596-1650), Father of western philosophy and believer in rationalism

• The Critique of Pure Reason: Immanuel Kant (1724-1804), Mind shapes our experience; proposed the concept of space and time as well as cause and effect

• How we think (1910) ? : John Dewey(1859-1952), American philosopher and thinker who propagated the view that democracies encouraged free thought

Human individuals are the primary agent of creativity

You are that which you create : Don Reitz, American Sculptor 1920-2014
Science, technology and innovation are social activities.

They can not be done in isolation and therefore, we can not disregard its history………History, if viewed as a repository of more than anecdote or chronology, could produce a decisive transformation in the image of science in which we are now possessed.”

Thomas Kuhn

Thomas Kuhn defined the history of science in the mold of an evolution

The domain of the natural is not essentially different from the domain of the social
THE SOCIAL FUNCTION OF SCIENCE
(J.D. Bernal, George Rutledge and Sons, 1939)

- 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

The Sage of Science, A. Brown, Oxford University Press, 2007
THE ROMANTIC VIEW OF SCIENCE

Individual scientists pursuing truth leads to the most efficient social outcomes

Michael Polanyi
The Republic of Science: Its Economic Theory,
Minerva, I, 54 (1962

The intellectual debate between Bernal and Polanyi was one of the most engrossing debates of the second half of twentieth century!
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
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!
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

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
WHY SHOULD GOVERNMENT FUND SCIENCE?

- Economic growth and prosperity of a nation depends on investments in science (Vannevar Bush’s hypothesis)
- Science is too delicate or precious to leave it to non-governmental sectors
- 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

Scientists love public funds, because it comes with no obligations other than to their own community
JUSTIFICATION FOR PUBLICLY FUNDED SCIENCE

• Public funding of science provides a framework of theory and experimental data that places limits on available space for innovation
• It creates human resources trained in critical inquiry
• It supports innovation that are too risky for industry to pursue
• Public funded research has led to a vast body of knowledge that lie at the foundation of all technologies
• Science leading to solutions in areas such a new energy sources, public health, built habitats, environment, natural resource conservation and recycling will need public investments

It is perfectly reasonable to build an economic case for basic research. However, to realize value one needs practical and financial support to underpin training, networks and start up investment

M. Peplow, www.chemistryworld.org, August 2015

V. Sivaram, The Newsweek, October 28, 2015
Science in Independent India: Evolution of public policies
POLITICAL AND ECONOMIC THOUGHT: EARLY YEARS OF INDIA’S INDEPENDENCE

- State wielding “commanding heights” of the economy (Socialistic Pattern of Society)
- State ownership of industries; Government’s ability to promote technologies in public enterprises
- Control on import of processes, products and knowhow; regime of industrial licenses
- Central planning as an instrument of public policy (The Soviet Model)

For a country gaining independence after almost four hundred years of external dominance, issues such as “self-reliance” and “indigenous development” of technology were the underlying basis of national pride, echoes of which we hear even today.
BEYOND MERE PRACTICE OF SCIENCE: THE SCIENTIFIC TEMPER

Large numbers of people talk glibly about science today and yet in their lives or actions do not exhibit a trace of science.....But science is something more. It is a way of training the mind to look at life and the whole social structure...So I stress the need for the development of a scientific mind and temper which is more important than actual discovery as it is out of this temper and method that many more discoveries will come.

Jawaharlal Nehru,
Inaugural Speech at the opening of National Physical Laboratory, New Delhi, January 1950

Nehru borrowed the concepts of “scientific thoughts” from Francis Bacon, John Stuart Mill and Bertrand Russell and gave it his own unique idiom
For Nehru the State was an instrument for building the scientific temper in the society; he assumed that the spread of education and research in S&T will embed the “scientific temper” in the lives of every Indian.

(It shall be the duty of every citizen of India) “to develop the scientific temper, humanism and the spirit of inquiry and reform”

42nd Amendment Part IV-A Article 51-A on Fundamental Duties to the Constitution of India, 1976
Science in pre-independent India was predominantly individual science pursued within the confines of an University.

State funding of science began in the early fifties. Emphasis was on creation of large R&D organizations to serve developments in industrial research (CSIR), atomic energy (BARC), space research (ISRO), agricultural research (ICAR), medical research (ICMR) etc.

In education, focus was on creating exclusive institutes for technology (IIT’s).

Education, originally a state subject, became a concurrent subject and federal government began to create central institutions. State Universities were left to the mercy of state funding.
BUILDERS OF SCIENTIFIC INSTITUTIONS
NEHRU’S COMRADE-IN-ARMS

• **Dr. Homi Bhabha** established the TIFR and BARC, leading to nuclear science and research. Today India has 14 reactors producing nearly 4000 MW electrical power.

• **Professor Vikram Sarabhai’s** space vision enabled India to acquire the capability to design, develop, build and launch any type of satellite from Indian soil. The recent journey of an Indian spacecraft to the orbit of Mars is a vindication of this vision.

• **Professor Shanti Swarup Bhatnagar** created multiple CSIR laboratories in various disciplines for developing technology for India’s industrial development.

• **Dr. D. S. Kothari** created a chain of Defense R&D laboratories for promoting self-reliance in critical defense technologies.
IMPACT OF S&T ON SOCIETY

Some noteworthy successes

- The Green Revolution (Agriculture)
- The White Revolution (Milk)
- The Blue Revolution (Space)
- The Grey Revolution (IT and Communication)

Much of these transformations were a consequence of India’s post independence investment in S&T education and infrastructure
PUBLIC POLICIES ON SCIENCE AND TECHNOLOGY

- Science Policy Resolution of 1958 (March 4, 1958)
- Technology Policy Statement of 1983
- Science and Technology Policy of 2003
- Science, Technology and Innovation Policy 2013
POLITICAL AND ECONOMIC EVENTS THAT INFLUENCED INDIA’S SCIENCE POLICIES

• The crisis of food, 1970
• The first nuclear explosion at Pokharan, 18 May 1974 leading to widespread sanctions and embargo on technology exports into India
• The liberalization of economic policy, 1991
• The era of coalition Governments, 1989 to 2014
• The second nuclear explosion at Pokharan, 18 May 1998 leading to further economic sanctions
• The National Action Plan on Climate Change and the Eight Missions, 2007
INDIA’S R&D INVESTMENTS

First formal R&D investment policy

Private Sector R&D investment: Rupees 300 billion

Rupees 800 billion

Rupees in Crores (10 million)
INDIA SCIENCE INDICATORS

- R&D investment as a % GDP (2011) : 0.88
- Gross domestic expenditure on R&D : 42.8 billion US $ (PPP, constant 2005 prices)
- Gross expenditure on R&D per researcher : 201,800 US $ (PPP, 2013)
- Number of researchers : 1,93,000
- Total publications : 53,733 (4 % of global)
- Patents granted per million population : 1.6 (USA 160, UK 90, China 13, Russia 7.7)
### RESEARCH SPENDING AND SCIENTIFIC PROWESS

<table>
<thead>
<tr>
<th>Country</th>
<th>R&amp;D as % GDP</th>
<th>GERD *, 2015 at PPP $ billion</th>
<th>Share of world GERD, %</th>
<th>GERD per researcher, PPP $ thousand, 2013</th>
<th>Share of Publications, %</th>
<th>Researchers, lakh</th>
<th>Patents per million population</th>
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</thead>
<tbody>
<tr>
<td>USA</td>
<td>2.8</td>
<td>396.7</td>
<td>28.1</td>
<td>313.6</td>
<td>25.3</td>
<td>12.65</td>
<td>910</td>
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<tr>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>6.9</td>
<td>2.59</td>
<td>-</td>
</tr>
<tr>
<td>Japan</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5.8</td>
<td>6.61</td>
<td>3,716</td>
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<td>S.Korea</td>
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<td>-</td>
<td>-</td>
<td>4.0</td>
<td>3.22</td>
<td>4,451</td>
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<tr>
<td>Brazil</td>
<td>1.2</td>
<td>-</td>
<td>2.2</td>
<td>210.5</td>
<td>2.9</td>
<td>1.39</td>
<td>34</td>
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<tr>
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<td>290</td>
<td>19.6</td>
<td>195.4</td>
<td>20.2</td>
<td>14.84</td>
<td>541</td>
</tr>
<tr>
<td>India</td>
<td>0.9</td>
<td>42.8</td>
<td>3.2</td>
<td>201.8</td>
<td>4.2</td>
<td>1.93</td>
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- Gross Domestic Expenditure on R&D
## R&D INSTITUTIONS AND NATIONAL INVESTMENT ON R&D ACTIVITIES (DSIR, 2007)

<table>
<thead>
<tr>
<th>R&amp;D Institutes</th>
<th>Number of institutions</th>
<th>Percentage of national investment on R&amp;D (2003-04)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central government R&amp;D institutions</td>
<td>707</td>
<td>62.6</td>
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<tr>
<td>Public sector institutions</td>
<td>115</td>
<td>4.5</td>
</tr>
<tr>
<td>State government institutions</td>
<td>834</td>
<td>8.5</td>
</tr>
<tr>
<td>Universities and institutions of National importance</td>
<td>284</td>
<td>4.1</td>
</tr>
<tr>
<td>Private sector institutions</td>
<td>2020</td>
<td>20.3</td>
</tr>
<tr>
<td>Total</td>
<td>3960</td>
<td>100</td>
</tr>
</tbody>
</table>
GLOBAL RANKINGS : INDIA

- Global Innovation Index (INSEAD), 2015 : 81
- Global Competitiveness Index, 2016 : 50/142 ( USA 2, UK 10 , China 49)
- Global Intellectual Property Index (University of Maastricht, NL): 7.05, 37/38
- Bloomberg Innovation Index, 2016 : 45/50 ( S. Korea 1, Sweden 3, Singapore 6 and USA 8)

India has to transition from a “Factor” driven to “Efficiency” driven and ultimately “Innovation” driven economy
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
- CSIR: Align R&D with national missions, sanitation, cleaning of rivers, smart cities etc; 50% of expenditure earn through external grants, licensing incomes and industry collaborations

*Increasing pressures on publicly funded science to deliver solutions that benefit society*
INDIA’S S&T IN THE NEXT DECADE

- S&T operates within the framework of politics, economics and social fabric of a nation; India is changing rapidly in all these spheres.
- Resources will always be lesser than the demands of a growing economy.
- Private sector will become increasingly more important; Government function will be limited to acting as regulators and facilitators, not gatekeepers.
- Government focus will remain limited to public health, water, sanitation, education, infrastructure, energy and national security.
- In the economic sphere emphasis will be on manufacturing industries leading to creation of employment; However, much of “come, make in India - sell anywhere” policy will be initially based on capital and technologies sourced from outside India.
- Funding for scientific research in public institutions will become more directed and even scarcer in the next few years. The dream run in increase in funding for S&T between 2000 and 2010 is unlikely to be repeated.
- Greater pressure to focus more on science that contributes to “nation building” and improve the “quality of life” of its citizens.

More questions are likely to be asked on how and where S&T is making an impact; merely stating that we are doing cutting edge, globally competitive science will not do!
Science in the 21st Century
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
- A scientific order, philosophy and public policy that served us for over fifty years is now broken; there is a need to construct a new public policy framework that will defend future science
THE RISE AND FALL OF CORPORATE R&D

- Corporate R&D flourished for over two centuries, ushering in the explosive growth of industries in Europe, Japan and America.
- DuPont, GE, GM, IBM, Exxon, Bell Labs, Kodak, Shell, BASF, ICI, Dow, Monsanto, Hoechst, Ciba, Bayer etc became great hub for science and technology.
- Corporate R&D were large and diverse with a balance of curiosity and market driven programs. Industry had great execution and process skills. It attracted the best of talent; Flory, Rochow, Knowles, Pederson, Davisson, Bardeen, Shockley, Penzias, Carothers, Langmuir, Hay, some of whom went on to win Nobel Prize.
- Post nineties R&D restructured as part of SBU and funded by business; leadership transitioned from professional R&D managers who had cut their teeth in S&T to professional business managers.
- Corporate leadership came under increasing pressure to perform; time needed to recover investments in R&D became short.
- Increasing input cost, globalization, faster technology diffusion, product commodatization, product liability, environment, health, safety and sustainability issues made investment in R&D more risky.
WE ARE STILL GRAPPLING WITH SEMANTICS!

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

The lack of precision in the language of the scientists is symptomatic of the lack of clarity on the nature of scientific enterprise.
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 increasingly used in biology and medical science
- 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 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
Pasture's Quadrant

Bohr

ΔE = hν

Pasteur

Electric light bulb

Edison

Use Inspired Research

Fundamental Research

1997
BASIC AND APPLIED SCIENCE: ARE THEY DIFFERENT?

Metaphor: Buckets of paint vs painting

There is science and the applications of science: Louis Pasteur

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))
SCIENCE IN THE 21st CENTURY

- Blue skies vs Directed Science
- Small vs Big Science
- Individual vs Team Science
- Curiosity driven vs Grand Challenges or Utilitarian Science
- Open access vs Intellectual Property
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
WHY SHOULD GOVERNMENT FUND SCIENCE?

- Economic growth and prosperity of a nation depends on investments in science (Vannevar Bush’s hypothesis)
- Science is too delicate or precious to leave it to non-governmental sectors
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- Our country needs to produce more Noble Prize winners

Scientists love public funds, because it comes with no obligations other than to their own community
Government funding of science under stress; In no country is the scientific community satisfied

**NEWS AND ANALYSIS**

**SCIENCE IN UNCERTAIN TIMES**

**Australian science base eroded by cuts**

**FUNDING**

Scientists today said that their universities and research laboratories were facing a crisis as government funding for science was cut. The cuts are part of a broader trend of reduced funding for science and research in Australia, which has been ongoing for several years. The cuts have led to a reduction in the number of research projects, a decrease in the number of researchers, and a decrease in the amount of funding available for research. The cuts have also led to a decrease in the number of students enrolled in science programs, which is a concern for the future of the science community in Australia.

**Scientists**

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**News and analysis**

**Portuguese chemistry faces disaster**

Scientists are fighting to save their research, which is under threat due to cuts in government funding. The cuts are part of a broader trend of reduced funding for science and research in Portugal, which has been ongoing for several years. The cuts have led to a reduction in the number of research projects, a decrease in the number of researchers, and a decrease in the amount of funding available for research. The cuts have also led to a decrease in the number of students enrolled in science programs, which is a concern for the future of the science community in Portugal.

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**Scientists unsure about Modi**

Scientists are unsure about the future of their research under the new government in India. The government has cut funding for science, which has led to a reduction in the number of research projects, a decrease in the number of researchers, and a decrease in the amount of funding available for research. The cuts have also led to a decrease in the number of students enrolled in science programs, which is a concern for the future of the science community in India.

**News and analysis**

**Evidence against climate change**

Scientists have found evidence that climate change is not occurring, which contradicts the widely accepted scientific consensus. The evidence includes studies that show that the Earth's temperature has not increased significantly over the past few decades, and that the amount of greenhouse gases in the atmosphere has not increased significantly. The evidence also includes studies that show that the Earth's temperature has not increased significantly over the past few decades, and that the amount of greenhouse gases in the atmosphere has not increased significantly.

**News and analysis**

**Innovative approach**

Scientists have developed a new approach to solving complex problems, which involves the use of artificial intelligence. The approach has been successful in solving problems that were previously thought to be unsolvable, and it has the potential to revolutionize the way that science and research are conducted.

**The science community**

The science community today is facing a crisis as government funding for science is cut. The cuts are part of a broader trend of reduced funding for science and research in the country, which has been ongoing for several years. The cuts have led to a reduction in the number of research projects, a decrease in the number of researchers, and a decrease in the amount of funding available for research. The cuts have also led to a decrease in the number of students enrolled in science programs, which is a concern for the future of the science community.
Funding impasse hits Illinois chemists

Political division 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 Edmund Garcia, chair of CSU’s department of chemistry, physics and engineering. CSU sees 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 were unfunded for several months, but also because students are worried and looking elsewhere.

Undergraduate enrollment at CSU for 2016–2017 is currently down 50% compared with 2015–2016. ‘We lived from 1 July 2015 until April 2016 with only 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 vetoes a state budget devised by the Democrat-controlled Illinois government. Rauner said the budget would add $4 billion (3.5 billion) to Illinois’ existing debt, entailing to be around $100 billion. In April 2016 the opposing sides agreed a $600 million stopgap package for higher education, where the Democrat budget originally earmarked $1.7 billion. In June, the opposition sides agreed another $1 billion for higher education. The budget took effect on 1 July 2016. 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. The department, says Jonathan Blitt, 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. Giorgioani, head of the Urban-Champaign campus’s chemistry department, says that research and teaching has been unaffected although faculty and non-university staff have had no salary increase over the last two years.

Hopes that the situation will be resolved in the November U.S. elections are tenuous. Rauner is up for re-election, but the entire Illinois House of Representatives and most of the State Senate in Together, the House and Senate can override Rauner’s veto. ‘The House is a couple of votes short,’ Blitt highlights, and if Democrats gain seats, they can force their budgets through. EIU income taxes may be raised at the election, says Giorgioani, ‘we would certainly help.’

Andy Estense

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 Arthene Donald, the ERC’s president, (ERC) in the ERC at the ERC. It was following US model, a

Worst may still be to come for Spanish science

Science chief sounds alarm on funding

Calls for R&D spending exceed 3% of GDP

White House science advisor John Holdren, and the leaders of 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 funnelled most 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’s comment is significant because the US R&D intensity is decreasing in comparison 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% 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 advisor John Holdren was critical of the US’ efforts to increase R&D spending.

within a dozen years of their

The financial blow for countries, such as Italy and the UK, on R&D spending is far worse. Nazario Martin, president of the Spanish Scientific

Worsen may still be to come for Spanish science

Effects of budget cuts from the financial crisis still felt

Spain’s scientific community has been hit hard by the financial crisis, with cuts to R&D funding having a significant impact. Nazario Martin, president of the Spanish Scientific Council, says that the crisis has forced the country to reduce its spending on R&D from 1.1% of GDP in 2007 to 0.6% in 2016. This has had a severe impact on the country’s research capacity and innovation, he says. For example, the country has lost many of its top researchers, who have moved to countries with more stable funding environments. Martin also highlights the impact that the crisis has had on the country’s reputation as a scientific leader, with many international collaborations and grants declining. He calls for increased investment in R&D as a way to rebuild Spain’s scientific standing.

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 95,000 scholarships to enable the international exchange of Brazilian researchers, undergraduates and postgraduates. In 2015, about 300,000 R$1.1 billion was provided to the programme by CAPES and BRLL.1.4 billion by CNPq. This year, those amounts were slashed to BRLL.46 billion and BRLL.50 million respectively.

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WHAT THE FUTURE HOLDS?

- New ways of practicing science; where science is done, how knowledge is shared and how credit is assigned
- Increased connectivity in the world of science driven by openness and real time collaboration
- Changes in global demography and its impact on mobility and talent; how will nation compete to attract talent?

*It is impossible to predict the future; we can either create it or prepare ourselves to face it*
THE FUTURE OF SCIENCE FUNDING

- Competing demands for public funding to meet the needs of a growing population and meet social objectives will limit spending on science
- Public funding will be heavily focused on outcomes that tackle the immediate problems of society
- Private funding of research will grow, not from industries, but from individuals, foundations, philanthropy, prizes and crowd sourcing; private institutes will be created for pursuing basic research
- Consumers of research will become its funders

Will the original meaning of a research university supported by public funds become redundant? Will public funding be limited to only teaching and imparting skills?
IS PHILANTHROPHY AN ALTERNATIVE TO GOVERNMENT FUNDED SCIENCE?

• Science philanthropy is emerging as the biggest patron of big science, a third pillar along with the Government and the private sector.
• The donors are attempting to do what public funding of science has been less efficient at accomplishing; massive and guaranteed funding, greater freedom to the investigators to pursue risky ideas and fabulous research infrastructure.
• Pursuit of big science; high risk explorations with a long term payoff; escape from the vagaries of Government funding which is subject to political uncertainties and bureaucratic controls.
• There is both criticism and support for philanthropic funding of basic science.
• Will such funding skew research priorities, enrich elite universities, undermine political support for Government funded research?
• As a third pillar of funding of research, philanthropic funding is yet to be objectively assessed.
• Entrepreneurship, new technologies and markets are throwing up increasing number of high net worth individuals, much quicker than ever before in the history of the world. Many of these individuals are driven by their desire for a lasting place in history.

“For better or worse the practice of science in the 21st century is becoming shaped less by national priorities or by peer-review groups and more by the particular preferences of individuals with huge amounts of money.”

Steven A. Edwards, American Association for the Advancement of Science
IS PHILANTHROPY AN ALTERNATIVE TO GOVERNMENT FUNDED SCIENCE?

Emergence of philanthropic funding of science

New Institutions

- Janelia Farm
- Allen Institute of Brain Sciences
- Broad Institute
- Welcome Trust
- Schmidt Ocean Institute
- Ellison Medical Foundation
- Bill and Melinda Gates Foundation
- Perimeter Institute of Theoretical Physics, Waterloo, etc

High net worth individuals/ not for profit entities

- Craig Venter (Celera)
- Elon Musk (Tesla)
- Gordon Moore
- Fred Kavli
- David Koch
- Kris Gopalakrishnan (Brain Research Institute)
- Tata Trust (IIT Mumbai), etc

William J. Broad,
http://www.nytimes.com/2014/03/16/science/billionaires-with-big-ideas-are-privatizing-american-science.html?_r=0
DOES PUBLICLY FUNDED SCIENCE DRIVE INNOVATION?

- The linear model of pure science leading to applied science which in turn becomes useful technology is considered a myth by some.
- Are scientific breakthroughs cause or effect of technological change?
- Is there a relationship between public funding of science and economic development?
- Does public funding crowd out private funding?
- Should the Government subsidize research for industry?
- Is innovation an autonomous, self-perpetuating process? Does technology find inventors or vice versa?
- Is tinkering with existing technologies sufficient to produce “new” technologies?

Matt Ridley, Wall Street Journal, October 23, 2015
**DOES PUBLIC INVESTMENT IN SCIENCE DRIVE ECONOMIC GROWTH?**

- US became a rich nation around 1900 when there was no state funding of science; the industrial revolution occurred without state funding.
- Much of twentieth century’s economic growth was the consequence of two World Wars.
- Economic activity is stimulated by privately funded research; Publicly funded research has no effect on economic growth (*The Source of Economic Growth, OECD Report, 2013*).
- Returns on publicly funded research is near zero.
- Between 1998 and 2003, the budget of US NIH doubled. What were the economic or health outcomes of this increased investment?
- GDP growth of a country has no correlation to its investment in S&T.
- Investment in science and engineering research boosts economic growth (*CaSE, UK Report, Chemistry World, June 2014, p.9)*.

*The integration of Vannevar Bush’s tenet with the economic theories of Joseph Schumpeter and Robert Solow in the early fifties led to the creation of the thought (or myth) that Government investment in R&D is critical to a nation’s growth.*

INDIA’S S&T IN THE NEXT DECADE

- S&T operates within the framework of politics, economics and social fabric of a nation; India is changing rapidly in all these spheres.
- Resources will always be lesser than the demands of a growing economy.
- Private sector will become increasingly more important; Government function will be limited to acting as regulators and facilitators, not gatekeepers.
- Government focus will remain limited to public health, water, sanitation, education, infrastructure, energy and national security.
- In the economic sphere emphasis will be on manufacturing industries leading to creation of employment; However, much of “come, make in India - sell anywhere” policy will be initially based on capital and technologies sourced from outside India.
- Funding for scientific research in public institutions will become more directed and even scarcer in the next few years. The dream run in increase in funding for S&T between 2000 and 2010 is unlikely to be repeated.
- Greater pressure to focus more on science that contributes to “nation building” and improve the “quality of life” of its citizens.

More questions are likely to be asked on how and where S&T is making an impact; merely stating that we are doing cutting edge, globally competitive science will not do!
IN CONCLUSION………..

• The human race in the early part of 21\textsuperscript{st} 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 quarter 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 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!
Beyond the science bubble

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

One question dominated discussion at the annual meeting of the American Association for the Advancement of Science (AAAS) this week. Research is journalism and science advising is squeezed into a conference, perched on a balcony and set on the floor of an alley of hallways, crowded with papers and posters. It is far from the usual scene, but it is an important one to those who work in science. The question was: how is modern science and its institutions responding to the needs of the people it serves and the interests of modern society?

The answers were, unsurprisingly, from political and social scientists, to better communication— and more outreach to journalists and the public— standing at an altar. Many scientists will have left the conference renewed hope, but little sense of being supported. They feel they have been left behind by supposed progress and that the current state of affairs is not supported by evidence or policy decisions.

The need for millions of people in the United States to be served by the agenda and interests of science is becoming harder to tell; and the important audience is increasingly less inclined to listen.

Stories of impact of science on society is becoming harder to tell; and the important audience is increasingly less inclined to listen.
THANK YOU

for your patient listening