THE SHAPING OF INDIA'S SCIENCE, TECHNOLOGY AND PUBLIC POLICY: PAST, PRESENT AND FUTURE

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OUTLINE

- The epochal events of February 28
- Science in pre-independent India
- Publicly funded science: Origins
- Science in Independent India : Evolution of public policies
- Science in contemporary India
- Science in the 21st century
- Public funding of science: Is it necessary?

"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

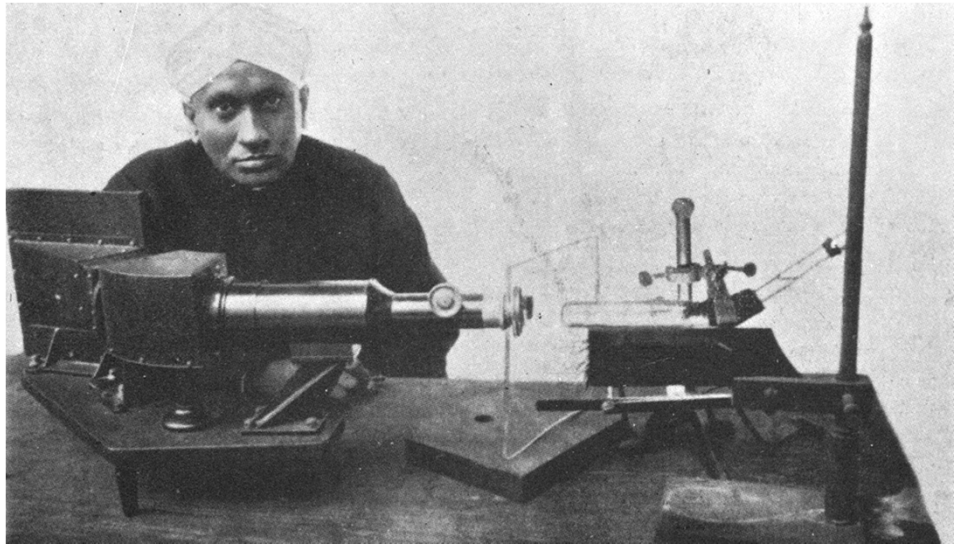
C. V. Raman

7 November 1888 - 21 November 1970

1906 Stood 1st in M.Sc (did not attend classes!!)
1907 Assistant Auditor General, AG`s Office, Calcutta
1907 Starts research at IACS, part time and publishes the first paper

"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"

THE RAMAN EFFECT



On February 28, 1928, through his experiments on the scattering of light, Raman discovered a phenomena called Raman Effect

Raman was confident of winning the Nobel Prize in Physics and 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.

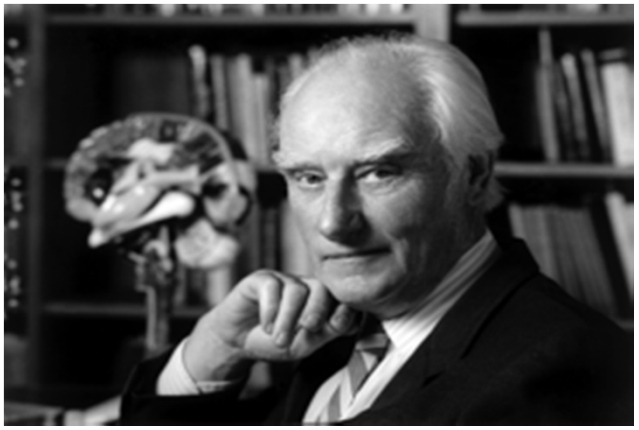
ASUTOSH MUKHERJEE ON RAMAN'S SACRIFICE

"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.""

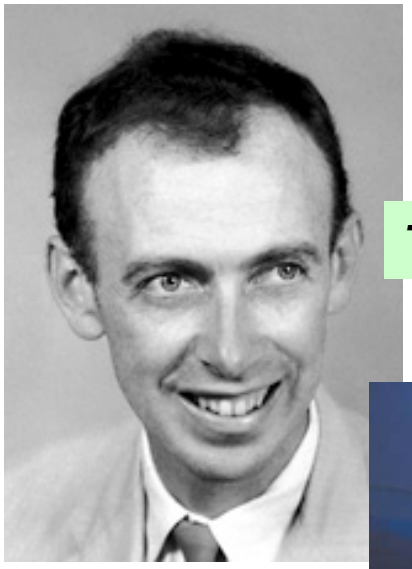
" Sir Asutosh ventured to ask an young and unknown official to devote himself to the pursuit of knowledge under the aegis of the Calcutta University. This, on his part, was an act of courage. But for the action of Sir Asutosh, my scientific career would long ago suffered an abrupt termination."

C. V. Raman

28 FEBRUARY 1953 : ANOTHER HISTORIC DAY FOR SCIENCE



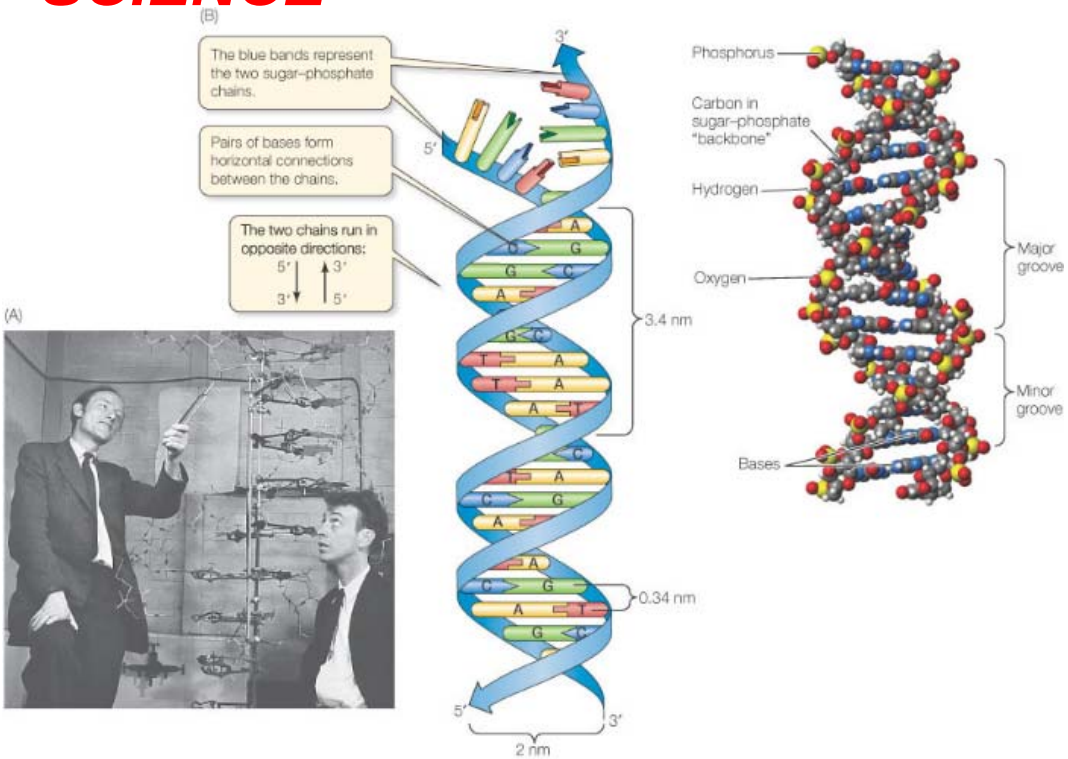
F.Crick
(1916-2004)



Then

J.D.Watson
(1928-)

Now



"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

LESSONS FOR SUCCESS

- Choose a problem ahead of its time, not because it is fashionable; Big challenges are truly ahead of their time
- You have to say either the first word or the last word in science to be noticed
- Never be the brightest person in a room; In science, it is better to be criticized than adored ! Getting out of intellectual rut requires jolts. If there are more smart people around you, smarter you will become

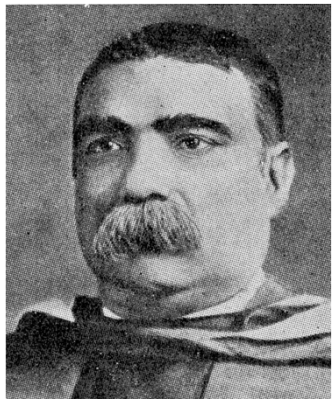
JD Watson, 1970

LESSONS FOR SUCCESS

- Stay in close contact with your intellectual competitors competition is inevitable, if you are pursuing important objectives. To know who else is tackling similar problems as you are is an indication of how important the problem is
- Work with teams where intellectual partnership is equal
- Always have some one to save you. Build a network of well wishers, mentors, men of consequence and angels. In spite of all your accomplishments, you will always need a helping hand as you climb the ladder

JD Watson, 1970

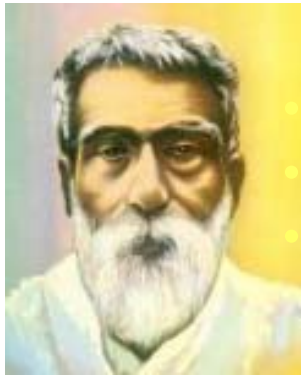
BEGINNINGS OF MODERN INDIAN SCIENCE



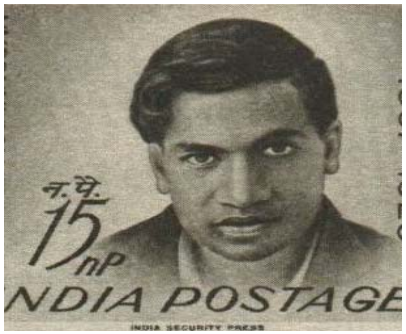
Asutosh Mukherjee (1864-1924)
First Indian to publish a paper (1881)

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)



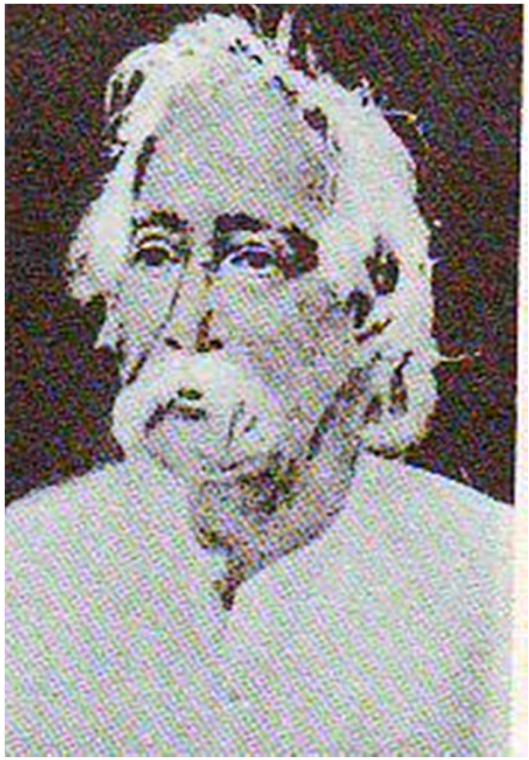
S. Ramanujan (1887-1920)

- FA fail (1908), First paper 1911, FRS (1918)

MAHENDRA LAL SARKAR 'S VIEWS ON INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE,ESTD 1876

"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)



1833-1904

JEWELS OF INDIAN SCIENCE IN PRE INDEPENDENCE PERIOD

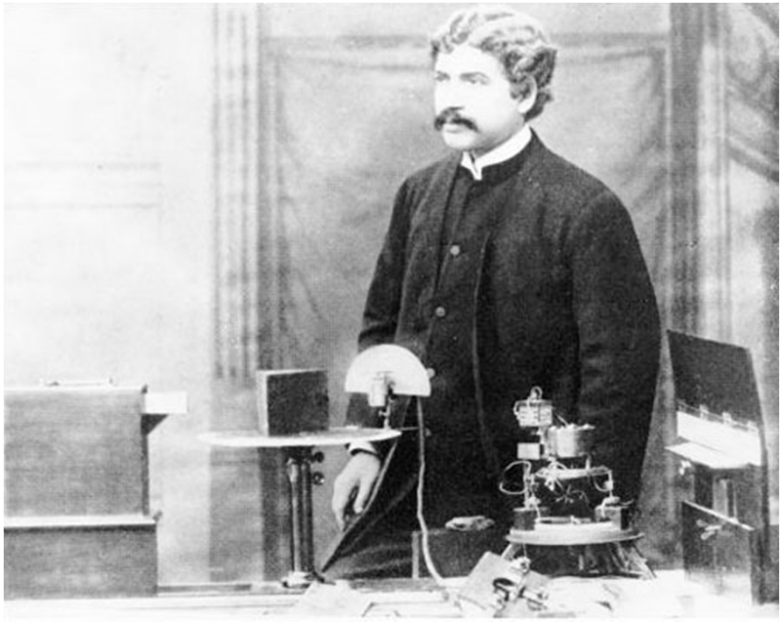
- **C V Raman**
- **S Ramanujan**
- **Sir KS Krishnan**
- **S N Bose**
- **Sir M Visvesvaraya**
- **J C Bose**
- **Birbal Sahni**
- **P C Ray**
- **M N Saha**

Five Indians were elected to FRS during 1937-46; Five were elected also during 1997-2006

J.C.BOSE AND THE FIRST PATENT FROM INDIA

He developed the use of galena (lead sulfide) crystals contacted by a metal point for detecting millimeter electromagnetic waves, and filed patent 755840, for a "Detector for electrical disturbances" in 1901. It was the first device to use a semiconductor junction to detect radio waves.

Bose created a portable device to study the optical properties of short waves, which incorporated the earliest waveguide and horn antenna. It would be more than 30 years before more research and analysis was done with the now widely-used horn antennas. His use of dielectric lenses, polarizers, prisms, and semiconductors at frequencies as high as 60 GHz, were also well ahead of his time.



Sir J.C. Bose
1858-1037

Sir C.V RAMAN AS AN ENTREPRENEUR !

- Krishnamurthy and Raman started a company called Travancore Chemical & Manufacturing in 1943, with Raman as the Chairman and Krishnamurthy as the Managing Director. They established 4 factories across South India and the company was listed on the Bombay Stock Exchange. For over 5 decades, the company was a leader in the manufacture of copper sulphate, sodium chlorate and other chemicals.

- The company closed down in 2002 as manufacturing became unviable due to high cost of power in Kerala

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

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

" Science, technology and innovation are social activities. They cannot be done in isolation and therefore, we cannot 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

The Structure of Scientific Revolutions,

Fourth Edition, 2012

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 beginning of organized science or government funded or directed science

Roger Pielke, Nature, 27 March 2014, Vol. 507, 427

The Sage of Science, A. Brown, Oxford University Press, 2007

SMALL SCIENCE VS BIG 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; With the decline of communism and the rise of capitalism, Bernal lost this intellectual battle !

GOVERNMENT (PUBLIC) FUNDED RESEARCH IS OF A RECENT ORIGIN

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

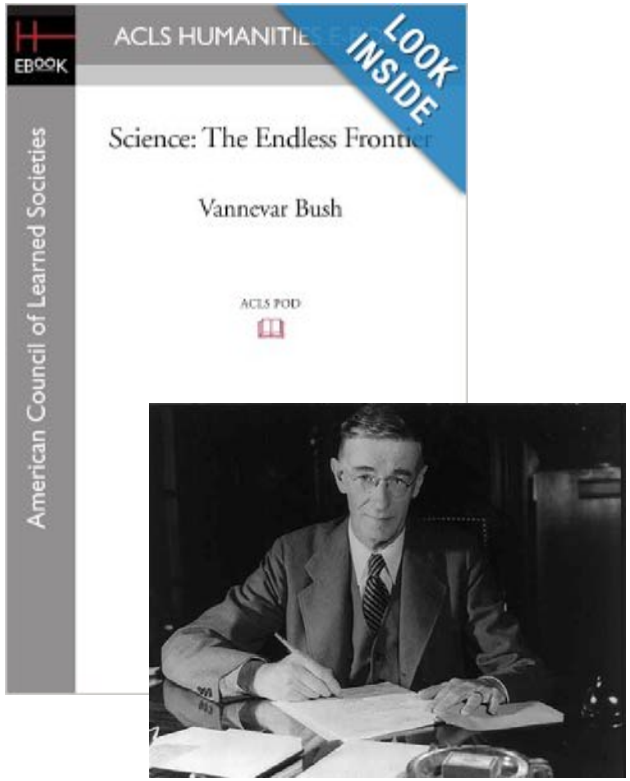
- A large part of nineteenth and twentieth century research and explorations in science were not funded by the state.

- 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 !

IMPACT OF SCIENCE ON SOCIETY

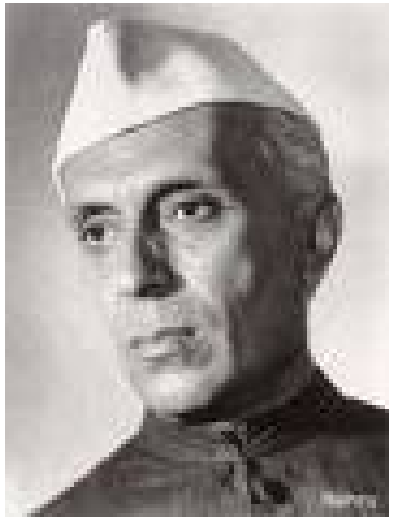
- The tenet : investment in "basic research" by a nation "performed without thought of practical ends" will lead to prosperity for its people.
- More money, more Institutions, more research, more papers and PhD's will result in greater prosperity and wealth creation in society
- Basic leading to applied leading to development leading to production and markets : A linear model
- This tenet was implicitly accepted by Governments around the world as an established public policy
- Only a few years ago, the world began to question this assumption
- Rising above the gathering storm: Energizing America for a better future : National Academy of Sciences , 2007; Is the frontier really endless ? Bruce Alberts, Science 330, 1587 (2010); Gathering Storm revisited : Rapidly approaching Category 5 : National Academy Press, 2010; Roger Pielke, Nature, 466, 922, 19 August 2010



1945

The phenomenon of Increased public funding with reduced public accountability

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

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 ay 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

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.

(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

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

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

PUBLIC POLICIES IN S&T : EVOLUTION

1958
Pursuit of science as a tool to realize the objective of a **welfare state**; foster , promote and sustain the cultivation of science and scientific research; to encourage **individual initiative** for the acquisition and for the **discovery of new knowledge**

1983
To attain technological competence and self reliance, **develop indigenous technology, restrict import of technology** to only critical needs, offer protection to locally developed technologies

2003
Direct efforts to alleviate poverty, enhancing livelihoods, remove hunger and malnutrition, reduce regional imbalances and combine India's traditional knowledge and wisdom with modern science and technology; promote **globally competitive technologies, define policies for intellectual property protection for publicly funded science**, and ensure that the S&T enterprise in the country is fully committed to its **social responsibilities and commitments**

2013
Integration of science, technology and innovation to create **value in society** **or** **wealth in economy**; increase private sector participation in R&D ; convert **R&D outputs to commercial applications;** recognize, **reward and respect performances which create S&T to wealth;**

Reference: http://www.dst.gov.in/

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 wide spread 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

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

EDUCATION IN INDIA

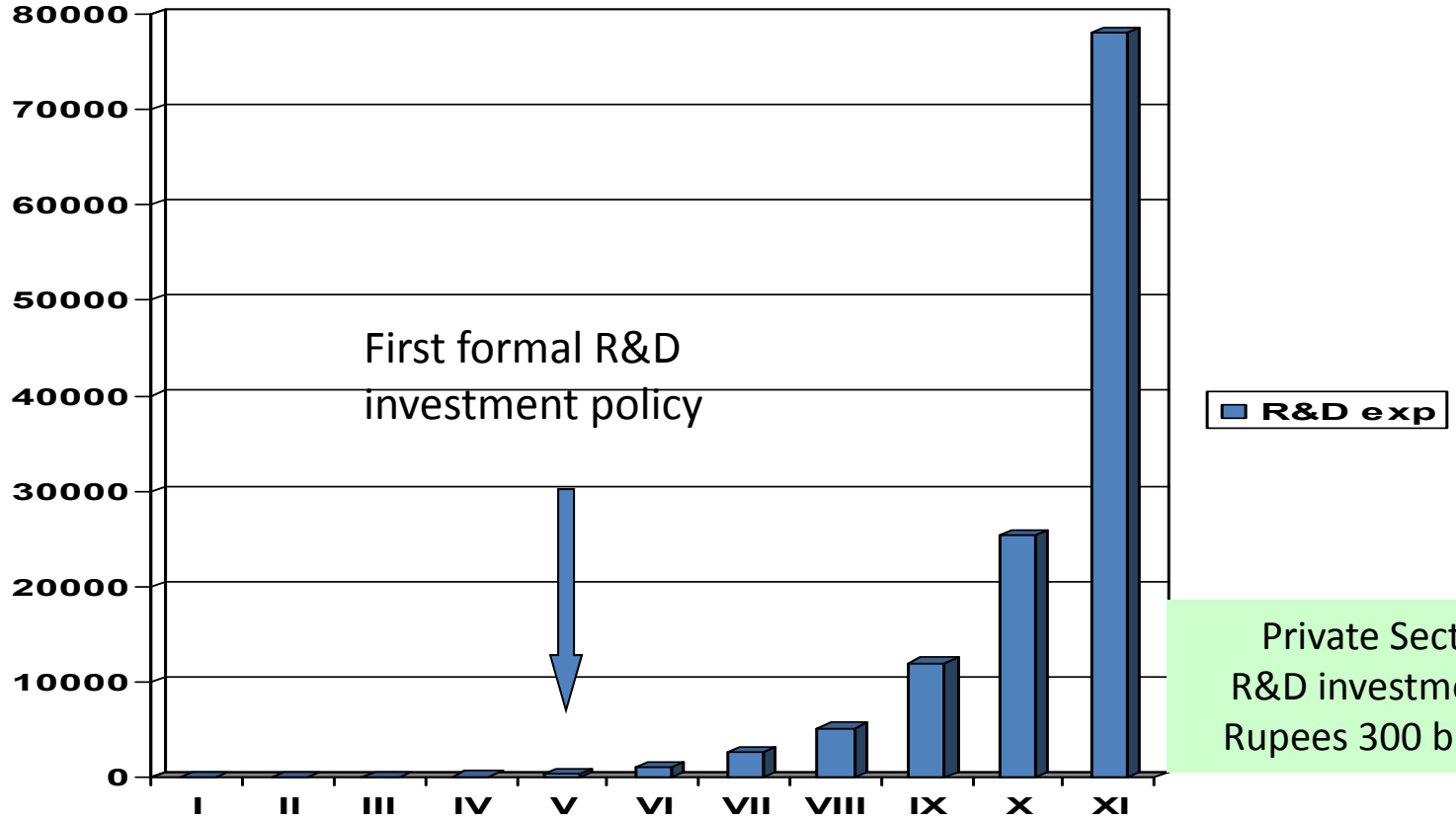
- Universities : 665; Colleges : 36,000
- Private to Public : 70 : 30; in states like Andhra and Telengana , the ratio is approaching 80:20
- 30 million students enrolled in colleges and universities
- 80% are undergraduates; 0.3 % are pursuing PhD
- India produces ~ 15,000 PhD's; PhD's in Engineering < 2000
- Gross Enrollment Ratio : 22 % (Bihar : 12% and Tamil Nadu : 45%)
- Investment in education : 4.5 % of GDP; Higher Education : 0.4 %

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)

INDIA'S R&D INVESTMENTS

Rupees 800 billion



Private Sector R&D investment : Rupees 300 billion

R&D INSTITUTIONS AND NATIONAL INVESTMENT ON R&D ACTIVITIES (DSIR, 2007)

R&D Institutes	Number of institutions	Percentage of national investment on R&D (2003-04)
Central government R&D institutions	707	62.6
Public sector institutions	115	4.5
State government institutions	834	8.5
Universities and institutions of National importance	284	4.1
Private sector institutions	2020	20.3
Total	3960	100

BUDGET ALLOCATION, 2016-17
SCIENCE AND TECHNOLOGY

Total : 57, 607 Crores (US $ 8.5 million)

S.NO	AREA	RS, CRORES	%
1	DEFENCE R&D	13,593.8	23.5
2	ATOMIC ENERGY	11,682.5	20
3	SPACE	7,509.1	13
4	AGRICULTURE	6,620.0	11.5
5	RENEWABLE ENERGY	5,035.8	9
6	SCIENCE AND TECHNOLOGY	4,470.2	7.5
7	CSIR	4,062.8	7
8	BIOTECHNOLOGY	1,820	3.1
9	EARTH SCIENCES	1,672.4	2.9
10	HEALTH	1,144.8	2

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

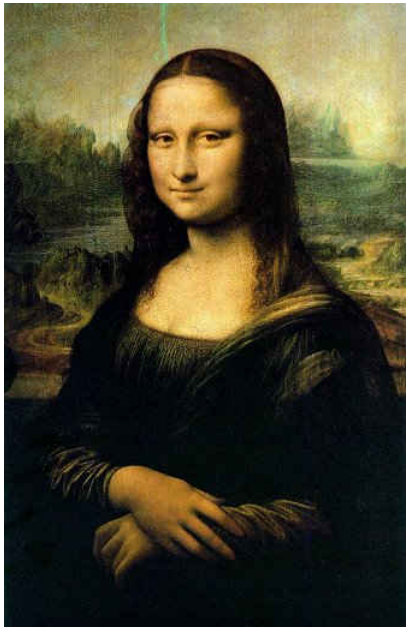
WE ARE STILL GRAPPLING WITH SEMANTICS !

- 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

BASIC AND APPLIED SCIENCE : ARE THEY DIFFERENT ?

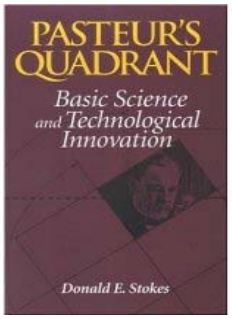
Metaphor: Buckets of paint vs painting



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)

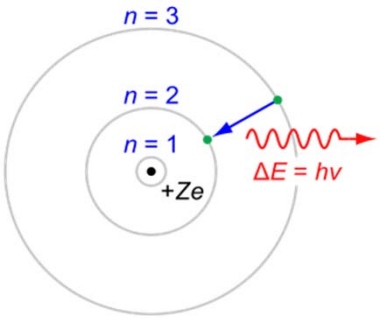
Pasteur's Quadrant



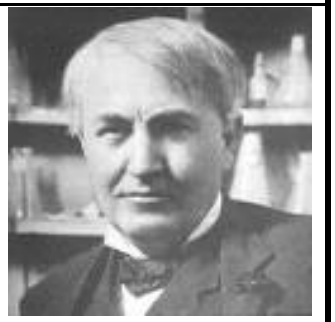
1997

Fundamental Research

Bohr



Pasteur



Edison

Use Inspired Research

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

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

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

SCIENCE IN UNCERTAIN TIMES

Chemistry World, April 2014, p.9

NEWS AND ANALYSIS

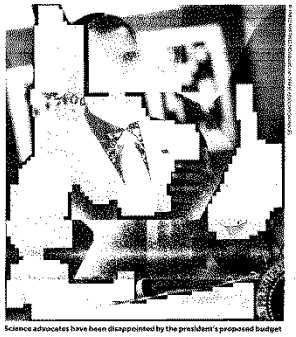
Obama's science budget disappoints

US
Funding fails to keep pace with inflation

US researchers and science advocates are expressing significant disappointment at funding proposals for research agencies in President Obama's budget request for 2015. 'The proposed increase only allows agencies to keep their heads above water, therefore the opportunity for new funding for chemistry, and other disciplines, will not be very bright,' warns Glenn Ruskin, a spokesperson for the American Chemical Society.

The Obama administration's budget request, released on 4 March, would deliver about $1 trillion (£606 billion) for discretionary spending, including science agencies, the same level agreed to in the bipartisan budget deal reached in December 2013.

Specifically, the president would provide $135.4 billion in federal funding for R&D, an increase of 1.2% from the current level. Meanwhile, non-defence R&D would receive $66.9 billion, an increase of 0.2%, and basic research would receive $32.2 billion, which represents a reduction of about 1%.



Science advocates have been disappointed by the president's proposed budget

Inflationary pressures

Some of the biggest research agencies, like the National Institutes of Health (NIH), the National Science Foundation (NSF), Nasa and the Department of Energy's Office of Science, would see their budgets increase 1% or less under the president's proposal. NIH's funding would reach $30.2 billion, NSF's would go to $7.3 billion and the Department of Energy's Office of Science's would hit $5.1 billion. Nasa, too, would see its overall budget rise about 1%, but its science budget would fall by about 3.5% to $3.15 billion.

The president's funding requests become bleaker after accounting for inflation. For the US economy as a whole, inflation between fiscal year 2014 and 2015 is 1.7%, according to White House figures. In addition, the biomedical research inflation rate is projected at around 3%.

Nevertheless, details about the administration's proposed budget remain elusive. For example, it is unclear how the requested funding increases or cuts for science agencies would be dispersed across programmes or research directorates.

Meanwhile, the research lobby has been comforted by the fact that the president has submitted to Congress, alongside his budget proposal, a separate $56 billion Opportunity, Growth and Security Initiative that would provide an extra $5.3 billion for R&D activities. This would include an additional $970 million for the NIH, $886 million for Nasa and $552 million for the NSF. But that proposal will need congressional approval, which appears unlikely.

Above and beyond

'The initiative [...] is above and beyond the approved funding levels agreed to in December,' says Ruskin. 'In light of that it will likely face an uphill battle on Capitol Hill.' Nevertheless, Ruskin calls the president's budget request 'a step far beyond the dark shadow of sequestration', referring to the automatic across-the-board cuts that kicked in in March 2013. 'In light of our nation's continuing difficult national economic times, the president's budget strives to provide for predictable and sustained funding for the science enterprise,' he adds.

In fact, the budget request would also replace the sequestration cuts slated to begin in 2016 with new spending cuts, added tax revenue and immigration reform.

But many US research lobby groups are not enthused. 'The anaemic funding levels for these agencies wasn't and isn't the best we can muster, it's a strat error that needs to be con says BesearchAmerica pr and chief executive Mary' 'Many researchers have al been forced to shutter the and stall promising resea clinical trials, leaving pat with more delays to acces treatments and therapies

Flat cash

Even fellow Democrat Ed Bernice Johnson, who ser the science, space and tec committee that oversees t research areas and agenci expressed reservations ab the president's budget re She is concerned by 'flat e even decreased funding' a number of key areas of th government's R&D budge In particular, she noted th proposed funding for Nas reach even 2014 levels. If Johnson says it will 'hand agency's performance in t coming years'.

In its request for Nasa, t administration sets aside for the Wide-Field Infrare Survey Telescope (WFIRS space observatory that w probe exoplanets and sta for dark energy. It also pr ending the US's involvem the Stratospheric Observatory for Infrared Astronomy (SOF the world's largest airborne observatory that is an 80:20 partnership of Nasa and the German Aerospace Center. Th administration's proposal co just days after SOFIA reached operational status.

Given that this is an electio year, and sharp differences ha been expressed between the political parties about fundin in 2015, observers agree that the fate of the budget remain uncertain. In addition, they a that the odds of Congress pas the Opportunity, Growth and Security Initiative seem espec long because it exceeds the budget caps that recently gair bipartisan support.

Rebecca Trager

Chemistry World, July 2014, p.6

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, enshrined 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 2123. 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 Morgan, 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 for seeing a doctor. The money will be ploughed into medical research once the fund reaches its A$20 billion goal.

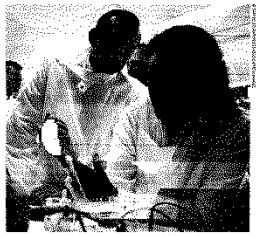
'There is no thought as to how to use the money they don't have any understanding of the science system,' says Morgan. CSIRO – the largest government research organisation – faces cuts of A$114 million. It will lose 420-500 staff in the next year. Coming on top of 200 previously announced redundancies, 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 Morgan welcome an additional year's funding for big infrastructure projects, such as the Australian Synchrotron and the Square Kilometre Array's supercomputer. But a feature of the budget will see science funding redirected from one programme to another, so 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$142.9 million will be cut from the carbon capture and storage flagship, and a commitment to 2 million solar roofs has been withdrawn.

Abandoning carbon pricing will cost the Australian treasury A$20 billion, while mining corporations will get A$13 billion in subsidies through diesel fuel rebates, asset 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 positions Australia to take advantage of its natural resources. 'A great opportunity to change our economy has been squandered – the question is whether through willful ignorance or a fundamental misunderstandin



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

Fees quandary

From 2016, the university funde model is changing so that universities will be able to decid their own course fees. Universit will have to cover an 8.5% drop i funding compared with what we promised in last year's budget – and one which already included stringent cutbacks. Changes to t higher education loan programe 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. 'For do universities set 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 [... and that may mean people chor shorter degrees.'

The Australian Research Council will have to find almost A$75 million in efficiency saving over the next three years, and A$50 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 Mehta

THE BUDGET IN NUMBERS

Winners

A$20 billion for a medical research fund

A$140 million to continue mo raise silicosis

A$150 million for the National Collaborative Research Infrastructure Strategy for 2015-16

Losers

CSIRO funding cut by A$114.4 million

Clean technology programme axed saving A$141 million

Innovation and commercialisation programmes cut by A$80m

Carbon capture and storage flagship cut by A$142.9 million

Government funding of science under stress; In no country are the scientific community satisfied

Chemistry World, September 2014, p.7

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 Évora'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 Sérgio Seixas de Melo tells *Chemistry World* that the society carried out its own bibliographic study based on data provided by Elsevier. 'We found that in many research fields some of the most productive [centres] were excluded from the second stage,' he says. 'Something definitely went wrong in this evaluation procedure.'

But the FCT strongly denied that its assessment methods were in any way flawed. It issued a statement saying it had 'full confidence in the robustness of the ongoing review' and that it was being carried out with 'total transparency, rigour, independence and in line with the highest international standards'.

Research centres can appeal the FCT's decision, and some have already begun this process.

Emma Stoye

Chemistry World, July 2014, p.9

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 Madhu 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 scientists?

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 decades's years, but nothing happened,' says N Raghunun, 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 1.1% 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 15.1%.

According to an analysis by the thinktank Centre for Public Policy Research, India's science budget was cut by 1.62% in 2012-13, compared with the previous year. However, it did see a year-on-year increase of 11% in 2013-14.

The last government earmarked just R$825 billion (£829 million) for the ministry of science and technology, compared with R$202 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 2013 – 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.

Ajey 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 renamed 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, Vinuta 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 has been put back on display in the US's Tate Modern gallery, following months of restoration after was vandalized with toilet ink. Conservators used a mixture of butyl propyl ethyl lactate, applied under a microscope using a very fine brush, to dissolve the ink bit by bit, removing the graffiti without damaging the 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. Researchers found that tomato pills improved the functioning blood vessels in a test gro 70 adults, when compared a placebo.
BBC News, 8 June 2014

Brushing back enamel
Unilever has launched a toothpaste that they claim restore and whiten damag teeth by regenerating 92% enamel in just three days use. The toothpaste cont calcium silicate and sodiu phosphate, which provide building blocks for a fresh of enamel (calcium phosp
The Daily Mail, 15 June 20

Booze 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 dri related offences. The 'scra bracelet', which has been successful in the US, cont a fuel cell that works in a similar way to a breathaly generating a current whe alcohol is present.
The Times, 14 May 2014

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

Terence Kealey, www.telegraph.co.uk/news/politics; Roger Pielke, http://thebreakthrough.org/index.php/voices/roger-pielke-jr/tall-tales-of-economic-growth/ ; C.Macilwain, Nature, vol.495, 143, 13 March 2013

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

J. Stilgoe, The Guardian, October 26, 2015
V. Sivaram, The Newsweek, October 28, 2015

REDEFINITION OF ACTIVITIES OF GLOBAL PUBLICLY FUNDED INSTITUTIONS

TNO innovation for life

CSIRO

VTT

cnrs dépasser les frontières

Activities no longer defined in terms of scientific disciplines but by stakeholder focus

Health, nutrition and well being
Environment
Safety and Security
Information and communication
Transport and Mobility
Built Habitats
Energy and water

CSIR our future through science

Fraunhofer

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

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.

THE RISE AND FALL OF CORPORATE R&D

- Breakup of large corporations: mergers, acquisitions by private equity and even disappearance of companies: ICI, Hoechst, Monsanto, Ciba
- Research expenses became a cost ; cost reduction led to downsizing of internal R&D.
- Corporations sought out external partners for performing research and seed new ideas. Initial motivation was cost reduction
- Academic labs became once again innovation hubs for industry
- New models of academic industry interactions emerged
  - Contract/ collaborative R&D
  - Industrial consortia around knowledge competencies
  - Joint centers of research in academic campuses
  - Industry new venture funds to encourage academic start ups

These changes, created in its wake, new dichotomies, dilemma and mutual learning

WHAT IS GOOD SCIENCE

- Criteria for good science: Excellence, pertinence and appropriateness
- 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
- In reality, practical importance of scientific discoveries are often overestimated (purely for selfish interests) and discoveries which initially appear irrelevant turn out to be of great practical value

J. Chem. Educ., 61, 91 , 1984

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 !

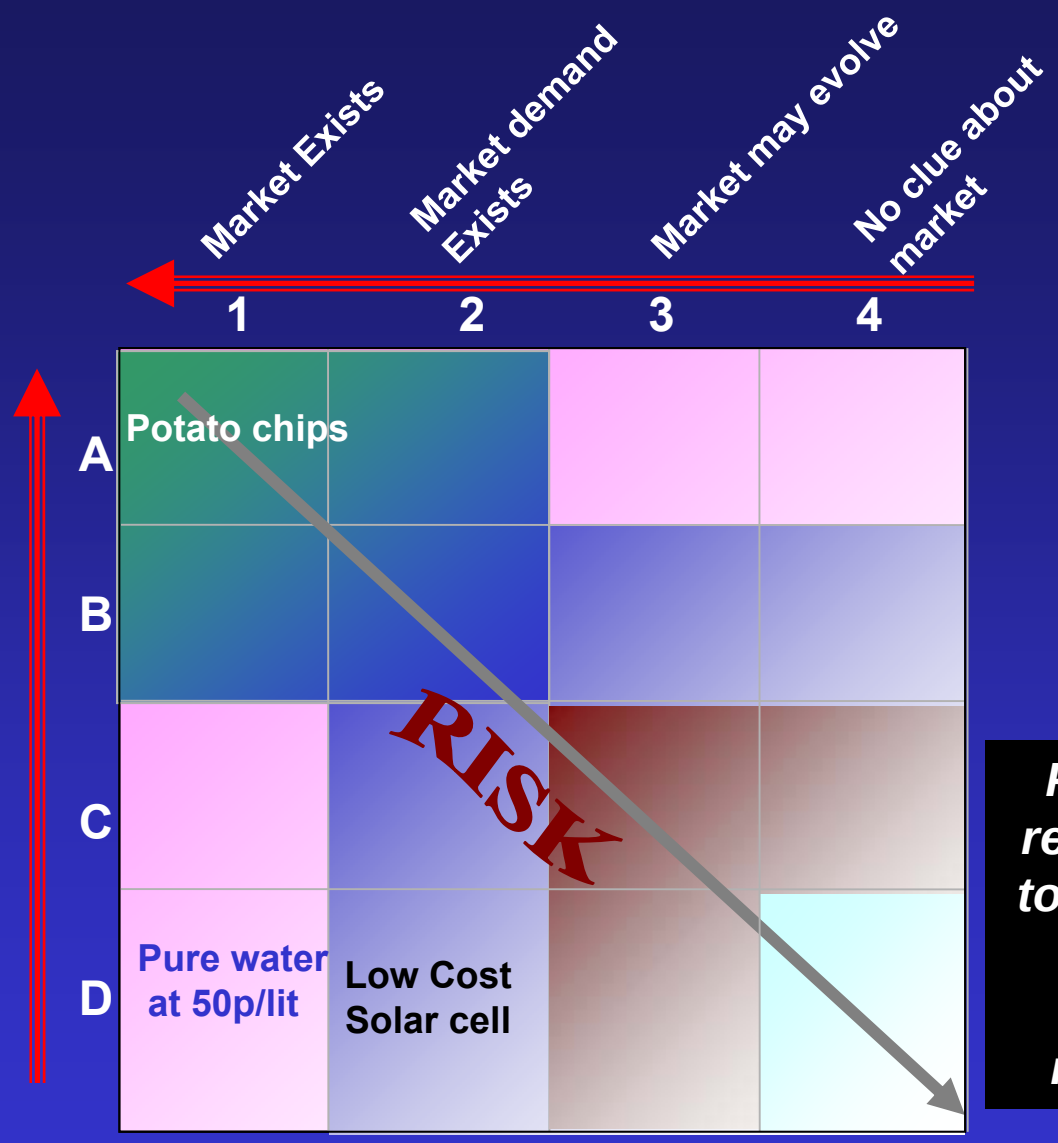
POSITIONING OF PUBLIC FUNDED R&D IN KNOWLEDGE – MARKET SPACE

Knowledge exists, Technology exists

Knowledge exists, Technology needs to be developed

Knowledge exists, No clue about Technology

Problem exists, Knowledge needs to be developed



Public funded research needs to operate in the C-D 3-4 knowledge – market space

Goethe once said about science: "To one man it is the highest thing, a goddess; to another it is a productive cow who supplies them with butter. We must honor the goddess and feed the cow.

Johann Wolfgang Goethe
1749-1832
Writer, poet, natural philosopher, statesman; wrote treatises on botany, geology, anatomy and color


THANK YOU