# **Reciprocity of Science and Technology**

# Better Living Through Photochemistry

V. Ramamurthy

### • Science

- A system of acquiring knowledge
- Probing reality
- Legacy is embodied in publications and teaching
- Technology (Applied Science)
  - The application of science and/or scientific method, especially to industrial and commercial objectives
  - Legacy is embodied in patents and the material advancement of society
- Impact of Science and Technology on Society
  - New products, new industries and more jobs

# Pure Science Often Triggers a Technological Revolution

# How basic understanding of light changed the way we live?



Konark



Suryanar koil



Modhera



Recognizing the importance of light, SUNits ultimate source has been worshipped in many ancient cultures. Only a few have gone beyond to probe its nature.

Ranakpur



#### Lucretius (50 BC)



What is LIGHT?

The light and heat of the sun is composed of minute particles.





# Light: Prosperity through basic science



Oil lamp



### Filament lamp



Fluorescent lamp



Gas arc lamp



Light emitting diodes

### LASER (Light Amplification by the Stimulated Emission of Radiation) Invention and Innovation



**1917: Albert Einstein derives the theoretical basis for the laser.** 



1960: The first working (ruby) laser.



1965: The compact laser disc (CD) invented.



1974: A laser-driven barcode scanner used for the first time.

The world market for laser technology is now over \$100 billion a year

# **Natural Cure for Jaundice**



### **Phototherapy - Jaundice Treatment**



### **Skin Disorders**



Psoriasis



### **Polymorphic light eruption**







Acute dermatitis

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### **<u>Photodynamic Therapy (PDT)</u>**

- **Photodynamic therapy first used in 1978.**
- □ There is currently one photodynamic drug available on the market: Photofrin.<sup>™</sup>
- **Approved for the treatment of lung cancers.**



Chlorins





**Phthalocyanines** 



### A reaction discovered in 19<sup>th</sup> century revolutionizes the lithographic industry



**C. T. Libermann** 1842–1914



Ann. Chem. Pharm. 158, 300, 1871

# **Photolithography: Invention 1949-50**



Louis Minsk (Kodak) Polyvinylcinnamate-Based Photoressist



**Otto Suess** (Kalley's) Diazoquinone-Based Positive Photoressist



Louis C. Plambeck (DuPont) Acrylate-Based Photopolymer Imaging



### Lithographic Printing is the Backbone of Modern **Printing Industry**



#### DUPONT PROGRESS REPORT

#### DU PONT DISPLAYS PLATE AT NEWSPAPER CONFERENCE



WILMINGTON, DEL.

for return and flat had up

**Plans Three Types of Photopolymer Plates** 

PTTYSBURGH, Pa., Mar. 13 — The Photo Products Department of E. 1. du Pont de Nemours & Co., Inc., exhibited samples of experimental photopolymer print-ing plases taken you to the news- expected to be available in shour paper production men attending two years, the time required to the Mid-Alustic NewsQuark (journari production labilities). These ri tes are con

No. 2a Mid-Atlantic Edition

sa report in violet light e nulsion side) enu he plastic to harden through plastic to harows its ordire depth. Subsequent ash out" with a dilute alka-colution removes the

and unhard al steps can se heat 15 minutes. A Du Pont Photo Pro-A Du Pont Photo Pro-Martin W. H. V

New Product stated that c

relignent, stated that current plans are to market three types of plans - a steel-ausported plans - a steel-ausported plans - best do insh that will be the state and the steel of the state of the steel WILMINGTON, Det.

### **Photolithography Applications in Electronic Industry**



#### **Printed Circuit Boards**



**Micro-Electro Mechanical Systems (MEMS)** 

### **Photolithography Applications in Medical Technology DNA Chips (Micro-array)**





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Several more rounds - of light directed

de-protecting and nucleotide addition....

Legends Wafer Surface Linker Molecule Protective group Mask UV lightA C Nucleotides



### **Biosensors Based on Photopatterning**





### Applications

- blood glucose measurements for diabetes management
- testing food for the presence of pathogenic microorganisms (Salmonella and E. coli)
- **sensing chemical and biological warfare agents**

- => Photomedicine
- => Lithography
- Industrial Synthesis of Chemicals
- => Photography, Xerography and Holography
- ➡ TiO<sub>2</sub>: Environmental Cleanup
- => Sunscreen, Photochromic Glass
- Photostabilization
- ➡ Photocuring
- ⇒ Solar Energy

## **Photosynthesis and Solar Energy**

#### **The Nobel Prize in Chemistry 1961**



Joseph Priestley 1733–1804





**M. Calvin** 1911-1997

#### **The Nobel Prize in Chemistry 1992**

#### The Nobel Prize in Chemistry 1988



R. Marcus



J. Deisenhofer



R. Huber



H. Michel 23

## **Ciamician's prediction is yet to come true**

"On the arid lands there will spring up industrial colonies without smoke and without smokestacks, forests of glass tubes will extend over the plains, and glass buildings will rise everywhere; inside of these will take place the photochemical processes that hitherto have been the guarded secret of the plants."



**G. Ciamician** 1857-1922

Science 1912, 36, 385

# More optimism

"I have no doubt that we will be successful in harnessing the sun's energy. ... If sunbeams were weapons of war, we would have had solar energy centuries ago."

Observer, 1973

**George Porter** (1920 - 2002)

### Our fore-fathers knew it, time for us to harness it



"The rising sun is the giver of energy, heat, all powers, happiness and prosperity."

Rigveda, 2000-1500 BC 26

# **Technology Precedes Science in Developing Countries**

# **Indian Example**

## **Science Policy Outlined**

We are <u>intensely interested</u> in the scientific development of India and we shall do everything in our power to <u>encourage</u> <u>scientific research</u>.



Jawaharlal Nehru (1889–1964)

We should like to <u>tap</u> all the <u>latent scientific</u> talent in the country and to give it opportunity for <u>growth</u> and <u>service</u> to the <u>humanity</u>.

### **Atomic Energy Commission**

What the developed countries and the underdeveloped countries lack is <u>modern science</u>, and economy based on <u>modern technology</u>.

Science, 151, 541, 1966



Homi J. Bhabha 1909–1966

We must have the capability. We should <u>first prove ourselves</u> and then talk of Gandhi, non-violence and a world without nuclear weapons.

### **Space Technology: Man to Moon**

Having produced the men who can do research, it is necessary to organize task oriented projects for the nation's practical problems.



Vikram Sarabhai 1919–1971

We are convinced that if we are to play a meaningful role nationally, and in the community of nations, we must be <u>second to none</u> in the <u>application of advanced technologies</u> to the real problems of man and society.

# **Green Revolution**

I have yet to meet anyone familiar with the situation who thinks India will be self-sufficient in food by 1971.

India couldn't possibly feed two hundred million more people by 1980.

Paul R. Erlich, Population Bomb, 1968







M. S. Swaminathan

# PharmkcouticalgenCenteys Grebedia Drugs



**Du Pont** 



Astra-Zeneca

GlaxoSmithKline (GSK), India Novartis India Limited Wyeth India Limited Parke Davis India Ltd Aventis Pharma India Pfizer India Ltd UCB Pharma Ltd E Merck India Ltd Eli Lilly and Company (India) AstraZeneca Pharma India Ltd Johnson & Johnson Cipla Limited Ranbaxy India Limited Dr. Reddy Laboratories Nicholas Piramal India Limited Sun Pharma Ltd **RPG Life Sciences Ltd** 



Honeywell



# **Technological Revolution**

- Atomic Energy
- Space Technology
- Green Revolution
- Pharmaceutical
- Computer software

National security and energy self sufficiency

National security and communication self sufficiency

Food self-sufficiency

Healthcare self-sufficiency

Economic prosperity and international respect

**Scientific Revolution Yet to Come** 

# Science in Pre-Independent India

### **Early Britishers' view of India and Indians**

It is, no exaggeration to say, that all the historical information which has been collected from all the books written in Sanskrit language is <u>less</u> <u>valuable</u> than what may be found in the most paltry abridgments used at preparatory schools in England.



**T. B. Macaulay** Member, Supreme Council of India

Indians <u>do not</u> possess the requisite temperament for exact science.



**A. Croft** Director of Public Instruction Vice-Chancellor, Culcutta Uni<sub>5</sub>

# **Indian Response**

1895: Demonstration at Kolkata Town Hall the possibility of signaling by micro-waves through a wall.

1897: Demonstrated at Royal Institution, London the possibility of signaling by short micro- waves at the invitation of Lord Rayleigh.



Jagadish Chandra Bose 1858–1937

1901: Discovered the first semiconductor (lead sulfide crystal) that detects mircowave to visible light and obtained US patent (1904; application filed by Mrs. Bull and Nivedita in 1901).

Indians doing science on their own initiative received recognition but not financial support from Britishers

"Bose was God's instrument in the removal of India's shame."

**Rabindranath Tagore** 

"The people from the East have just the burning imagination which could extract a truth out of a mass apparently of disconnected facts."

London Spectator, 1897

"The Eastern mind was equally capable of making great scientific discoveries and producing experimentalists as eminent as those of the west."

Henry Roscoe, Vice-Chancellor of the University of London, 1987

### **Vision of J. C. Bose: Globalization of Science**

The land from which I come did at one time strive to extend human knowledge, but that was many centuries ago. It is now the privilege of the West to lead in work. I would hope that a time may come when <u>both the East and the West that will</u> <u>work together</u>, each taking her share in <u>extending the</u> <u>boundaries of knowledge</u>.

**Address to the Royal Institution, 1897** 





Abdus Salaam



S. Chandrasekhar



H. G. Khorana



V. Ramakrishnan 39

# Science, Technology, and Politics A Common Problem

### **Faraday and Electromagnetism**



Michael Faraday, 1791–1867

**Prime Minister Robert Peel:** What is the practical value of this new device (electromagnetically driven transformer)?

*Michael Faraday*: I know not, but I wager that one day your government will tax it.

**Conversation recorded in 1831** 

The first industry to be built on the invention made in a laboratory rather than in a workshop



**Santiago Ramon y Cajal**, 1852–1934 Nobel Prize in Physiology (1906)

People with little understanding fail to observe the mysterious <u>threads</u> that <u>bind</u> the <u>factory</u> to the <u>laboratory</u>.

In response to the admonition by Nehru asking Indian scientists to come out of ivory towers in which they had confined themselves---



**C. V. Raman**, 1888–1970 1930 Nobel Prize in Physics

The men who matter are those who sit in ivory towers. They are salt of the earth and it is to them that humanity owes its existence and progress.

> C. V. Raman, 1950s IIT-M, Convocation address, 1966



**Peter Doherty** Nobel Prize in Medicine, 1996

Once the political process tries to direct research, disaster inevitably results. Scientists at the top are no longer funded, and the politicians end up paying third-rate 'canon-builders to put a man on Mars. It takes a sophisticated political process to deal with this reality.

The Beginner's Guide to Winning the Nobel Prize, 2006



Hans Krebs Nobel Prize in Physiology or Medicine 1953

Another disturbing attitude that has crept into university life in recent years: a <u>cynicism about basic research</u>. Students question the virtue of the search for new knowledge, in the face of the urgent practical problems which confront the world.

Hans Krebs, Reminiscences and Reflections, 1981

John C. Polanyi The Nobel Prize in Chemistry 1986



(Concerning the allocation of research funds) It is folly to use as one's guide in the selection of fundamental science the criterion of utility. Not because (scientists)... despise utility. But because. .. useful outcomes are best identified after the making of discoveries, rather than before.

Excerpt from the keynote address to the Canadian Society for the Weizmann Institute of Science, Toronto June 2, 1996.



**Venki Ramakrishnan**, Nobel Prize in Chemistry, 2009

I had ideas of solving the structure of the ribosomes. As soon as we started <u>insecurities about funding set in</u>. --- I know that LMB laboratory had a long standing tradition of supporting difficult and fundamentally important project.

The Hindu, April 9, 2010

## **More Pragmatic Approach**

**P. B. Medawar**, *1915-1987* Nobel Prize in Physiology, 1960



The most sinister consequence of looking down on applied science (technology) was a backlash that has diminished pure science in favor of its practical applications ---- that sought to fund research on the basis of retail trade: the so called consumer-contractor principle.

Advice to a Young Scientist, 1979

## **Synergism Between Science and Technology**



Archimedes, 287-212 BC



Eureka



#### The Golden Crown

# **Summary**

## • Science and technology are synergistic.

- Science needs technology for financial support
- Technology needs science for generating new products
- Value of technology is easy to see but not that of science
- Money is central to the development of a dynamic scientific culture.
- Cooperation among scientists and technologists is necessary for economic and human prosperity.
- Public and politicians outreach is a MUST