ICTS | INTERNATIONAL CENTRE for THEORETICAL SCIENCES

TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Curiosity Driven Research

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Curiosity about nature

"Man's power over nature is the source of history."

Man's curiosity about nature is in fact the source of that the power!

Few people would deny the importance of answering the following questions:

1) The origin and the fate of our universe.

2) The origin and evolution of life on earth.

3) How did matter organize itself to `think'.

Basic sciences are involved in the quest to answer these and similar questions.

The Basic Sciences

Basic science is a curiosity driven exploration of how nature works.

The Basic Sciences

Kepler discovered his laws of planetary motion from a desire to make sense of a vast amount of earth-based astronomical observations of the motion of planets. Kepler's laws played an important role in Newton's formulation of his law gravitation and his laws of motion. (Mechanical engineering...)

Maxwell discovered the laws of electromagnetism from a quest to make consistent the (then-)known laws of electricity and magnetism. His discovery led to the prediction of electromagnetic waves (light is such a wave), in particular, microwaves. It was this prediction that enabled Roentgen to interpret X-rays as another form of electromagnetic radiation. (Electrical engineering, optics…)

Crick and Watson discovered the information encoding scheme of biology from a desire to interpret the crystal structure of DNA. Their discovery forms the foundation of all of modern biology including gene-editing technology.

The Basic Sciences

Scientists ask questions whose answers need not be immediately applicable to any real-world problem.

The history of science teaches us that most scientific discoveries are owed to serendipity and curiosity driven explorations in `knowledge space'. Such accumulation of knowledge often translates into technologies.

Vannevar Bush in “Science the Endless Frontier”

“Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. One of the peculiarities of basic science is the variety of paths which lead to productive advance. Many of the most important discoveries have come as a result of experiments undertaken with very different purposes in mind.”

(Vannevar Bush in “Science the Endless Frontier”, 1945)

The Applied Sciences

Applied sciences draw from the `basic science knowledge bank'. It directly leads to technology that shapes the modern world:

1) communications technology (e.g. cell phones...),

2) air transport (e.g. the modern jet engine...),

3) medicine, medical engineering, healthcare, genomics, ...

4) large scale computing, AI, ...

All this is the domain of applied research that delivers the `ultimate product'.

Of course there is a feedback between applied science and basic research e.g. Hubble, CERN, LIGO...cutting edge technologies that enable fundamental science!

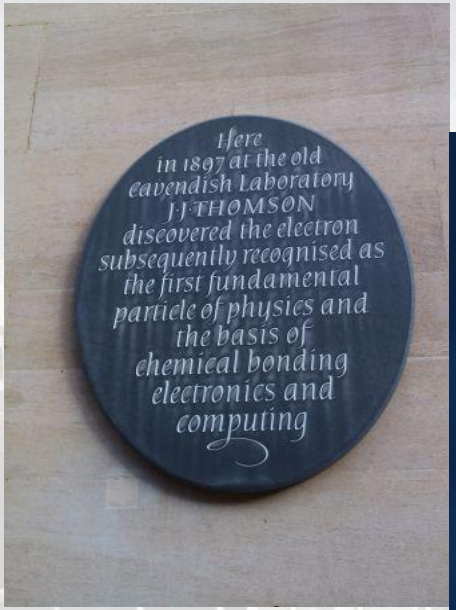
The Applied sciences: how the transister came about at Bell Labs

There is a deep connection between basic discoveries in solid-state physics and the invention of the transistor, the basic component of all modern electronic devices that ushered in the electronics age.

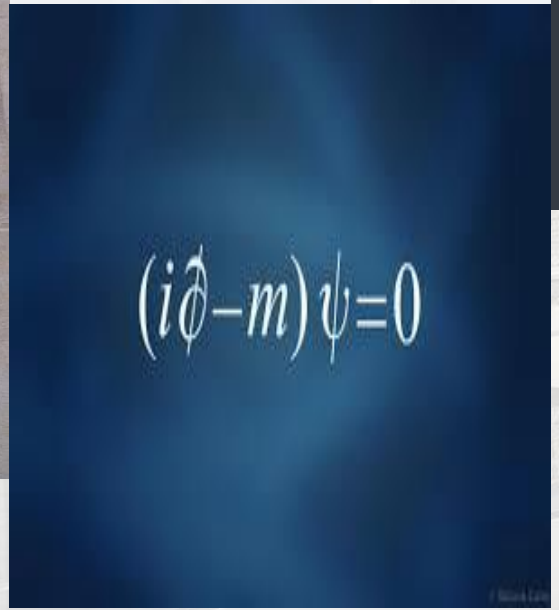
"One study group in particular, informally led by William Shockley at the West Street labs, and often joined by Brattain, Fisk, Townes, and Woolridge, among others, met on Thursday afternoons. The men were interested in a particular branch of physics that would later take on the name "solid-state physics." It **explored the properties of solids** (their magnetism and conductivity, for instance) **in terms of what happens on their surfaces as well as deep in their atomic structure.** And the men were especially interested in the motions of electrons as they travel through the crystalline lattice of metals"... Excerpt From: Jon Gertner, "The Idea Factory: Bell Labs and the Great Age of American Innovation."

The cell phone

Electron



Dirac Equation



Einstein's General Relativity

$$R_{ab} - \frac{1}{2}Rg_{ab} = \frac{8\pi G}{c^4}T_{ab}.$$

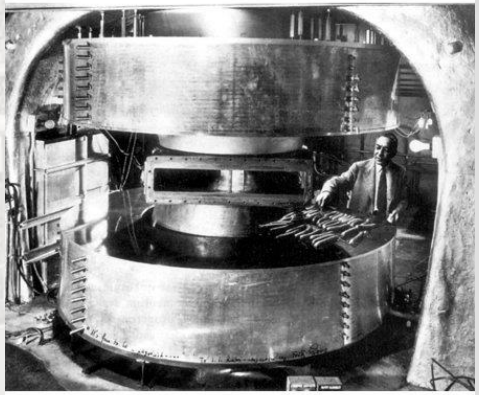
ALBERT EINSTEIN'S GENERAL THEORY OF RELATIVITY, 1916

NMR and MRI

Nuclear Magnetic Resonance or NMR is a spectroscopic technique developed by Isidor Rabi to study magnetic fields around atomic nuclei. Today it is widely used for Magnetic Resonance Imaging (MRI).

Rabi was reminded of his work when he was being examined in a MRI machine. He saw himself in the reflective inner surface of the machine and said…"I never thought my work would come to this".

1944 Nobel Prize for discovery of NMR



Prime numbers

Prime numbers are building blocks of the natural integers and mathematicians have discovered remarkable properties of prime numbers… the simplest being that there are an infinite number of them and every natural number can be uniquely factored into a product of primes.

Given 2 primes p and q, it is easy to find the product pq, but given pq it is very hard to find p and q. This fact is the basis of all of modern cryptography which e.g. ensures safe bank transactions.

Why support basic sciences?

"The distinction between applied and pure research is not a hard and fast one, and industrial scientists may tackle specific problems from broad fundamental viewpoints. But it is important to emphasize that there is a perverse law governing research: under the pressure for immediate results, and unless deliberate policies are set up to guard against this, applied research invariably drives out pure. The moral is clear: It is pure research which deserves and requires special protection and specially assured support".

(Vannevar Bush in "Science the Endless Frontier", 1945)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Thank you