



## Choosing a career

“You've got to find what you love. The only way to do great work is to love what you do.”



*Steve Jobs*  
CEO of Apple Computer

## Science



## What is Science?

- Science is a means to understand ourselves and the surroundings through verifiable facts.
- Helps to formulate important and interesting questions about nature, and then design a series of experiments to explore possible answers.

## Basic vs Applied Science

### Basic

Research carried out to increase understanding of fundamental principles. Many times the end results have no direct or immediate commercial benefits.

### Applied

Research done for a specific commercial, or market driven purpose. The practical question in this kind of research is – ‘Does this kind of research make profit?’

## Can I be a Scientist?

Science, like an army, needs generals as well as soldiers. Thanks to the work of soldiers the concept of a leader acquires vigor and clarity.



*Santiago Ramón y Cajal*  
Nobel Prize in Physiology 1906

*Advice for a Young Investigator, Santiago Ramon-y-Cajal, Spanish version, 1898, (English version, MIT Press, 1999)*

## Not smart enough to be a scientist – No problem?

“One does not need to be terrifically brainy to be a good scientist. Application, diligence, a sense of purpose, the power to concentrate and not be cast down by adversity are absolutely essential.”



*Santiago Ramón y Cajal*  
Nobel Prize in Physiology 1906

“You don’t have to be that smart to be a good scientist”



Venki Ramakrishnan  
Nobel Prize in Chemistry, 2009

## Motivation to Do Science

- Intellectual curiosity, desire to know the truth
- Professional pride
- Ambition, desire for reputation
- Passion to leave behind something of permanent value
- Desire to see one’s name in print and be credited throughout the scientific world



## Learning and Doing Science



- **Doing science is different from reading about science.**
- **Science is about discovery, excitement, persistence and integrity.**
- **The process of doing science is deeply rewarding, not only intellectually but also emotionally and socially.**

## Metamorphosis: Student to a Scientist



- **Getting trained to be a scientist**
- **Becoming a scientist**
- **Being a scientist**
- **Living as a scientist**

## Migrate to a Place with Opportunity and Knowledge



**Xuan Xang (Sanzang)**



Birds become migratory only to ensure that more individuals of a species will survive, despite the risk of being blown off course during their travels, than if they stay to eke out a precarious living.

## Find a Suitable Research Mentor

- **A world famous scientist in high demand**
- **An established scientist who is also an administrator**
- **A reputed scientist focused mainly on science**
- **An upcoming scientist**

## Find a Suitable Research Mentor

### An Ideal Research Mentor



#### On Otto Warburg:

- High standards in research and in general conduct
- Genuine dedication to his chosen area of activity
- Long and regular working hours
- Unwilling to publish trivia for publishing's sake

*H. Krebs  
Reminiscences and Reflections*

## Getting Started: Learning the Literature

The beginner must read, but intently and not too much. One should not spend weeks or months 'mastering the literature' before beginning a project.



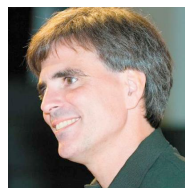
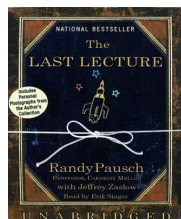
Lord Byron  
1788-1824

To be perfectly original one should think much and read little, and this is impossible, for one must have read before one has learnt to think.

## Time Management

The key question to keep asking while doing science is, are you spending your time on the right things?

Because time is all you have.



*Randy Pausch*

## Building Confidence

Once you get courage up and believe that you can do important problems, then you can.

It is psychologically most important to get results, even if they are not original. Getting results, even by repeating another's work, brings with it a great accession of self-confidence.

"When I questioned Mrs. Marcet's book (*Conversations on Chemistry*) by such little experiments as I could perform, and found it true----, I felt I got hold of an anchor of chemical knowledge---."

*Michael Faraday*





Jane Marcet

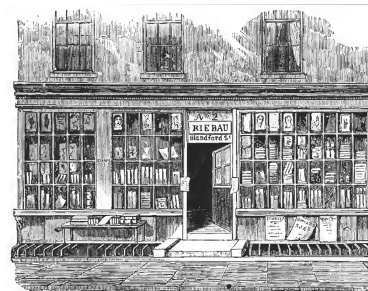
**“the most wonderful and the most interesting phenomenon of nature are almost all of them produced by chemical powers”**

*Conversations on Chemistry, 1817*

17



Michael Faraday

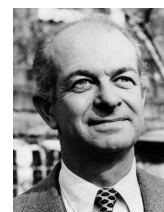


### Choosing a Research Project

The primary aim of research must not just be more facts and yet more facts, but more facts of strategic value.

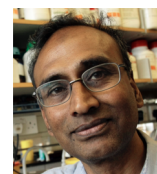
Great contributions rarely come from adding another decimal place.

Young scientists should aspire to become established within a particular discipline. Find a project that could be identified as his/her own.



Linus Pauling  
Nobel Prize, 1954, 1962

**“I have always liked working in some scientific direction that nobody else is working in”**



Venki Ramakrishnan  
Nobel Prize, 2009

**“Some science you’re doing, something that’s so far out and no one else cares, but you are interested in it. And that’s, I think, the best kind of science to do —.”**

## Qualities Needed to Succeed

- Ability to Concentrate & Focus
- Persistence and Determination
- Creativity/Originality
- Imagination and Intuition
- Ability to Collaborate
- Breadth and Depth
- Humility and Honesty

## Learn To Focus: Conquering the Mind

Still the restless mind

“O Krishna! Is not the mind always capricious, disturbing and too strong to be checked? It is easier to hold the air in the fist than to control the mind.”

Arjuna to Krishna in Bhagavad Gita.

“O Master! Is it not impossible to control the mind? One may sooner drink up the oceans or lift up Mount Meru or swallow flaming fire than to control the mind.”

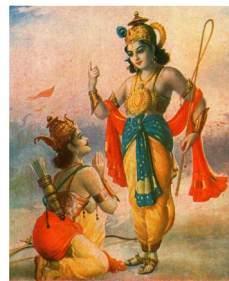
Rama to Vasishtha in Yoga Vasishtha.

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Arjuna to Krishna



Bhagavad Gita, ~ 400 BC

“There is no doubt mind is wayward and difficult to control. Nevertheless by dint of practice and dispassion it can be controlled”

Krishna to Arjuna

## Creativity

“Creativity involves breaking out of established patterns to look at things in a different way”

Edward De Bono



Bower Birds

## Creativity comes subconsciously

*Subconscious mind: state of mind where one is not totally aware of its activities.*

If you are deeply immersed and committed to a topic, day after day, your subconscious has nothing to do but work on your problem. New ideas often seem to pop up when the mind is idling.



## Intuition

*Intuition is the supra-logic that cuts out all the routine processes of thought and leaps straight from the problem to the answer----*

**The only real valuable thing is intuition.**

*Albert Einstein*

**All great men are gifted with intuition. They know without reasoning or analysis, what they need to know.**

*Alexis Carrel  
(Nobel Prize in Physiology or Medicine)*

## Persistence and Luck

**Let me tell you the secret that has led to my goal. My only strength lies in my tenacity.**

**Luck, it is true, is necessary, but the greater the number of experiments carried out, the greater is the probability of being lucky.**



Louis Pasteur

**In science as in lottery, luck favors he who wages the most.**

## Hypothesis and Learning to Retreat

**The hypothesis is the principal intellectual instrument in research.**

**Unlike in politics there is nothing wrong with changing one's mind when better evidence becomes available.**

**People who can't acknowledge to themselves that they were wrong should probably avoid a life based on research.**

### Learn From Mistakes

The scientist who is excessively cautious is not likely to make either errors or discoveries.

The most important of my discoveries have been suggested to me by my failures.

*Sir Humphrey Davy*

No great discoveries is ever made without a bold guess.

*Sir Issac Newton*

### Learn to Sell

It is not sufficient to do a good job, you have to make it known.

Science is about telling good, readable, memorable stories.

Priority of discovery in science goes to the one who publishes first.

Work, finish and publish. (*Michael Faraday*)

You must learn to give formal and informal talks and write clearly and concisely.

### Life of a Scientist

➤ Stress

➤ Rejections

➤ Intense competition (priority)

➤ Politics

➤ Balancing family and work

A scientific life is in reality exciting, rather passionate and – in terms of hours of work – a very demanding and some times exhausting occupation.



### Rejections

Do not get discouraged if manuscripts are rejected by journals.

**Kreb's cycle (H. Krebs -Nobel Prize in 1953):**

Rejected without review by Nature in 1937 later published in Enzymologia.

**Basis of modern 2D NMR (R. R. Ernst -Nobel Prize in 1991):**

Twice rejected by J. Chem. Physics in 1965 published in Rev. Scientific Instruments.

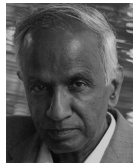
**Polymerase Chain Reaction (K. B. Mullis -Nobel Prize in 1993):**

Rejected by Nature and Science in 1987 published in Methods in Enzymology.

### Interpersonal Skills with Peers

Science is a human endeavor, driven by hopes, dreams and aspirations. They may be brilliant, even geniuses. But as human beings they may also be seriously flawed.

Occasionally, science can take on personal, almost vindictive quality.



S. Chandrasekhar  
1910-1995  
Nobel Prize, 1983



Sir Arthur Eddington  
1882-1944



Michael Faraday  
1791-1867



Sir Humphry Davy  
1778-1829

### Basic vs Applied Science



Hans Krebs  
Nobel Prize in Physiology or Medicine 1953

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

*Reminiscences and Reflections, 1981*

### Basic vs Applied Science

#### 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

### Basic vs Applied Science



Marie Curie  
The Nobel Prize in Chemistry  
1911

"in recognition of her — discovery of the elements radium and polonium, —"

"We must not forget that when radium was discovered no one knew that it would prove useful in hospitals. The work was one of pure science. And this is a proof that scientific work must not be considered from the point of view of the direct usefulness of it. It must be done for itself, for the beauty of science, and then there is always the chance that a scientific discovery may become like the radium a benefit for humanity."

Marie Curie,  
Lecture at Vassar College, May 14, 1921





G. H. Hardy  
1877-1947



S. Ramanujan  
1887-1920

## Invisible Value of Basic Science

No discovery of mine is likely to make--the least difference to the amenity of the world. I have helped to train other mathematicians of the same kind---their work has been as useless as my own.---- Anyhow I have added something to knowledge and helped others to add more---these have a value----

*A Mathematician's Apology, 1940*

## Struggle between basic and applied science

Making new knowledge is neither easy nor profitable in the short term. Fundamental research proves profitable in the long run, and, as importantly, it is a force that enriches the culture of any society with reason and basic truth.



Priestly Medal Address, 2011 "Dreaming The Future" Ahmed H. Zewail,

## 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
- Cooperation among scientists and technologists is necessary for economic and human prosperity.
- Public and politicians outreach is a MUST.

## Basic and applied science are interlinked

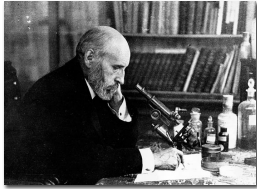
"I came to the conclusion that the objects of fundamental research were to increase the body of scientific knowledge. It was not expected to yield any results of direct financial value. Its success would be gauged by the significance of the scientific contributions produced, and any financial profit that might accrue would be so much gravy."



W. H. Carothers (1896-1937)  
Du Pont, comments in 1932

"If I had been asked to do research on anything that I pleased with the mutual understanding that the object was to develop something that would bring in direct profit, I would not have accepted the job. I never had any confidence in my ability to initiate and carry on research of this kind, and still haven't any. ---- I doubt that there are any with this talent on the present fundamental research staff."

## Science and technology are synergistic



Santiago Ramon y Cajal, 1852–1934  
Nobel Prize in Physiology (1906)  
*Advice for a young investigator*

People with little understanding fail to observe the mysterious threads that bind the factory to the laboratory.

## General Comments

- Most great scientists have tremendous drive.
- All great work is the fruit of patience and perseverance, combined with tenacious concentration on a subject.
- Two emotions must be unusually strong in a great scientific scholar: a devotion to truth and moderate passion for reputation.
- Ambition for recognition is not necessarily a deadly sin, but excess of ambition can certainly be a disfigurement.

## References

- *Advice for a Young Investigator, Santiago Ramon-y-Cajal, Spanish version, 1898, (English version, MIT Press, 1999)*
- *Advice to a Young Scientist, P. B. Medawar, 1979*
- *Reminiscences and Reflections, H. Krebs, 1981*
- *The Beginner's Guide to Winning the Nobel Prize, P. Doherty, 2006*
- *In Search of Memory, E. Kendal, 2006*
- *A Mathematician's Apology, G. H. Hardy, 1940*
- *You and Your Research, Richard Hammings (on the web)*