Science and Scientists

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Who am I?

What should I do?

What is right?

What is Science?

- Science is a means of formulating interesting questions about nature, and then designing a series of experiments to explore possible answers to a particular question.

- Science gives one a structured opportunity to try out ideas that are raw, important, and bold.

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.

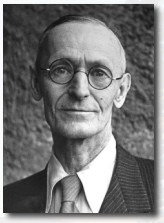
Applied

Research done for a specific commercial, or market driven purpose.

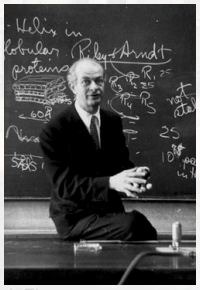
Opportunities as a Scientist

Every person's story is important, eternal, divine; and so every person, to the extent that he lives and fulfills nature's will, is wondrous and deserving full attention.

***in* Demian**



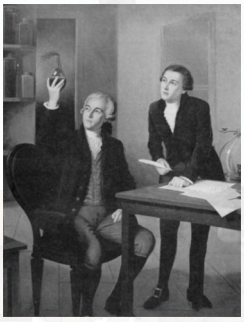
Hermann Hesse
Nobel Prize in Literature, 1946



Opportunities as a Scientist

- **Teach and communicate to the public**
- **Teach and do research in a university**
  - **Basic Science (mostly)**
- **Do research in a government or an industrial laboratory**
  - **Basic or Applied Science (mostly applied)**
  - **Discovery and Invention**
- **Manage science projects and formulate policies**
  - **Government**
  - **Industry**

Can I be a Scientist?



Santiago Ramón y Cajal
Nobel Prize in Physiology 1906

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
Advice for a young investigator

Doing Science

- **Doing science is different from reading about science.**
- **Science isn't about achieving high-sounding positions, or prizes, or riches. It is about discovery, excitement, persistence and integrity.**
- **The process of doing science is deeply rewarding, not only intellectually but also emotionally and socially.**
- **The joy of research must be found in doing, since every other harvest is uncertain.**

Theobald Smith (1859 –1934, a pioneering epidemiologist

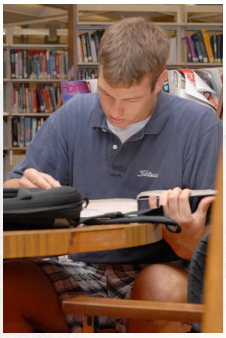
Incentives to Do Science

- Intellectual curiosity, desire to know the truth
- Professional pride
- Ambition, desire for reputation
- Passion to leave behind something of permanent value

Incentives to Do Science

The desire to see one's name in print and be credited throughout the scientific world with one's accomplishment is undoubtedly one of the most important incentives in research.

Metamorphism: Student to a Scientist



- Getting trained to be a scientist
- Becoming a scientist
- Being a scientist
- Life of a scientist

Getting trained to be a Scientist

Acquire the basic skills and work with the right people.

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

Migrate to a place with opportunity

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.

No nation should be complacent about losing top talent (brain drain), it is important to recognize that there will always be a 'global churn' when it comes to the movement profile of innovative scientists.

Find the right place to work

Young people must strive to have an open mind and seek out places where they will be surrounded by first-class intellectuals.

As a scientist, your chances of achieving anything can be greatly diminished by joining an institution that is under resourced financially and does not value creativity.

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

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.

Read not to contradict and confute, nor to believe and take for granted-----but to weigh and consider.

Francis Bacon
1561-1626

Designing a Workable Laboratory

A laboratory designed on the basis of togetherness: members accommodated in a single room, or at least in adjacent rooms.

In a co-operative and closely-knit team many new ideas originate and mature from the casual scientific exchanges.

Brings great educational benefits, especially to the beginner.

Choose 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 scientist should aspire to become established within a particular discipline. Find a project that could be identified as yours.

Choosing a Research Project

- **Important**
- **Interesting**
- **Doable**
- **General**
- **Depth**
- **Utility**

Building Confidence

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

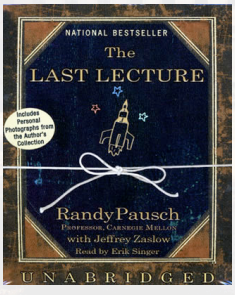
It is psychologically most important to get results, even if they are not original. Getting results, even by repeating another's work, brings with it a great accession of self-confidence.

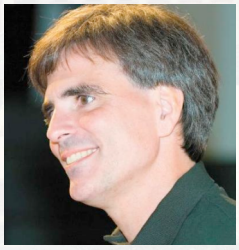
"So when I questioned Mrs. Marcet's book by such little experiments as I could perform, and found it true----, I felt I got hold of an anchor of chemical knowledge---."

Michael Faraday

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

Qualities Needed to Succeed

- Creativity/Originality
- Imagination and Intuition
- Persistence
- Ability to Collaborate
- Breadth and Depth
- Humility and Honesty

Creativity

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

Edward De Bono

Creativity comes out of one's subconscious

Subconscious Mind: is that state of mind where one is not totally aware of the mental activities of the mind.

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.

Learn to Sell

It is not sufficient to do a job, you have to sell it.

You must learn to give formal and informal talks.

You should spend as much time in 'polishing of a presentation' as you did in the original research.

Publications: Competition for Priority

Science is about telling good, readable, memorable stories. You have to learn to write clearly and concisely.

- **If scientists were motivated by curiosity alone, they should be delighted when someone else solves the problem they are working on–but this is not the usual reaction.**
- **Priority of discovery in science goes to the one who publishes first.**
- **Work, Finish and Publish.** ***(Michael Faraday)***

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

Humphrey Davy

No great discoveries is never made without a bold guess.

Sir Issac Newton

Life of a Scientist

- **Stress**
- **Rejections**
- **Intense competition (priority)**
- **Politics**
- **Balancing family and work**

Some Drawbacks

You have to put up with stress.

Like anyone who ventures into the unknown, scientists at times feel alone, uncertain, without a well-trodden path to follow.

Very few have the ability to reform the system and become a first-class scientist.

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.

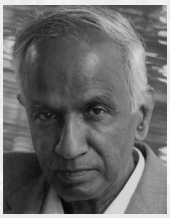
Basis of modern 2D NMR (R. R. Ernst -Nobel Prize in 1991):
Twice rejected by J. Chem. Physics in 1965 published in Rev. Scientific Instruments.

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

Humphry Davy
1778-1829

Sanity with help from eastern philosophy

"The man who is devoted and not attached to the fruit of his actions obtains tranquillity."

Bhagavad Gita, 2nd century BC

The love of fame compels us to order our lives by the opinion of others-----. But if a thing is not loved, no quarrels will arise concerning it, no sadness will be felt if it perishes, no envy if another has it; in short no disturbances of the mind----.

Vedanta translated by Clive Johnson

Balanced Life

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

"But one Sunday afternoon Denise showed up as I was working in the laboratory and simply exploded on me. Carrying Paul in her arms, she screamed, You can't go on like this! You are only thinking of yourself and your work! You are just ignoring the two of us!"

In Search of Memory, E. Kendal, 2006

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.**
- **Never put off till tomorrow when you can do today. Doing things at the last minute is much more expensive than just before the last minute.**
- **Two emotions must be unusually strong in the great scientific scholar: a devotion to truth and moderate passion for reputation.**

Science, Technology, Politics and Prosperity

Ideas, unless backed by cash are liable to evaporate into nothingness.

Faraday and Electromagnetism

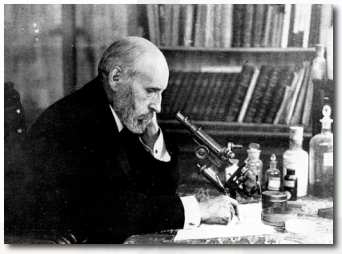
Michael Faraday, 1791–1867

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 threads that bind the factory to the laboratory.

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 'cannon-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 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

John C. Polanyi
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 insecurities about funding set in. --- I know that Laboratory of Molecular Biology, Cambridge had a long standing tradition of supporting difficult and fundamentally important project.

The Hindu, April 9, 2010

Invisible Value of Basic Science

G. H. Hardy
1877-1947

S. Ramanujan
1887-1920

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----.

G. H. Hardy
A Mathematician's Apology, 1940

Albert Einstein neither invented devices nor made any major scientific discoveries, yet his theories greatly influenced and shaped the development of late 20th century science and technology.

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.

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