



Being a Scientist

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Class timing: Friday, 2 to 4 PM
Oct 5 to Dec 13

- Human beings' curiosity about how things work has led to many fields of studies including science. Science has been a major player in not only rationalizing what goes on around and inside us, but also to the changes we experience. The mastery of scientific phenomenon besides helping build a better future has also led to detrimental outcomes. Contributions to a better future thus requires knowledge of both the good and bad aspects of science from everyone and especially from the youth with a greater role in it.
- This course is designed to bring knowledge:
 - on what is science
 - on what it takes to be a successful scientist
 - why a career in science is worth pursuing
 - how it could be intellectually and occasionally financially rewarding.
- Knowing what is science, what scientists do and how to be a scientist should help a novice to make a career choice and decide on a path that would provide a valuable and satisfying life. This course will analyze the life, achievements, triumphs and tribulations of a few scientists and the development of concepts that have helped us understand the Nature.

SYLLABUS

Being a Scientist- An Introduction

A Revolution in Modern Physics: Photon - Theory of light

The Chemical Revolution: Lavoisier, Davy & Faraday

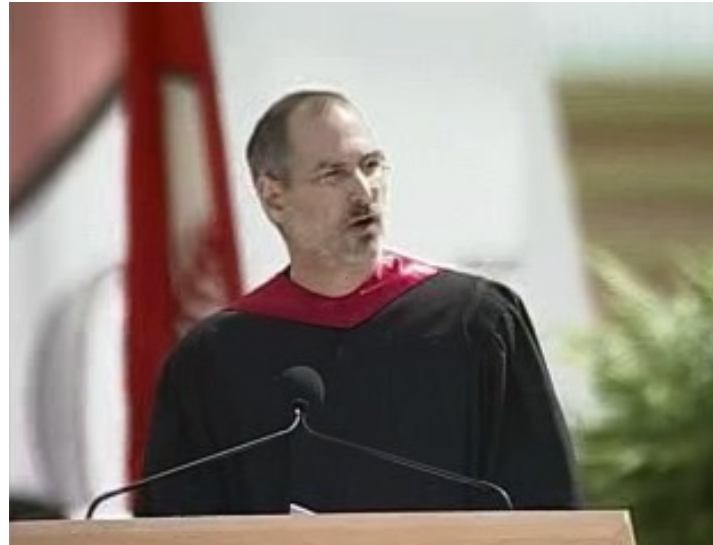
Chemistry grows with physics - Atoms, Molecules and Macromolecules

Molecules in Nature

How does science works - Normal, Extraordinary and Pathological Science
(Polywater & Cold fusion)

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

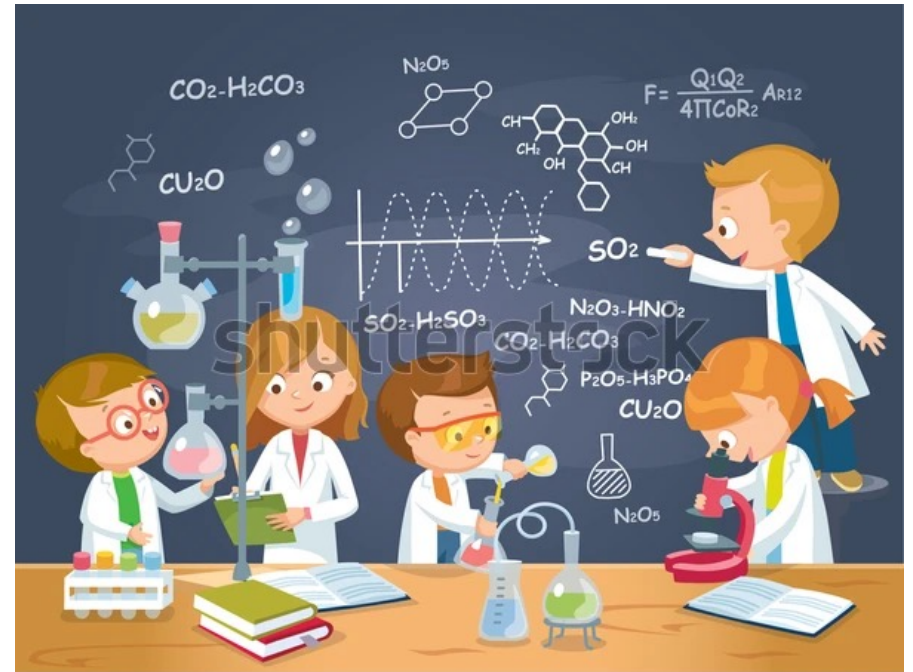
Possible choices

- **Arts**
- **Humanities**
- **Engineering**
- **Medicine**
- **Science**
- **Sports**

What is Science?

- **Science is a means to understand ourselves and the surroundings (Nature in general) through verifiable facts.**
 - **Experiments based**
 - **Evidence based**
- **Helps to formulate important and interesting questions and then design a series of experiments to arrive at answers.**

Science



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Science is doing experiments

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?’

Applied science = Technology = \$

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, ----.



Ahmed H. Zewail
Priestly Medal Address, 2011

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



Santiago Ramón y Cajal
Nobel Prize in Physiology 1906

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
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

Harold Varmus and John M. Bishop

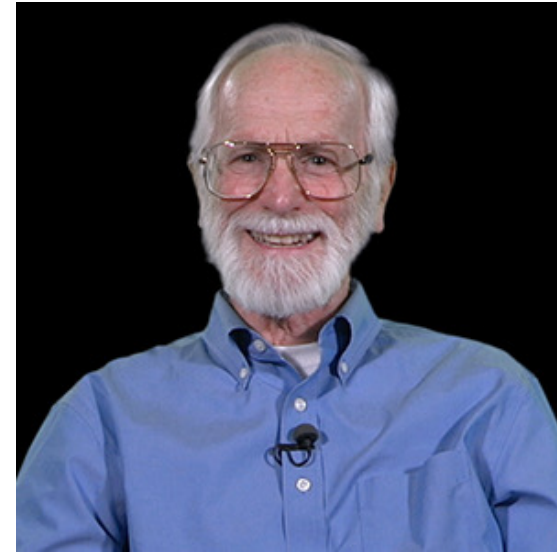
How I Became a Scientist



Harold Varmus, 1939 -

Nobel Prize-1989
Head, Sloan Kattering Cancer Center

<https://www.youtube.com/watch?v=ct3bDM6YBEw>



John M. Bishop, 1936 -

Nobel Prize-1989
Professor, UC, SF

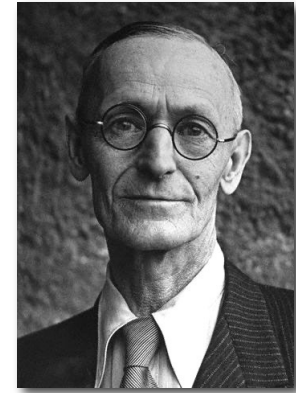
<https://www.youtube.com/watch?v=z9aSN6eB2I4>

Motivation to Do Science

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

Opportunities as a Scientist

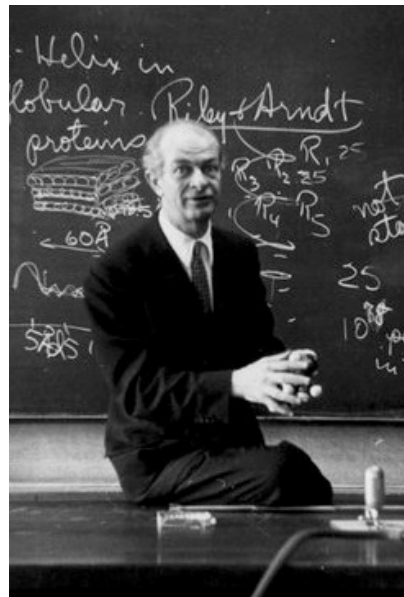
Every person's story is important, eternal, divine; and so, every person, to the extent that he lives and fulfills nature's will, is wondrous and deserving full attention.



in Demian

Hermann Hesse

Nobel Prize in Literature, 1946



What it takes a Student to become a Scientist?



Four stages in the life of a scientist

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



Learning and Doing Science



- **Doing science is different from reading about science.**
- **Science is about discovery---done with head and hand**
- **The process of doing science is deeply rewarding, not only intellectually but also emotionally**

Find the Right Place to Work/Learn

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.

Migrate to a Place with Opportunities



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.

Migrate to a Place with Opportunity and Knowledge



Xuan Xang (Sanzang)



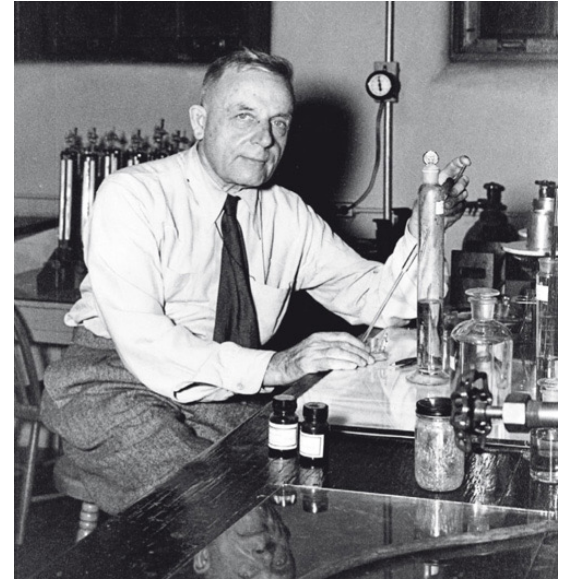
Adi Sankara

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 young scientist**

Find a Suitable Research Mentor

An Ideal Research Mentor

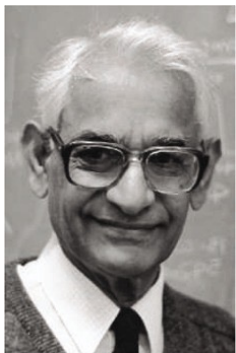


On Otto Warburg:

- 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

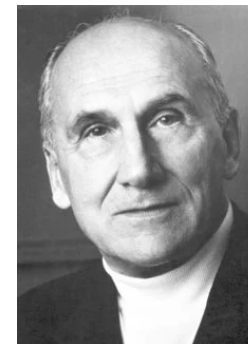
H. Krebs
Reminiscences and Reflections

Find a Suitable Research Mentor



H. Gobind Khorana
1922-2011
The Nobel Prize in
Physiology or Medicine 1968

Vladimir Prelog
1906-1998
The Nobel Prize
in Chemistry 1975



“---- I left my luggage at the railway station, took my Ph. D. thesis and went looking for Prof. Prelog. --- I requested that he might look at my Ph. D. thesis and I would come next day to ask if he would accept me. Next day, Prof. Prelog with his encouraging smile said ‘yes’ and added he is glad to see people happy.---- **During the year in Zurich, with no subsidy, of course I had to be very careful with my living expenses;** but looking back, I believe that spending the year in Zurich was probably the wisest thing I ever did in my life. Vladimir Prelog made me see beauty in chemistry, work and effort.”

“I wish to make a personal acknowledgement to one more scientist. Fortunately, I was accepted by Professor V. Prelog of the ETH as a postdoctoral student. The association with this great scientist and human being influenced immeasurably my thought and philosophy towards science, work and effort.”

Getting a break-Be persistent

Michael Faraday wrote to the President of The Royal Society Sir Joseph Banks requesting for any position, however menial.

After several reminders Bank replied: “the letter required no answer”.

“I am far from displeased with the proof you have given me of your confidence, and which displays great zeal, power of memory, and attention -----. I will then see you at any time you wish.”

Sir Humphry Davy

Choosing a Research Project

Asking the right questions

➤ **Important**

➤ **Interesting**

➤ **Doable**

➤ **General**

➤ **Depth**

➤ **Utility**

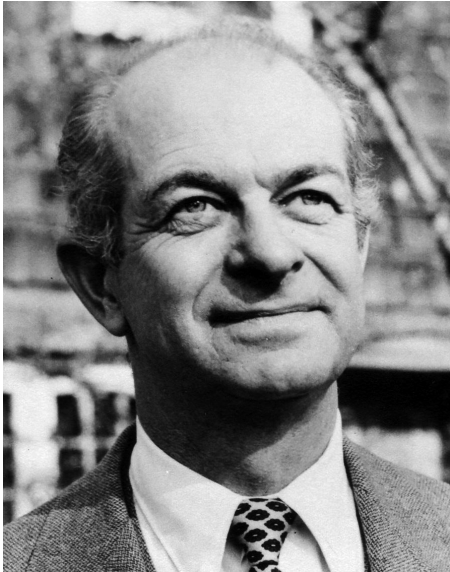
Choosing a Research Project

The most important quality of the scholar is originality, that is the ability to picture something beyond what is taught.

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

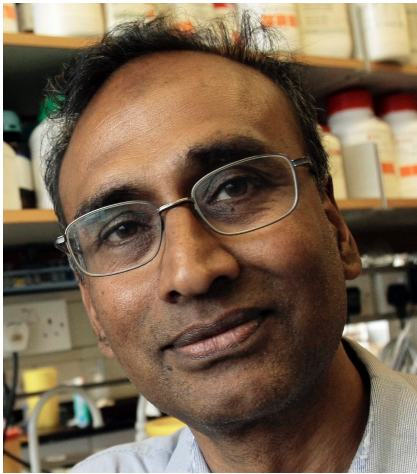
Young scientists should aspire to become established within a particular discipline. Find a project that could be identified as your own.

Choosing a Research Project



Linus Pauling
Nobel Prize, 1954, 1962

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



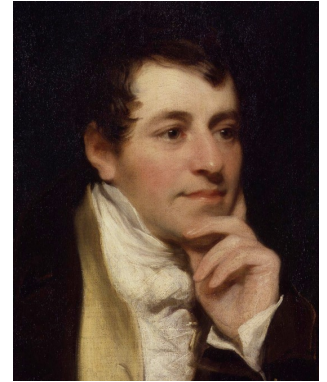
Venki Ramakrishnan
Nobel Prize, 2009

“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 —.”

Getting Started: Learning the Literature

We should proceed from the known facts to the unknown.

The beginner must read, but intently and not too much.



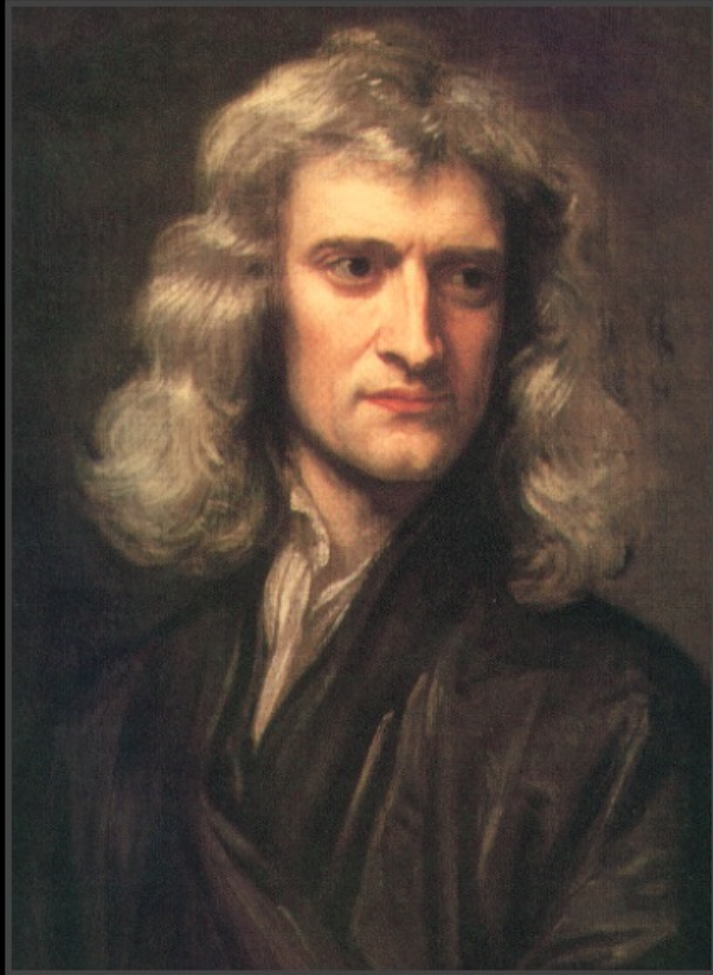
Sir Humphry Davy
1778-1829



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.

Importance of mastering prior knowledge



“If I have seen further, it is by standing on the shoulders of giants.”

Sir Isaac Newton, 1643-1727

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.

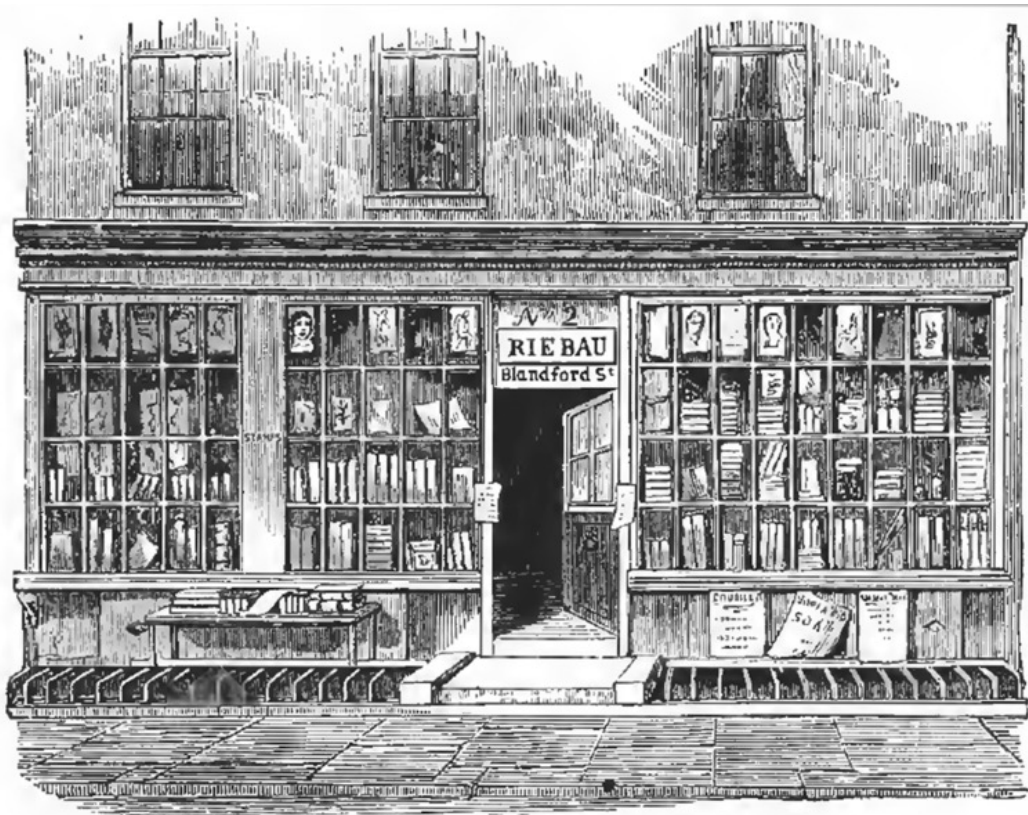
“So, when I questioned Mrs. Marcet's book (*Conversations on Chemistry*) by such little experiments as I could perform, and found it true----, I felt I got hold of an anchor of chemical knowledge---.”



M. Faraday



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

Ambition

Two emotions must be unusually strong in the great scientific scholar: a devotion to truth and a passion for reputation.

Ambition is not necessarily a deadly sin, but excess of ambition can certainly be a disfigurement.

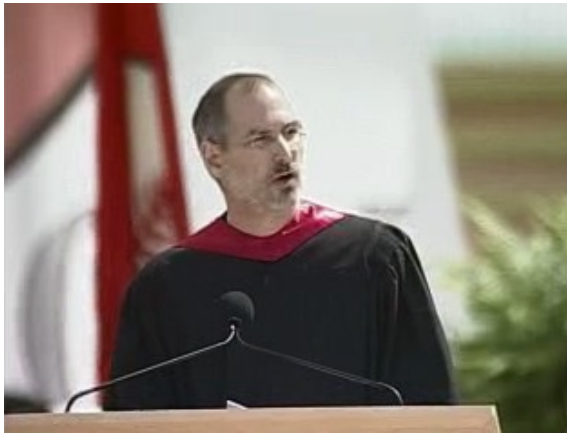
There is nothing ignoble about being ambitious to be recognized.

Qualities Needed to Succeed

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

Time is Precious

Your time is limited, so don't waste it. If today were the last day of your life, would you want to do what you are about to do today?



Steve Jobs
Stanford Commencement address
2005

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



Randy Pausch
Computer scientist

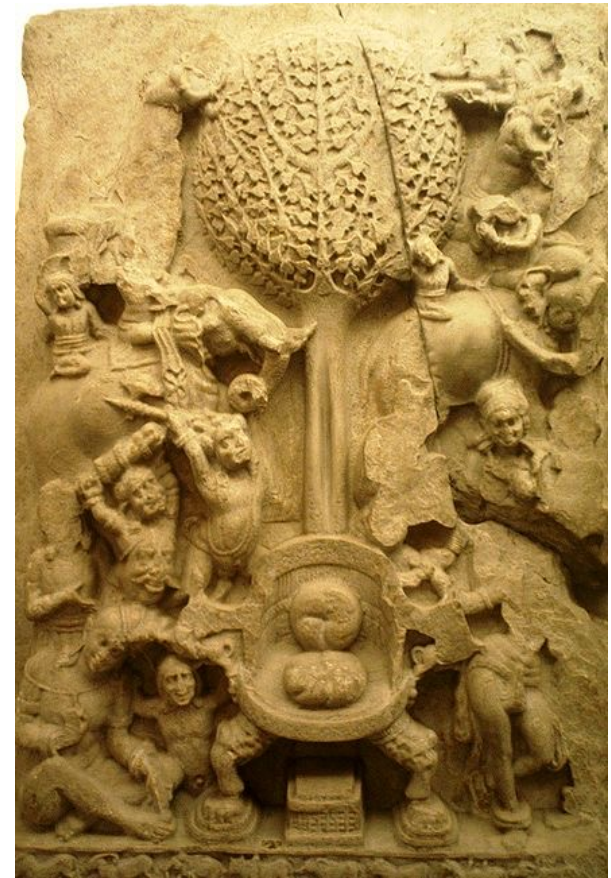
Problem of the restless mind

Buddha faced the same dilemma

Hard it is to train the mind, which goes where it likes and does what it wants. As a fish hooked and left on the sand thrashes about in agony, the mind being trembles all over.

As a well-trained horse needs no whip, a well trained mind needs no prodding from the world to be good.

Long ago my mind used to wander as it liked and do what it wanted.



The Dhammapada
3rd century BC

Mara's assault on the Buddha (the Buddha is only symbolized by [his throne](#)), 2nd century, [Amaravati](#), [India](#)

Creativity

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

Edward De Bono



Bower Birds

Creativity comes subconsciously

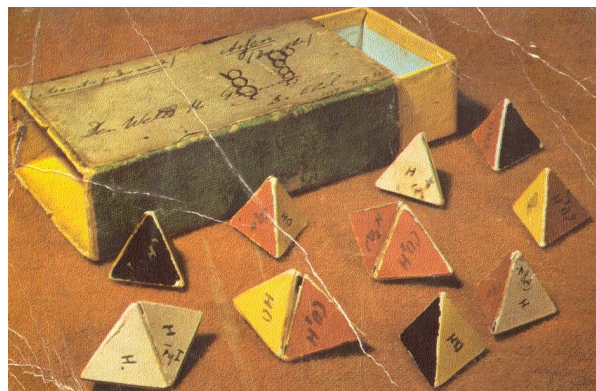
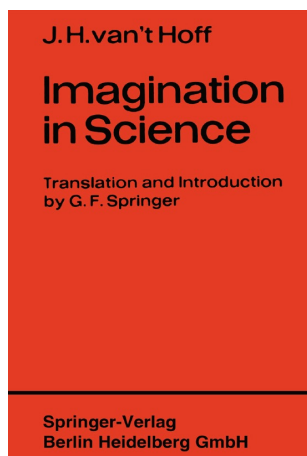
Subconscious mind: state of mind where one is not totally aware of its activities.

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.



Power of imagination

“imagination is the ability to visualize any object with all its properties so that one recognizes it with the same great certainty as by simple observation.”



Jacobus Henricus van't Hoff
First Nobel Prize, Chemistry, 1901

“I would like to give you students a recipe for making discoveries. Libraries . . . have always had a mind-deadening effect on me. So, when I was studying Wislicenus’s just-published paper on lactic acid in the Utrecht library, I interrupted my reading half-way through to take a walk, and it was on this walk, under the influence of the fresh air, that the thought of the asymmetric carbon atom first occurred to me.”

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, 1912)

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.

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



**Louis Pasteur
1822-1895**

Learn 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

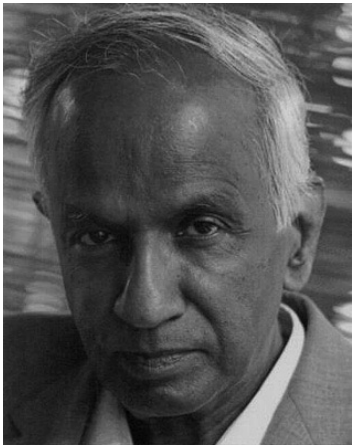
No great discoveries is ever made without a bold guess.

Sir Issac Newton

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.



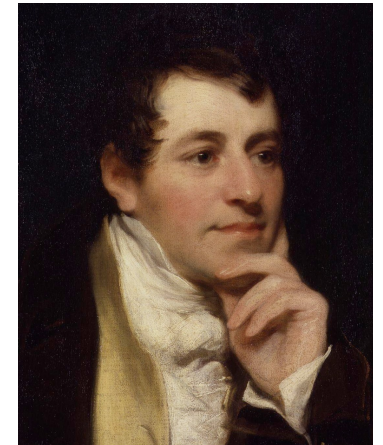
S. Chandrasekhar
1910-1995
Nobel Prize, 1983



Sir Arthur Eddington
1882-1944



Michael Faraday
1791-1867



Sir Humphry Davy
1778-1829

Life of a Scientist



➤ **Stress**

➤ **Rejections**

➤ **Intense competition (priority)**

➤ **Politics**

➤ **Balancing family and work**

Life of a Scientist

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

“Science [is] a harsh mistress, and in a financial point of view but poorly rewarding those who devote themselves to her service”

**Davy’s reply to Faraday
when he approached him for a job, 1812**

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.

Balanced Life

A scientific life is in-reality exciting, rather passionate and – in terms of hours of work – a very demanding and sometimes 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
2000 [Nobel Prize in Physiology or Medicine](#)

Qualities Needed to Succeed

- **Time management**
- **Ability to Concentrate & Focus**
- **Creativity/Originality**
- **Imagination and Intuition**
- **Persistence and Determination**
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Why do so few scientists make significant contributions and so many are forgotten?

Stress and frustration: One has to put up with stress.

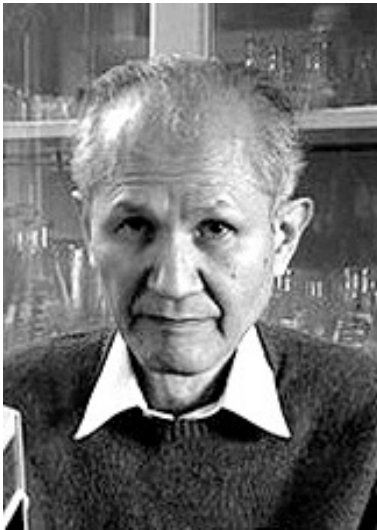
Loneliness: Like anyone who ventures into the unknown, scientists at times feel alone, uncertain, without a well-trodden path to follow.

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

(You and Your Research, Richard Hammings)

The Nobel Prize in Chemistry 2008

"for the discovery and development of the green fluorescent protein, GFP"



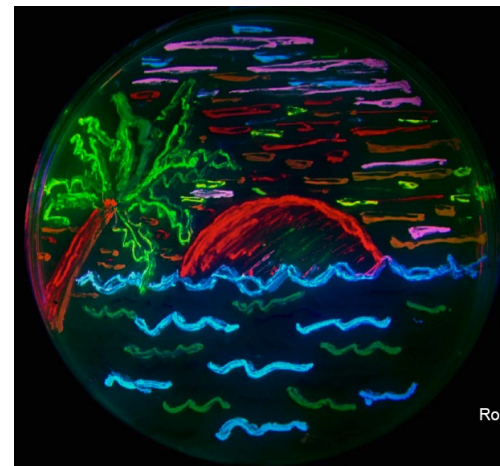
Osamu Shimomura



Martin Chalfie



Roger Y. Tsien



The Fourth Man in the GFP Story

"They could've easily given the prize to Douglas and the other two and left me out,"

M. Chalfie.

"Both of them have always given me credit," he says, including during the Nobel ceremonies in Stockholm, which he attended as the winners' guest. "I've always felt proud in what I provided them. ... I can't imagine the Nobel Committee ever seriously considering me, because I simply dropped out of science." D. Prasher

Prasher lost his research funding while he was employed at Woods Hole Res. Lab, MA. Eventually he took a job as courtesy shuttle driver for \$8.50-an-hour in Huntsville, AL.



Douglas Prasher, who discovered the glowing jellyfish protein used in research that won a Nobel Prize, now drives a courtesy van for a car dealer in Huntsville, Ala.

Science, Feb, 2009

PNAS, 106, 1007, 2009

NY Times, 2008, 10, 17

Lessons from Prasher's Life

- **Mentorship, networking, and the ability to secure funding can be as important as talent and intelligence.**
- **Scientific opportunities often appear only at specific times and places.**
- **Work done in the wrong place or published in the wrong journal may vanish without a trace.**
- **Once someone drops out of science, it is hard to get back in.**
- **There may be exceptions, but they are not the norm.**

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.

Tips for success

- **Recognize: All great work is the fruit of patience and perseverance, combined with tenacious concentration.**
- **Most great scientists have tremendous drive.**
- **Achieve total absorption. Recognize the marvelous power of prolonged concentration.**
- **If a solution fails to appear, try resting for a while. Relaxation in a peaceful environment brings calmness and clarity of mind.**

The symphony of science

<https://www.nobelprize.org/symphony-of-science/>



“Life without playing music is inconceivable for me.” – Albert Einstein



Planck sang as well as played the piano and organ



“I still play and get immense enjoyment from the guitar” M. Chalfie

“Scientists need more than one leg to stand on in order to move forwards. Getting involved in something outside the specialist area where you wish to make your mark not only expands your horizons, but also enriches your scientific work. For some people this is sport, while others like to read or play a musical instrument.”

Searching and Researching
Richard Ernst, 2021

Importance of Funding

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



“Gentlemen, we have run out of money. It is time to start thinking.”

Sir Ernest Rutherford, Nobel Laureate in Chemistry, 1908

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 (1867-1934)
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**

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**.

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

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.**

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***
- **The Beginner's Guide to Winning the Nobel Prize, *P. Doherty, 2006***
- **In Search of Memory, *E. Kendal, 2006***
- **Reminiscences and Reflections, *H. Krebs, 1981***
- **A Mathematician's Apology, *G. H. Hardy, 1940***
- **Avoid Boring People, *James D. Watson, 2007***
- **Letters to a Young Scientist: Edward O. Wilson,**