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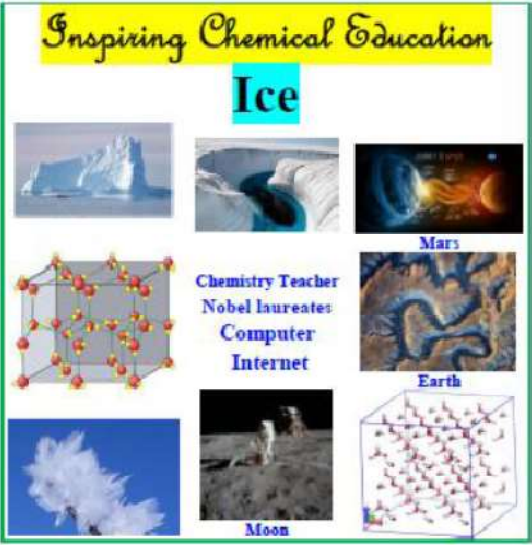


### Chemical Education

### Inspiring Chemical Education

**K. Somasekhara Rao<sup>1</sup>, K. Ramakrishna<sup>2</sup>, Ch. V. Kameswara Rao<sup>2</sup>  
and R.Sambasiva Rao<sup>3\*</sup>**

1. Dept. of Chemistry, Acharya Nagarjuna Univ., Dr. M.R.Appa Rao Campus, Nuzvid-521 201, **INDIA**
  2. Department of Chemistry, Gitam Institute of Science, Gitam University, Visakhapatnam-530 017, **INDIA**
  3. School of Chemistry, Andhra University, Visakhapatnam 530 003, **INDIA**
- Email: [sraokaza1947@gmail.com](mailto:sraokaza1947@gmail.com), [karipeddirk@gmail.com](mailto:karipeddirk@gmail.com), [rsr.chem@gmail.com](mailto:rsr.chem@gmail.com)

	<h2>ICE-7: Nobel Prizes in 2018</h2>
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Alfred (Bernhard) Nobel, was born to Immanuel Nobel (an inventor and engineer) and Carolina Andriette (Ahlzell) Nobel on October 21, 1833 in Stockholm, Sweden. Dr. Nobel, a chemist, engineer, technocrat and entrepreneur of nineteenth century, invented dynamite and other powerful explosives bagging around 350 patents of different countries. He instituted awards in Chemistry, Physics, Physiology or Medicine, Peace and Literature. In 1969, Economics was also added to the list. These awards are popular as Nobel Prizes and each award is conferred every year to one or shared among not more than three living recipients for their contributions highly beneficial to humankind. This year ten men and two women are conferred with Nobel Prizes by Swedish Academy, Sweden. The core findings of scientific inquiry resulted in cancer therapy and climate with economic growth. The Noble prize for peace is shared by a medical doctor and a woman of 25 years. They promoted the need to put an end of molestation/gang rape in war crimes.



Björkborn Manor residential house right up until 1972;  
Now Nobel Museum with Alfred Nobel's original furniture; Shows how Manor may have looked during the 1890s.

The county/year of birth, institute/employer at the time of announcement and the outcome beneficial to humankind of Nobel Prize winners of 2018 are briefed in [Table 1](#). The typical first response of recipients of Noble prize winner when informed of the award are in [SI-1](#).

The basic laws of physics, instruments and their application to living- and non-living systems have direct and/or indirect impact in monitoring environment health and combating with pollutants to achieve the best health for all depending upon local ambient conditions/functional limitations/Governance priorities.

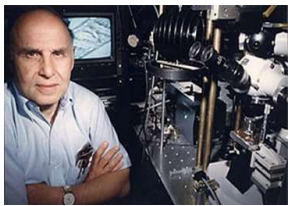
A hundred and odd chemical elements containing electrons (/protons) equal to atomic number and neutrons (equal to difference of mass number and atomic number) were formed during one phase of evolution of Universe. Subsequently Zillions of compounds (inorganic, organic, geo-, bio-, astro-bio-, oceanographic-, ...) came forth in Nature's laboratory, referred as natural compounds. The preparation/synthesis in Scientist's laboratory employed accumulated wisdom/knowledge and sometimes intuition/random attempts (alchemy with inner ambitious goal of conversion of less precious metals to gold).

Biology is such a complex system. It's totally different from man-made design, engineering and technology. The invention of new pharmaceuticals, surgical tools/instruments, radiation/laser techniques in curing, relieving/decreasing pain/discomfort from bacterial/viral/auto-immune diseases, extending life span of patients with different stages of morbidity, physical/psychological pain management in end-of-life care all promote good of humankind. Yet many efforts to find complete therapy for cancer are not a complete success.

## Nobel Laureates in Physics 2018

Table 1.1 Focal theme (a) of Nobel Prize for Physics in 2018

<b>Obj_achieved</b>	Development of optical tweezers Application to biological systems.	<b>Prime Method</b>	Lasers
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Affiliation	Nobel Laureate Photo, Date & place of birth	Share
Bell Laboratories, Holmdel, NJ, USA  9th Nobel Prize winner for their work at Bell Labs (SI- 02,SI-03)	Arthur Ashkin  2 September 1922, New York, NY, USA	1/2

In 1970, Ashkin,

for the first time, demonstrated the two- and three-dimensional trapping of small transparent beads (0.59 to 2.68 microns) employing focused laser beams. When these beads suspended in water are exposed to laser beam, the beads were drawn into the centre of the beam and pushed along by the beam. Ashkin *et.al.* in 1986 invented optical tweezers and were interested to study effect of less intense IR laser on cells, viruses and bacteria. This low intensity laser compared to green does not damage the life material.

Steven Chu, a co-scientist at Bell Laboratories used this technique to trap single atoms/molecules. The momentum of atoms in all directions slowed down when placed at the junction

of six laser beams aimed at right angles to each other. The consequence was a clump of atoms cooled to less than 0.001 degree above absolute zero. Further application of magnetic field increases confinement and reduce their temperature to one-millionth degree above absolute zero. This created of a new state of matter, called a Bose-Einstein condensate. These results led Steven Chu, Claude Cohen-Tannoudji, and William D. Phillips to win 1997 Nobel Prize in Physics.

Application to	Discipline
Study the interaction between light and matter	Physics
<ul style="list-style-type: none"> <li>Measure small forces at the single molecule level</li> <li>Study of machinery of life</li> <li>Measure viscoelastic properties in single cell</li> <li>Investigate the integrity of the cells</li> <li>Probe into interaction between molecule-molecule, cell-cell and cell-molecule cells sorting</li> </ul>	Biology
Measure surface properties	Chemistry
Built arrays of nanoparticles	Nano-technology

Education			
1947	Bachelor's Degree (BA)	Physics	Columbia University New York City
1952	Ph.D	Nuclear physics	Cornell University
	Post-doctoral research		
Employment			
1942 to 1945	Columbia Radiation Lab from while in the	Army service	
1952-1992	Bell Laboratories Murray Hill, New Jersey	Bell Laboratories Holmdel, New Jersey	Arthur Ashkin
	still considered an active part of the Bell Labs family		

This technique, as anticipated by DrAshkin in eighties, resulted in multi-facet applications in physics, biology, chemistry and nano-technology. The forces of pico-Newtons scale operate in optical tweezers in a fluid and thus used to trap particles in biological samples. These optical tweezers grab particles, atoms, viruses and other living cells with their laser beam fingers. He succeeded in getting laser light to push small particles towards the centre of the beam and to hold them there. In 1987, another major breakthrough came in, when tweezers captured living bacteria without harming them.

**Old Bell Labs Holmdel Complex. Located in New Jersey, about 20 miles south of New York**



First transistor, a point-contact germanium device, was invented at Bell Laboratories in 1947.  
This image is a replica

Now, Dr.Ashkin is 96 years old. His interest in science was since he was a child. He has a home lab and concentrates on research, not on any type of distractions; He says that he does not celebrate about old stuff.. He involved in preparing research manuscript for Science with something new and important results he got now on climate change and solar energy. He is busy in writing a paper when Adam Smith (from Nobelprize.org, Stockholm, Sweden) telephoned for an interview on the occasion


of award of Nobel prize. He tells his wife as ‘science research is the only thing that I’m really good at’. When he described catching living things with light, co-scientists at that time said: ‘Don’t exaggerate Ashkin’.

**Table 1.2 Focal theme (b)of Nobel Prize for Physics in 2018**

<b>Obj_achieved</b>	method to generate high-intensity, ultra-short optical pulses	<b>Prime Method</b>	Lasers
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Affiliation	Nobel Laureate (Phys) Photo, Date & place of birth	Share
École Polytechnique, Palaiseau, France University of Michigan, Ann Arbor, MI, USA	 Gérard Mourou 22 June 1944, Albertville, France	1/4

One of the uses of ultra-fast lasers is one can accelerate particles with really stunning efficiency. If really this accelerator is made very compact, then it can be put in hospitals and radio isotopes can be prepared then and there. It is power of science and applied science derives heavenly benefit for mankind. When this idea was proposed to the then Ph.D. Student Donna Strickland’s response was that it was so simple and thus cannot be for doctoral thesis. Now, Dr Gérard Mourou exclaims it is Nobel Prize material; not a Ph.D task.

Affiliation	Nobel Laureate (Phys) Photo, Date & place of birth	Share
University of Waterloo, Waterloo, Canada	 Donna Strickland 27 May 1959, Guelph, Canada	1/4

The first two women who won Noble prizes in Physics were Marie Curie, in the year 1903; and Maria Goeppert-Mayer (German-born US physicist) in 1963. Donna Strickland, born in 1959, shares half of Nobel Prize this year with her Ph. D. guide and mentor Dr Gérard Mourou (University of Rochester, New York) for Chirped pulse amplification (CPA) published in 1985. The prize is for her first research publication which was in her Ph.D. thesis. She worked out producing ultra-short, high-intensity laser pulses, the brain wave of her research supervisor. The unique feature is that the high energy does not destroy the material amplifying the light. This scientific procedure given way to development of small but powerful lasers extensively brought out proto-type tools used in corrective eye surgery, industrial machining and medical imaging.

Her father was an electrical engineer and mother an English teacher. University of Waterloo, Canada hired Dr. Donna Strickland in 1997 and her focus is to create ultra-fast lasers, not known earlier.

### Nobel Laureates in Chemistry 2018


Chemistry focusses in making and breaking of covalent bond(s) between atoms or molecules. The energy of hydrogen-bond/ halogen bond generally is lower than 5 Kcal mol<sup>-1</sup>. But, it is very high reaching covalent bond strength or very low in some systems. The non-covalent interactions including electrostatic, dispersion, van der Waal, hydrophobic, stacking, cooperative, anti-cooperative contributions are significant and occupy a niche in simple as well as macro-molecules of basic chemical or bio-chemical importance. Recently metallic bond in molecules (a noble prize thesis in chemistry) is a new category of bond.

The chemical, physico-chemical and physics based characteristics/properties have been rationalized with chemical bonding and non-bonding interactions between chemical elements, molecules and/or materials

Classical quantum chemistry with electrons and their configuration was adequate to solve Schrodinger wave equation (SWE) generating energy of system ideally. But, Classical CQC of is inadequate for larger molecules or in presence of solvent/micelle/vesicles. Van der waals contribution, dispersion interactions were included. Time dependent SWE, nuclear Overhaussen effect increased the accuracy of calculations.

The term "Species" has different but definite meaning in biological and chemical sciences. To start with a century ago, 'chemical species refer to stoichiometric composition of elements in materials. Later the charge, number of solvent (or water) molecules in the inner and outer co-ordination spheres were added. Computational quantum chemistry necessitated consideration of ground/excitatory state. The conformers popular earlier in organic chemistry are now common in inorganic moieties added a layer of isomers. These details are minimum requirement to take care of major chunk of interactions.

Table 2.1 Focal theme (a) of Nobel Prize for Chemistry in 2018			
<b>Obj_achieved</b>	Preparation of novel enzymes	<b>Prime Method</b>	Directed evolution of enzymes
<b>Necessity</b>	Green synthesis Pharmaceuticals	<b>Phase</b>	Solid phase

Affiliation	Nobel Laureate (Chem) Photo, Date & place of birth	Share
California Institute of Technology (Caltech), Pasadena, CA, USA	Frances H Arnold  25 July 1956 Pittsburgh, PA, USA	1/2

Dr Arnold was in deep sleep at 4 A.M in a hotel at Dallas, when she was informed of Nobel prize award. She visited that place to give a lecture next day and was anxious whether call was emergency from home, Dr Francis is first American woman to win Nobel prize in Chemistry.

Fances' father was a nuclear physicist and encouraged scholastic progress of all his five children. Arnold has formal academic training in mechanical/aerospace /chemical engineering.

The universe started with a size of nut of less than 17cm (soccer ball!) 13.7 billion years ago and ever expanding to the present size of 46.5 billion light-years (or  $5.5 \times 10^{23}$  miles). The seeds of life started 3.7 billion years ago. The modern science is only a few hundreds of years, although the beginning of Science dates back to 300BC.

#### Procedure-Directed Synthesis (evolution guided and speeded up by artificial selection)

- Repeat
  - ✈ In a test tube under error-prone conditions DNA is copied → a small number of random mutations are introduced
  - ✈ Hard chemistry is done by bacteria
  - ✈ bacteria reads DNA
  - ✈ makes new proteins as per DNA code.
  - ✈ Millions of genes each with a few errors are inserted into bacteria → This renders enzymes with a few errors in them
  - ✈ tested to pick up better (i.e. more active in a particular environment) ones than the original,
  - ✈ Their genes are then taken
- cycle → new traits acquired

**Inspiration:** Arnold was excited with natural evolution which worked well for billions of years. Evolution is a broad term for consequent macroscopic and microscopic functional, structural changes of molecular to fundamental particles. Typical illustrations are futuristic Universe from its origin through current state (time, space), biological (living) species (from bacteria to humans/dolphins/monkeys, apes) and emergence of new/ disappearance or extinction of old features/traits. These have been probed through Darwinism. Evolution of bio-molecules, protein-machinery, enzyme machinery, metabolism, perception (seeing, hearing, touch, taste), communication (speaking, signal transmission by audio/ultra-sound, light-emitting, electric-current, change in dipole, chemicals [pheromones]) and their detection have been a subject of intense investigation. Proteins have been optimized, changed refined and new categories produced. Natural solutions produced life in hot springs, deep oceans, dry deserts and so on.

**Chemical evolution** is a subset of inanimate as well as inanimate domains. The core chemistry has a role in evolution at molecular level in the bio-systems. Cross-disciplinary scientists with expertise in basic Physics, Chemistry developed enzymes, proteins with hither to not known sequences in

laboratory. Of course, here the enzymes, viruses, and bacteria available in nature are used and concept of evolution applied for mutation, crossover, selection etc. The diverse results in late nineteen eighties won this year Nobel prizes in Chemistry and Physiology. Dr. Frances was keen in novelty of chemical evolution. Although it was not easy to capture how new enzyme catalysts arise zillion times in nature from old ones. The effect is felt only when new and old ones diverged significantly.


**Innovative approach:** She adopted technology to speed evolution a little bit to realize the fruits of it in shorter ( a few years of research period) or real time. New proteins (non-existed in nature) have been produced and carbon-silicon bond also has been achieved. In the words of Arnold “Nature is the best chemist of all times”

**New terminology:** Arnold coined the term ‘molecular sex’ similar to biological sex for production of new enzymes from living species. The term ‘sex molecules’ including hormones (responsible for sexual characteristics, sexual activity/inactivity) is a deep researched arena. Mating of hybrid categories of species (cat and dog; lion and tiger etc.) is to bring out new traits also retaining major characteristics both parents. The biological sex in a species at molecular level comprise different phases viz. production of spermin male and release/maturation of egg in female, their combination, production of zygote, growth during (full) gestation period and birth of infant. At every stage, biological lores, chemical processes, physical interactions (sub-categorized as, physical, chemical physics, physico-chemical, bio-physical) have a role with varying relative contributions. The power of evolution is in principles of Darwinism.


**Novel Outcome:** Directed Evolution is breeding basically at molecular level with a consequence of enzymes catalyzing altogether differently. Dr. Arnold applied evolution of enzymes in a test tube. The genetic operators are combination and mutation. The selection is made from fittest in the pool at each generation. The application of enzyme catalysts prepared in laboratory (based on new proteins not existing in nature) led to cure of dreaded diseases in mankind, green manufacture of fuels, chemicals and materials for human/environment health/comfort. In essence, it results in increase of physical/psychological peace.

**Table 2.2 Focal theme (b) of Nobel Prize for Chemistry in 2018**

<b>Method</b>	Phage display of peptides and antibodies Synthetic biology technique	<b>Obj_achieved</b>	New protein synthesis
<b>Process</b>	Virus + bacteria [Evolution] → new proteins	<b>Principle</b>	Genes responsible for protein –structure & function

Affiliation	Nobel Laureate (Chem) Photo, Date & place of birth	Share
University of Missouri, Columbia, USA	George P. Smith  10 March 1941, Norwalk, CT, USA	1/4

<b>Basis</b>	Engineered antibodies	<b>Obj_achieved</b>	Production of pharmaceuticals
<b>Principle</b>	Phage display of peptides and antibodies of G P Smith	<b>Benefit to Mankind</b>	<b>Medical cure</b> <ul style="list-style-type: none"> <li>✓ Cure for meta static cancer like melanoma</li> <li>✓ Counter acts auto-immune disease</li> </ul>
<b>Method</b>	Directed evolution of antibodies		

Affiliation	Nobel Laureate (Chem) Photo, Date & place of birth	Share
Protein and Nucleic Acid Chemistry (PNAC) Division MRC Laboratory of Molecular Biology (LMB), Cambridge, United Kingdom	Sir Gregory P. Winter  14 April 1951, Leicester, United Kingdom	1/4 Noble Cause

Earlier, eight noble prizes in chemistry and three in Physiology/Medicine were awarded to Scientists of MRC, UK (SI-04). This year Dr. Sir Gregory P. Winter won the Prize for producing pharmaceuticals with Phase display technique.

Degree in Natural Sciences	University of Cambridge	Sir Gregory P. Winter	
Ph.D	LMB	Amino acid sequence of tryptophanyl-tRNA synthetase from the bacterium <i>Bacillus stearothermophilus</i>	
Post-doctoral research	LMB's PNAC Division	protein and nucleic acid sequencing through in the	
Employment	LMB's PNAC Division	Group Leader in	1981
Awards	Gairdner Foundation International Award,	2013	
	MRC's Millennium Medal	2013	
	Cancer Research Institute's William B. Coley Award	1999	

## Nobel Laureates in Physiology or Medicine 2018



**Cancer:** Cancer comprises of many diseases. It is the net expression of several processes and difficult to be detected in early state and complete cure of all categories.

The proliferation of abnormal cells at a primary site spread to other healthy organs and tissues resulting in metastasis. To begin with in the last century, surgical removal of cancerous malignance was the only treatment. Later, exposure of cancerous cells to radiation became a practice prior to posting for surgery. The use of chemical pharmaceuticals to kill cancerous cells (popular as chemotherapy) was the third method in cancer treatment along with other procedures. Earlier, Nobel awards was bestowed in Physiology or Medicine to research scientists and medical doctors for hormone treatment for prostate cancer ([Huggins, 1966](#)), chemotherapy ([Elion and Hitchins, 1988](#)), and bone marrow transplantation for leukemia ([Thomas 1990](#)) [SI-04]. This year it is awarded for activation of immune system to combat with a deadened type of cancer,



**Table 3 Focal theme (a)of Nobel Prize for Physiology or Medicine in 2018**


<b>Obj_achieved</b>	Cancer therapy	<b>Prime Method</b>	Inhibition of negative immune regulation
<b>Necessity</b>	To combat with metastasis		

<b>Affiliation</b>	<b>Nobel Laureate(Physiology or Medicine)Photo Date &amp; place of birth</b>	<b>Share</b>
University of Texas MD Anderson Cancer Center, Houston, TX, USA, Parker Institute for Cancer Immunotherapy, San Francisco, CA, USA	James P. Allison  7 August 1948, Alice, TX, USA	1/2
Kyoto University, Kyoto, Japan	TasukuHonjo  27 January 1942, Kyoto, Japan	1/2

## Nobel Laureate in Economics 2018

**Table 4.1 Focal theme of Nobel Prize for Economics in 2018**

<b>Obj_achieved</b>	Integrating climate change into long-run macroeconomic analysis	<b>Nobel cause</b>	Assessment of the economic impact of climate change, including his advocacy for governments to tax carbon emissions.
<b>Necessity</b>	Importance of government policy in fostering sustainable economic growth.		

Affiliation	Nobel Laureate (Economics) Photo Date & place of birth	Share
Yale University, New Haven, CT, USA	William D. Nordhaus 	1/2

**Table 4.2 Focal theme of Nobel Prize for Economics in 2018**

<b>Obj_achieved</b>	Integrating technological innovations into long-run macroeconomic analysis	<b>Nobel cause</b>
<b>Necessity</b>	Role of policy in encouraging technological innovation	


Affiliation	Nobel Laureate (Economics) Photo, Date & place of birth	Share
NYU Stern School of Business, New York, NY, USA	Paul M. Romer 	1/2

## Nobel Laureates in Peace 2018

**Peace:** Balanced food, potable water, shelter, clean environment, and disease free long life are factors in the first dimension of peace to human race. Psychological health/freedom, good governance and invasion free society constitute another dimension. The Noble Peace prize awardees hitherto contributed for the sustenance and promotion of Peace to mankind.

**Table 5.1 Focal theme(a) of Nobel Prize for Peace in 2018**

<b>Obj_achieved</b>	<ul style="list-style-type: none"> <li>■ Visibility to war-time sexual violence</li> <li>■ Bringing awareness of recent incidents</li> </ul>	<b>Ultimate_Object</b>	No more war, as its consequences are brutal
<b>Basis</b>	Right to live Equal justice	<b>Penultimate_Object</b>	To end “sexual violence” as a weapon of war and armed conflict
<b>Dedication</b>	Dedicated his Nobel award to all women affected by sexual violence		

Affiliation	Nobel Laureate (Peace) Photo, Date & place of birth	Share
	<p style="text-align: center;"><b>Denis Mukwege</b></p>  <p style="text-align: center;">March 1, 1955 Bukavu, South Kivu province, Belgian Congo [now Democratic Republic of the Congo],</p>	1/2

Denis Mukwege, Congolese physician and gynecological surgeon, treated more than 3000 victims of sexual violence in the Democratic Republic of Congo. He authored the results of clinical case studies of research practices for treating sexual assaulted women and on experiences including psychological trauma of survivors.

	Denis Mukwege	Place
Degree	Medicine	Burundi
Practice	Initial : pediatric care	
Further study	Gynecology	Angers, France
Practice	Gynecology service	Lemera
Profession	Congolese physician, director and chief surgeon	Resettled in Bukavu treated 50,000 patients
Awards	<ul style="list-style-type: none"> <li>✈ United Nations Human Rights Prize (2008)</li> <li>✈ Olof Palme Prize for outstanding achievement in promoting peace (2008)</li> </ul>	



European Parliament's Sakharov Prize for Freedom of Thought (2014)

Designation	Nobel Laureate (Peace) Photo Date & place of birth	Share
"UN's first Goodwill Ambassador" for the Dignity of Survivors of Human Trafficking	Nadia Murad 	1/2








Nadia Murad is a survivor of sexual violence by the Islamic State war. She narrated her suffering in front of numerous government bodies and international organizations. Her campaign is against rape as a weapon of war to help other women in distress.






### Supplementary Information (SI)

SI-1: First Response of Noble prize winners		
Nobel Laureate (2018)	First Response	Discipline
Arthur Ashkin	I am preparing a paper for science with recent results on solar energy and environment I do not celebrate about old stuff and I dislike distractions	Phys
Gérard Mourou	Nobody's prepared for that kind of moment. Thus, it is amazing	Phys
Donna Strickland	I think like many people said we wondered if it was a prank. I knew it was the right day – it would have been a cruel prank, but that is what I was thinking.	Phys
Frances H Arnold	There are many chemists whose work deserves Nobel recognition. I certainly didn't expect as it is silly to aspire.	Chem
George P. Smith	Great surprise. so many years later it seems a little bit old hat.  Actually I thought it was one of the, sort of, numerous jokes 'Call coming in from Stockholm' [Laughs] which is kind of like a mean ... that's really what I kind of thought it was, but there was so much static on the line I knew it had to be real.	Chem


























	<p>what does it mean personally?  I retired three years ago.  I have very different interests now.  I don't know what NP will mean for my life.</p> <p>Did the idea come to you suddenly or was it a long process?  It was an idea from ... with many sources because I had all these streams that were very much in my background at the time.  So it was definitely not something that just popped into my head.  It's like evolution, you really don't know which mutation is going to be the one that, you know, that flourishes.</p>	
Winter	It came as a <b>bit of a shock</b> , and I felt a <b>bit numb for a while</b> . It's almost like <b>you're in a different universe</b> .	Chem
James P. Allison	<p>It's, as you might imagine, the dream of a lifetime.  I don't know what to say –  <b>I'm just stunned.</b>  <b>Yep. It's amazing. I'm still in shock</b>  <b>Yep, I always consider myself a basic scientist, but not any more I suppose!</b>  <b>Well speechless. It's kind of sinking in.</b></p>	Med
TasukuHonjo	<b>Certainly I am very much pleased and very much honoured.</b>	Med
<p>For a scientist,  a Nobel Prize is the highest accolade  there are so many brilliant scientists and not enough Nobel Prizes to go around</p>		

## SI-02: Nobel Prizes in Laser science

Year	Contribution	Nobel Laureate (Country)	
1964	Fundamental work in the field of quantum electronics→ construction of oscillators and amplifiers based on the maser–laser principle	Nicolay Gennadiyevich Basov	 Soviet Union
		Alexander Prokhorov	 Soviet Union
		Charles Hard Townes	 United State
1981	Development of laser spectroscopy	Nicolaas Bloembergen	 Netherlands  United States
		Arthur Leonard Schawlow	 United States
1997	Development of methods to cool and trap atoms with laser light.	Steven Chu	 United States

		Claude Cohen-Tannoudji	 France
		William Daniel Phillips	 United States
2005	Development of laser-based precision spectroscopy, including the optical frequency comb technique	Roy J. Glauber	 United States
		John L. Hall	 United States
		Theodor W. Hänsch	 Germany

### SI-03: Nobel Laureates from Bell Labs

Year	Contribution	Nobel Laureate
2009	 Invention of the charge-coupled device (CCD), for electronic memory  CCD image sensor possible.	 Willard S. Boyle  George E. Smith
1998	<b>Fractional Quantum Hall Effect</b>  Discovery and explanation of a new form of quantum fluid with fractionally charged excitations	 Horst Störmer, Daniel Tsui,  Robert Laughlin
1997	 Development of methods to cool and trap atoms with laser light	 Steven Chu  Claude Cohen-Tannoudji  William D. Phillips.
1978	 Discovery of the cosmic microwave background radiation →  provided clear substantiation of the "big bang" theory of how the universe began.	 Arno A. Penzias  Robert W. Wilson
1977	 Fundamental theoretical insights into the electronic structure of magnetic and disordered systems	 Philip W. Anderson
1956	 Research on semiconductors that led to the invention of the transistor in 1947	 John Bardeen,  Walter H. Brattain  William Shockley
1937	 Discovery of the diffraction of electrons by crystals  demonstrated the wave nature of matter.	 Clinton J. Davisson  George Paget Thomson

<b>SI-04: Nobel Prizes from LMB</b>				
	<b>Discipline</b>	<b>Year</b>	<b>Scientist</b>	<b>Nobel prize in</b>
Cryo-electron microscopy for the High-resolution structure determination of Biomolecules in solution	Structure biological molecules	2017	Richard Henderson	Chem
Multiscale models for Complex chemical systems	Computational Structural Biology	2013	Michael Levitt	Chem
Structure and function of the ribosome	DNA-Life	2009	VenkiRamakrishnan	Chem
Genetic regulation of organ development and programmed cell death' in C. Elegans	Control of Cell Growth & Programmed Cell Death	2002	Sydney Brenner, Bob Horvitz John Sulston	Physiol
Elucidation of the enzymatic mechanism underlying synthesis of ATP	Energy Conversion in Cells	1997	<b>John Walker</b>	Chem
Theories concerning the specificity in control and development of the immune system The discovery of the principle for production of monoclonal antibodies	Antibodies human immune system	1984	César Milstein Georges Köhler	Physiol
Development of crystallographic electron microscopy and his structural elucidation of biologically important nucleic acid-protein complexes	Biological Structure in 3D	1982	<b>Aaron Klug</b>	Chem
Determination of base sequences in nucleic acids Developing a technique to determine the exact sequence of the building blocks in DNA	DNA Sequencing	1980	<b>Fred Sanger</b>	Chem
Structures of globular proteins	Structure Proteins	1962	John Kendrew Max Perutz	Chem
Molecular structure of nucleic acids and its Significance for information transfer in living material	DNA	1962	Francis Crick Jim Watson	Physiol
Structure of proteins, especially that of insulin	Protein sequence	1958	<b>Fred Sanger</b>	Chem