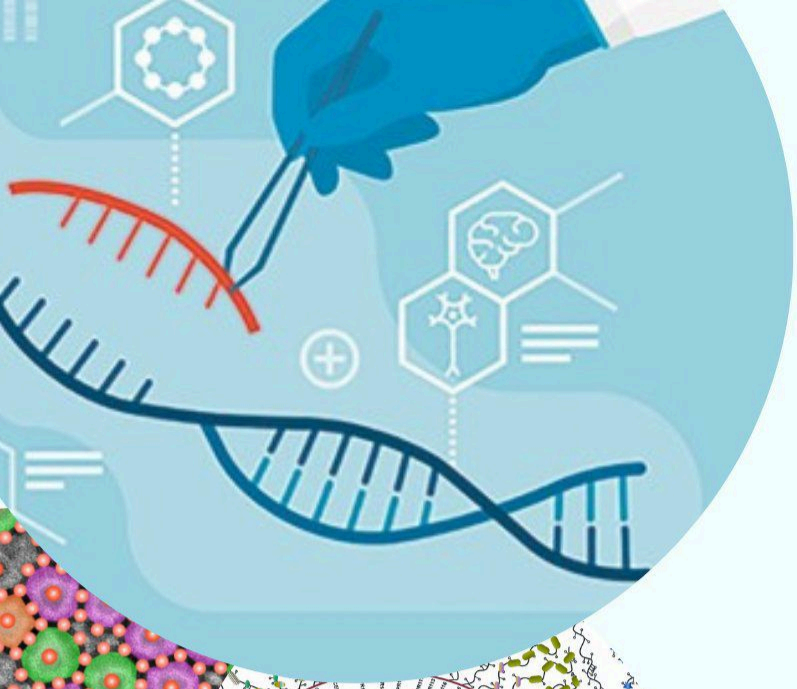

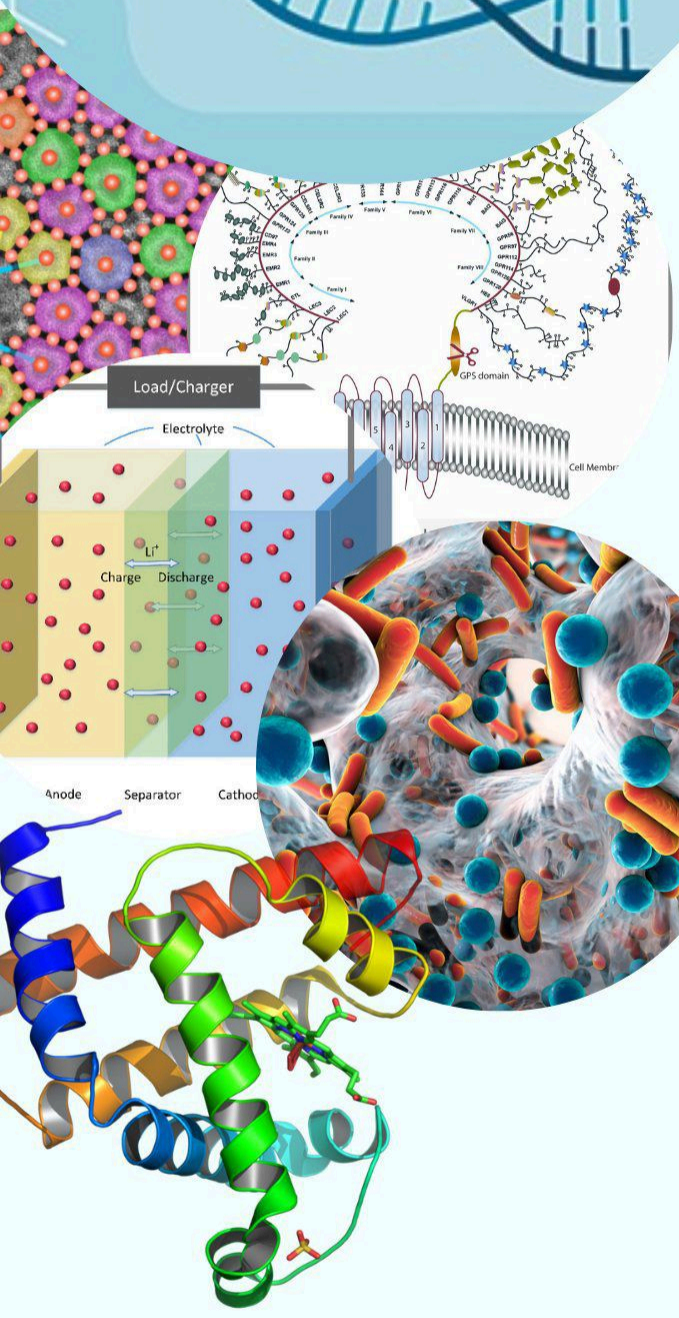

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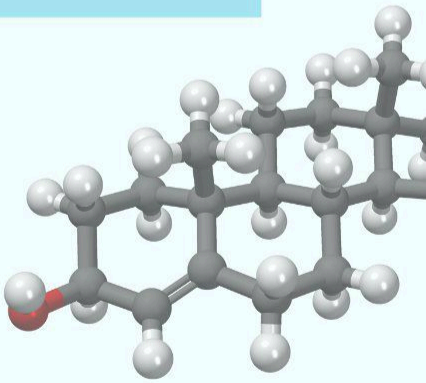
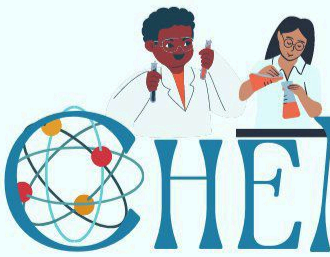
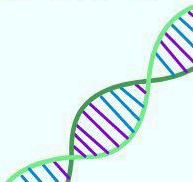
Nobel Prize Edition





A yearly magazine

CHEMYSTERY



CHEMYSTERY

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(Editor)

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(Mentor)

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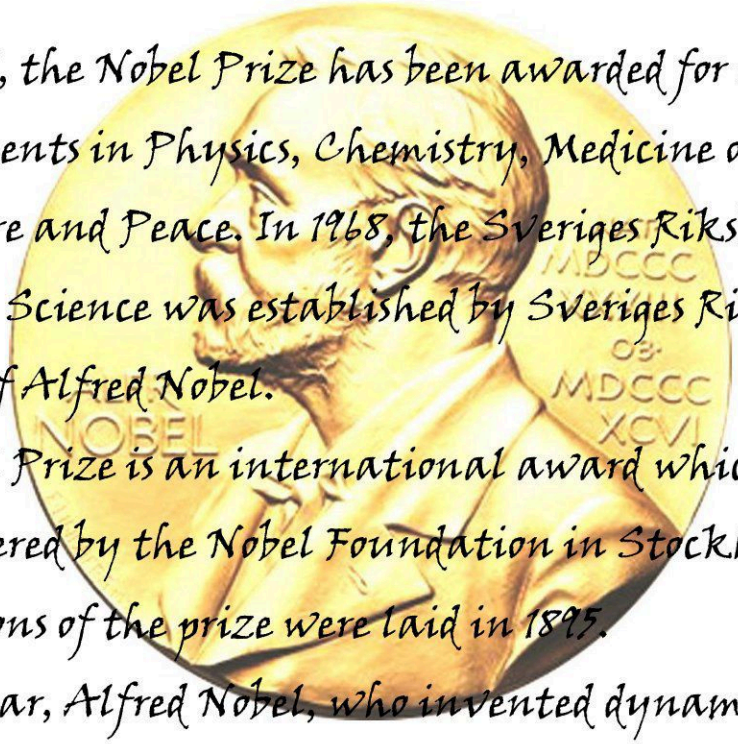
(Mentor)

About Nobel Prize



Since 1901, the Nobel Prize has been awarded for outstanding achievements in Physics, Chemistry, Medicine or Physiology, Literature and Peace. In 1968, the Sveriges Riksbank prize in Economic Science was established by Sveriges Riksbank in memory of Alfred Nobel.

The Nobel Prize is an international award which is administered by the Nobel Foundation in Stockholm. The foundations of the prize were laid in 1895.

In this year, Alfred Nobel, who invented dynamite, wrote his last will in which he left most of his wealth to establish the Nobel Prize. Nobel was not just an inventor. He was also a scientist, author, entrepreneur and pacifist who spoke against war. The Nobel Foundation was established in 1900.

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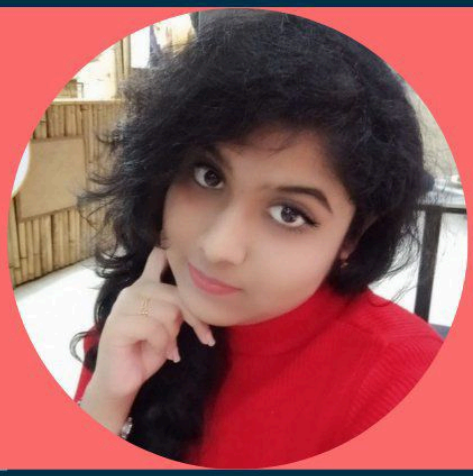
~ Poulami Bhattacharjee



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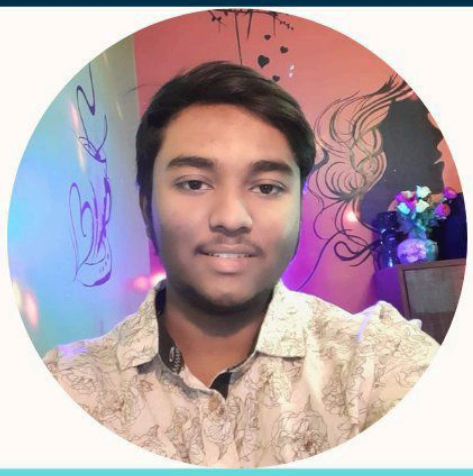

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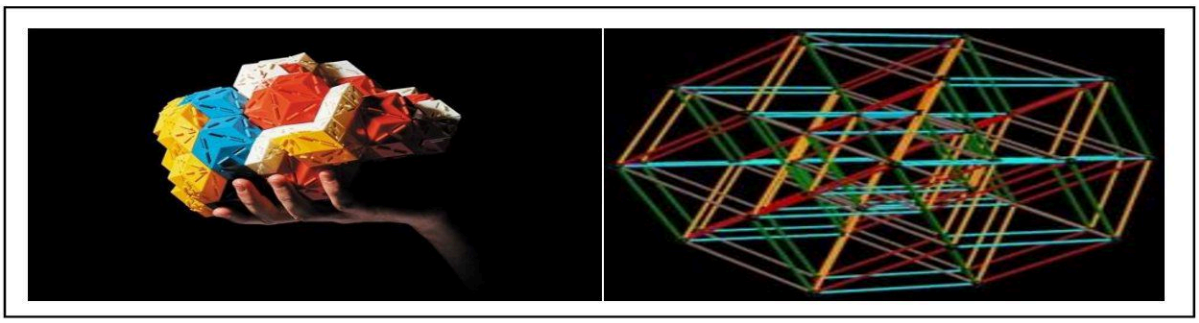
1.QUASICRYSTAL - THE THRILL OF THE CHASE

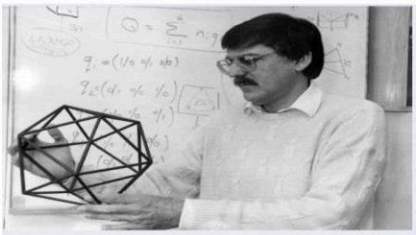
The Nobel Prize in Chemistry 2011 was awarded to Dan Shechtman "for the discovery of quasicrystals."

"Quasicrystal" – A Term Which Brought Hostility &Violation Among Scientists During 1984's, A Wonderful State Of Matter Which Is Thought Of Only Having Its Existence In Imaginary World Has Declared Its Own Existence In Reality . So A Curious Question Must Come " What Is Quasicrystal?" –" A Quasicrystal Is A Structure That Is Ordered But Not Periodic" A Quasi Crystalline Pattern Can Fill All Available Spaces But It Lacks Translational Symmetry.

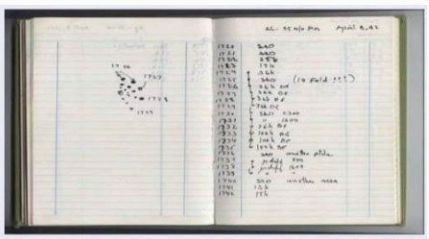


'Quasi Crystal' By The Term We Can Guess That It Is Linked With Crystal. But What Is Its Speciality?Crystal According To The Classical Crystallographic Restriction Theorem Is Both Ordered With Usual Repeating Arrangements While Quasicrystal Is A Form Of Crystal With Unusual Arrangement Of Atoms Thought Impossible For A Crystal. Crystal Is Periodic While Quasicrystal Is Aperiodic . This Oddity Results In Unexpected Rotational Symmetries.

❖ DISCOVERY



Dan Shechtman, 1983. (Credit: Technion – Israel Institute of Technology)



Shechtman's lab book with a note "10 fold???" next to the sample label.

cDan Schechtman Was Awarded The Nobel Prize In Chemistry In 2011 For His Discovery On Quasicrystal. But This Strange Matter Has A Hidden Past About Its Discovery-

•On July 16, 1945, In Alamogordo, The Trinity Nuclear Bomb Test Produced Icosahedral Quasicrystal Which Went Unnoticed.

• In 1961, Hao Wang Discovered Tiling Of The Plane Method For Quasicrystal

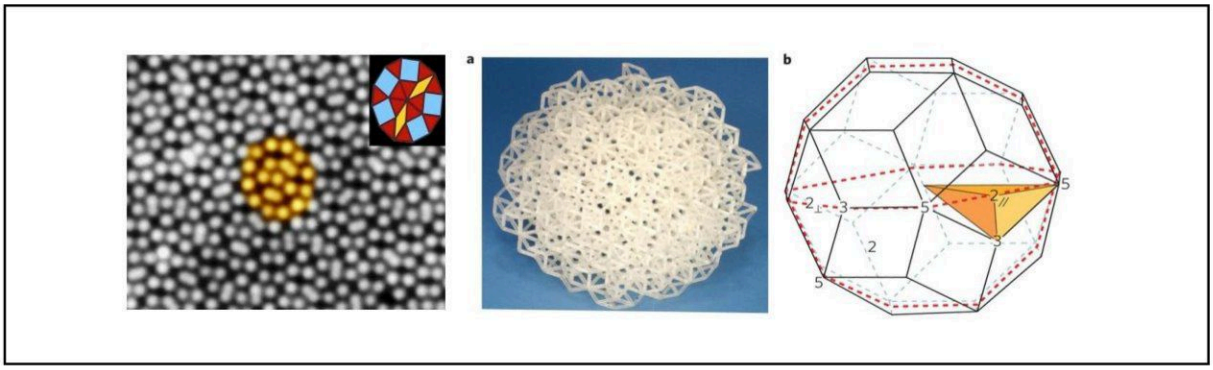
- •In 1976, Roger Penrose Discovered 2 Tiles That Produced Only Non – Periodic Tilings Of Plane

- In 1977, Alan Mackay Experimentally Showed That Penrose Tiling Had A 2-Dimensional Fourier Arranged In 5-Fold Symmetric Pattern

•In 1982, Dan Schechtman First Discovered 10- Fold Quasicrystal From Al-Mn Alloys Which Produced Diffraction ,. Linus Pauling Created Hostility Against Dan Schechtman. Due To Fear Of Scientific Community's Reaction, It Took 2 Years To Publish His Results.

Recently, In 2018, Chemists From Brown University Announced Single Component Quasi Crystal Lattices Which Is Different From Normal Crystal.

❖ TYPES OF QUASI CRYSTAL



• 2- Dimensional (Periodic Along One Axis)

• 3- Dimensional (Aperiodic In Every Direction)

❖ PROPERTIES OF QUASICRYSTAL

• Low Conductivity. Resistivity Decreases With Temperature Having Thermopower& Small Specific Heat

• It Is Diamagnetic And Brittle In Nature

• It Has No Drude Peak And Is Corrosion Resistant

• The Stability Of Icosahedral Quasi Crystal Has Been Studied In Terms Of Hume- Rothery Rules. Most Of Stable Quasi Crystal Can Be Understood Within Framework Of Hume – Rothery Theory.

❖ APPLICATIONS

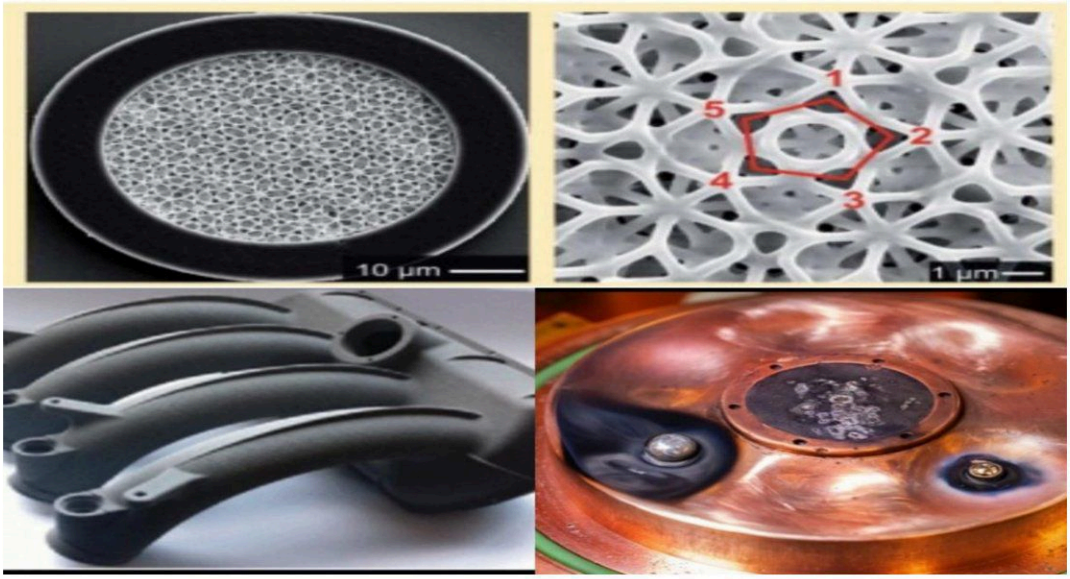
This Strange State Of Matter Has Numerous Applications making Our Lives Fruitful & Easy. Some Are Given Hereunder -

• Metallic Quasi Crystalline Coatings Can Be Applied By Thermal Spraying On Magnetron Sputtering .

• The Use Of Low Friction Al-Cu-Fe-Cr Quasicrystal As A Coating For Non- Stick Frying Pans.

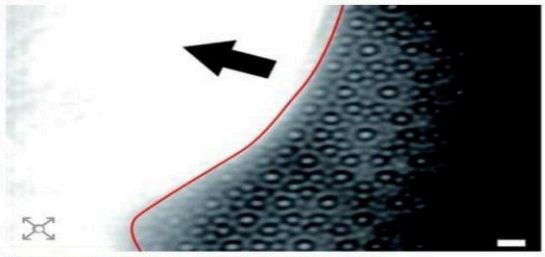
• Quasi Crystals Are Being Used To Develop Heat Insulation, LEDs, Diesel Engines & Materials That Convert Heat To Electricity.

• They Are Used In Embedding Particles In Plastics To Make Strong Hard Wares& Low Friction Plastic Gears.



❖ LATEST RESEARCH

Scientists Are Still Working On This Captivating Quasi Crystal To Discover Its New Angle. Recently, Physicists Got Surprised While Watching Quasi Crystals Grow.


Error correction: a growing quasicrystal

Nevertheless, Quasi Crystal Research Is Going On & New Fascinating Properties Eg;Superconductivity Are On The Way Of Discovery. Hope In Future Further Researches On Quasicrystals Will Open A New Vista Of Science.

Written By

~ *Poulami Bhattacharjee*

2. G-protein Couple Receptors

The Nobel Prize in Chemistry 2012 was awarded jointly to Robert J. Lefkowitz and Brian K. Kobilka "for studies of G-protein-coupled receptors."

The G protein couple receptors (GPCRs) are the largest and the most versatile superfamily among cell surface receptors. G proteins also known as guanine nucleotide-binding proteins, involved in transmitting signals and functions as molecular switches.

G protein-coupled receptors (GPCRs) also known as seven-transmembrane domain receptors, 7T receptors, serpentine receptor, and G protein-linked receptor (GPLR).

They are called seven transmembrane receptors because they pass through the cell membrane seven times. GPCRs are the targets for many drugs.

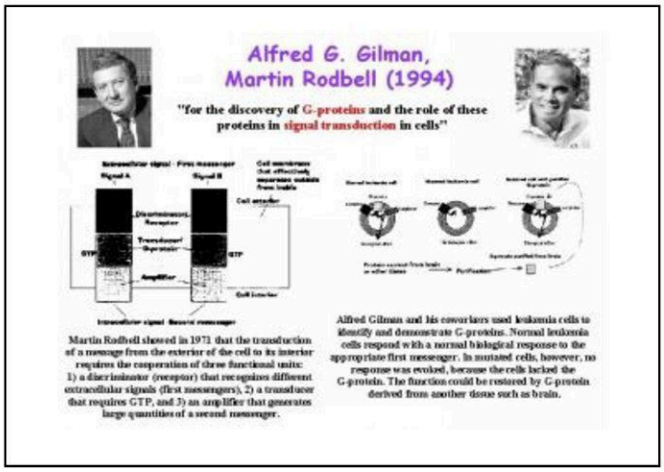
Around 800 GPCR are found in humans

- Olfaction (~400)
- Taste (33)
- Light perception (10)
- Pheromone signaling (5)
- ~350 non-sensory GPCRs mediate signaling

Around 100- 200 orphan GPCRs are known in human.

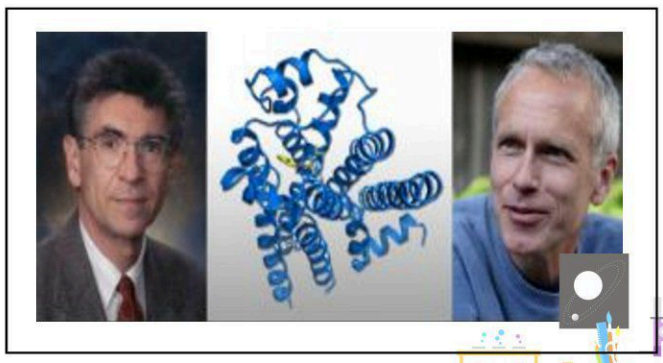
❖ BACKGROUND

ROBERT LEFTOWITZ and BRAIN KOBILKA won the 2012 Noble prize in chemistry for groundbreaking discoveries that reveal the inner workings of the important family receptors: G-protein Coupled

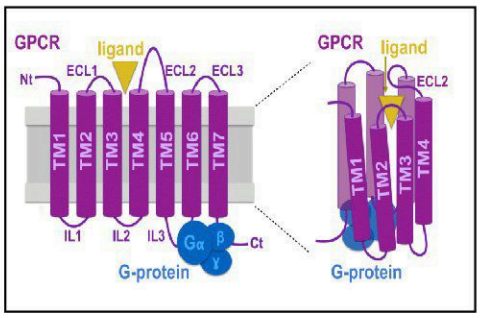


❖ STRUCTURE OF G PROTEIN

The structure of a GPCR can be divided into three parts:

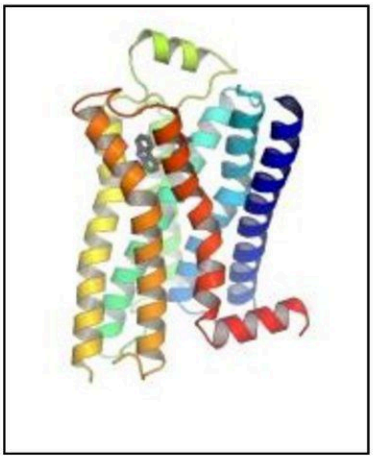


- The extra-cellular region, consisting of
  the N terminus and three extracellular loops (ECL1- ECL3)
- The TM region, consisting of seven a-helices (TM1-TM7)
- The intercellular region, consisting of three intracellular loops (ICL1- ICL3), an intracellular amphipathic helix (H8), and the C terminus.



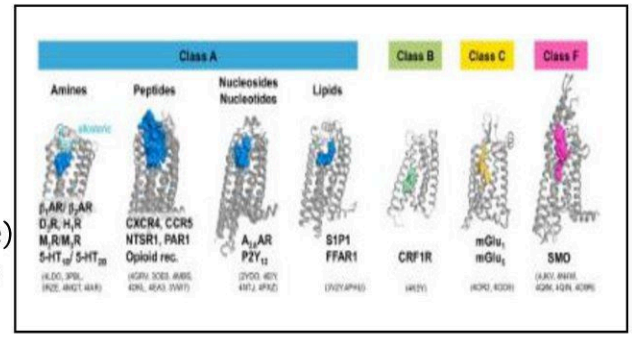
- G protein complex are made up
- 23 **α**
- 7 β
- 12 γ subunits
- Beta and gamma subunits can form a stable
  - dimeric complex referred to as beta-gamma
  - complex.
- In a broad sense the extracellular region moderates ligands access; the TM region forms the structural core, bunds ligands and transduces this information to the intracellular region through conformational change, and the intracellular region interfaces with cytosolic signalling proteins
- The **α** subunit falls into families (Gs, Gi, Gq and G12/13) which are responsible for coupling GPCRs to relatively distinct effectors.
- GPCRs are responsible for every aspect of human biology from vision, taste, sense of smell and parasympathetic nervous functions, metabolism, and immune regulation to reproduction.
- ~45% of all pharmaceutical drugs are known to target GPCR

❖ GPCR



- First GPCR to be fully characterized was the β adreno receptor
- X ray crystallography to study the molecular structure of these
  - receptors
- Fluorescence methods to study kinetics of ligand binding
  - and changes associated with activation
- First X ray crystal structure of GPCR-2000
- 72 structures of GPCRs Proteins Data Bank
- Rhodopsin is by far the best structurally defined GPCR
- GPCR signaling can be activated in 200-500 millisecond.

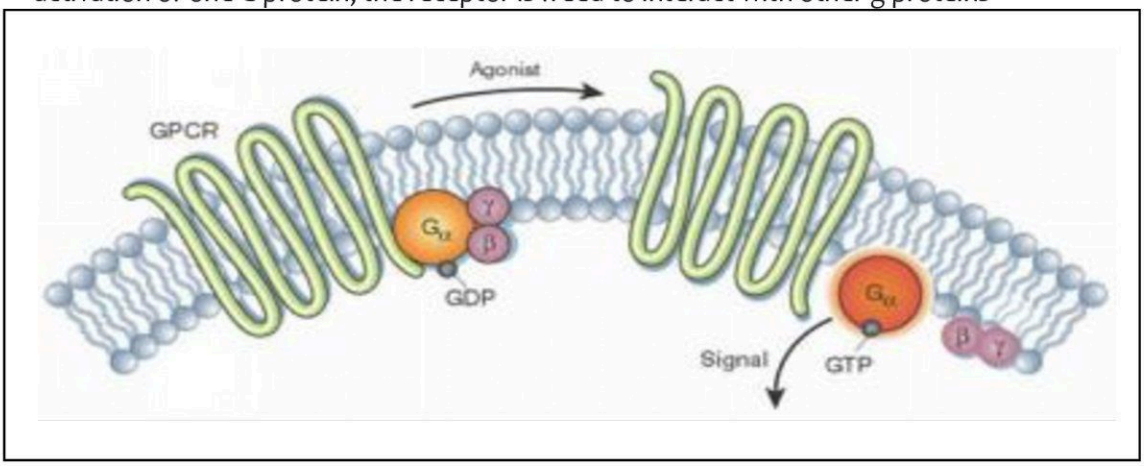
❖ GPCR: CLASSIFICATION



- Class A (Rhodopsin like)
- Class B (Secretin like)
- Class C (Metabotropic glutamate / pheromone)
- Class D (Fungal mating pheromone receptors)
- Class E (cyclic APM receptors)
- Class F (Frizzled/ smoothened)

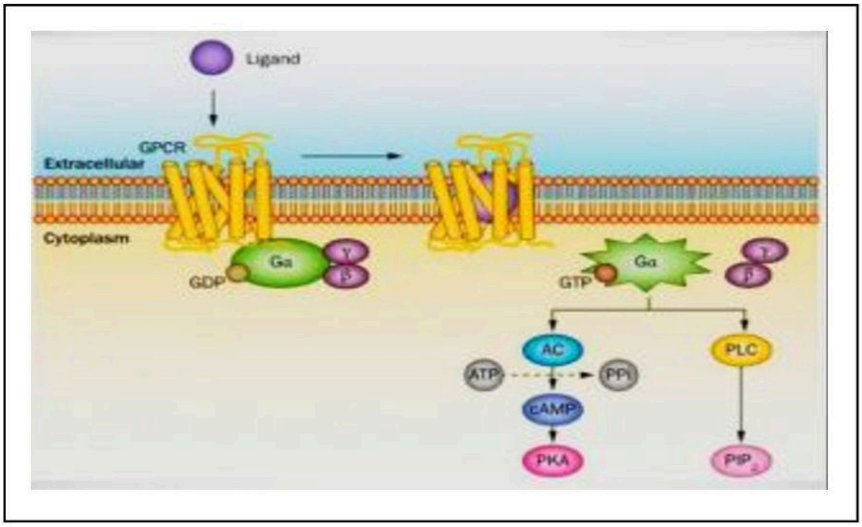
❖ MECHANISM

- When agonist bunds to a GPCR, there is a conformational change in the receptor that is transmitted from the ligand binding pocket to the second and third intracellular loops of the receptor which couple to the G protein heterotrimer.
- GPCR results in a conformational change in the receptor that is transmitted to the bound Gα subunit
- This is conformational change causes the **α** subunit to exchange its bound GDP to GTP
- Binding GTP activates the α subunit and causes to release both the β γ dimer and the receptor and active signaling molecules.
- The interaction of the agonist bound GPCR with the G protein is transient, following activation of one G protein, the receptor is freed to interact with other g proteins



There are two principal signal transduction pathways involving the G protein coupled receptors:

- The cAMP signal pathway
- The phosphatidylinositol pathway

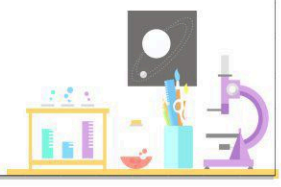


❖ CONCLUSION

- Nearly 40% of the drugs approved for marketing by the FDA target GPCRs
- 800 – 1000 different GPCRs and the drugs that are marked target less than 50 GPCRs
- GPCRs will continue to be highly in clinical medicine because of their large number, wide expression and role in physiologically important responses
- Future discoveries will reveal new GPCRs drugs, in part because it is relatively easy to screen for pharmacologic agents that access these receptor and stimulate or block receptor-mediate biochemical or physiological responses.

Written By

~ *Prerana Chowdhury & Sumita Dutta*



3.Development of multiscale models for complex chemical systems

The Nobel Prize in Chemistry 2013 was awarded jointly to Martin Karplus, Michael Levitt and Arieh Warshel "for the development of multiscale models for complex chemical systems."

❖ INTRODUCTION

➢ Everything in nature is made of atoms and molecules, which are microscopic objects, Their properties are governed by Quantum mechanics which is an exact theory, unlike Newtonian mechanics.

➢ Schrodinger equation [Hψ =Eψ] is the heart of quantum mechanics, but it can only be solved approximately[known as electronic structure method] for many body system like- atoms and molecules due to the nature of e-e repulsion term.

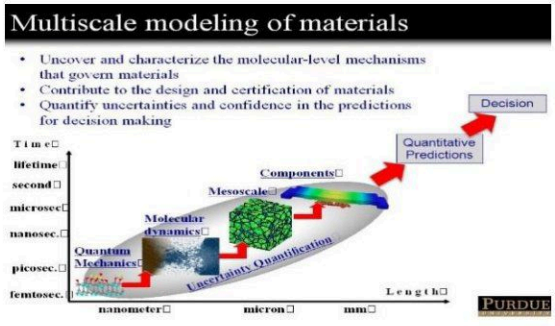
➢ Electronic structure methods scales steeply in terms of computational efforts, N3 or worse with system size, so for large system it`s very difficult solve.

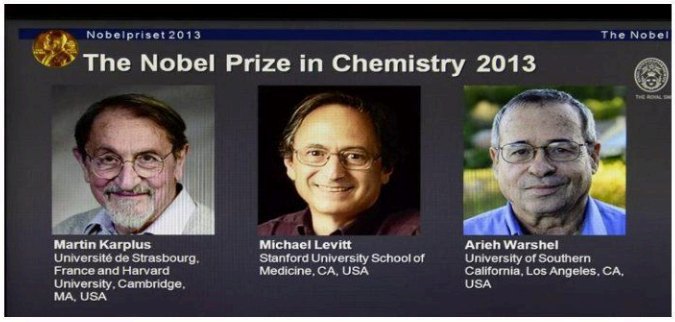
➢But, do we need Quantum mechanics all the time? No, for a length scale significantly larger than the inter-atomic distances, matter can be considered as continuous, and the motion can be defined by Classical Newton`s law. Which is known as Molecular mechanics[MM]. Fig: Different Physical methods that can be used for various time and length scale

➢ MM method does not consider electronic degrees of freedom so is inappropriate to capture important phenomena like bond breaking or Charge transfer etc,

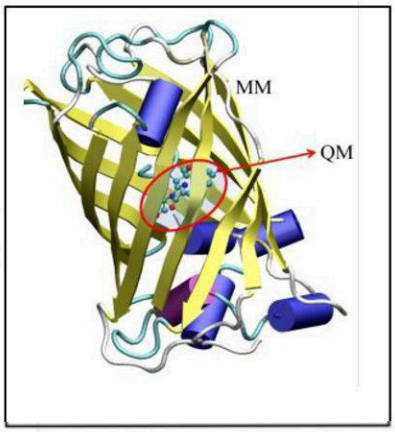
➢ Conclusion of above statement is, There is a trade off between speed and accuracy of QM and MM theories. So we have to use Hybrid methods [QM and MM] to simulate larger system like, complex Biomolecules.

➢This idea of using Hybrid was first implemented successfully by Warshel ,Levitt and Karplus and they are awarded with Nobel Prize in 2013.





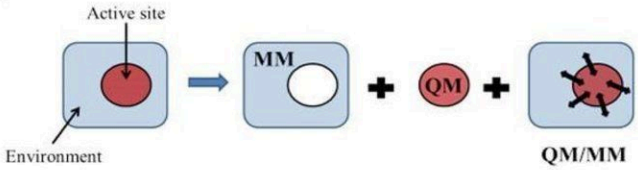
❖ THEORY OF MULTISCALE QM/MM METHOD



➢**Partitioning of System:** The large system [let`s say protein with 500 atoms with surrounded water molecules] is first partitioned into 2 domains, active part where Chemical changes takes place is treated by higher level QM theory and rest part of the system and surrounding environment is treated by Simpler theory Molecular Mechanics [MM]. **Fig-2**

Overall energy of the system: Within this framework the total Hamiltonian of the system is written as, Sum of energies of both Sub systems [HQM + HMM] and a coupling term[HQM/MM]. i.e.

I/MM]. i.e.



$$H_{\mathrm{QM/MM}}(\mathrm{sub}) = H_{\mathrm{MM}}(\text{full system}) + [H_{\mathrm{QM}}(\text{active site}) - H_{\mathrm{MM}}(\text{active site})]$$

❑**Calculation of QM part:** The energy and wave function of chemically active QM part is calculated by Solving Schrodinger equation.

Different Methods to Solve Schrodinger equation:

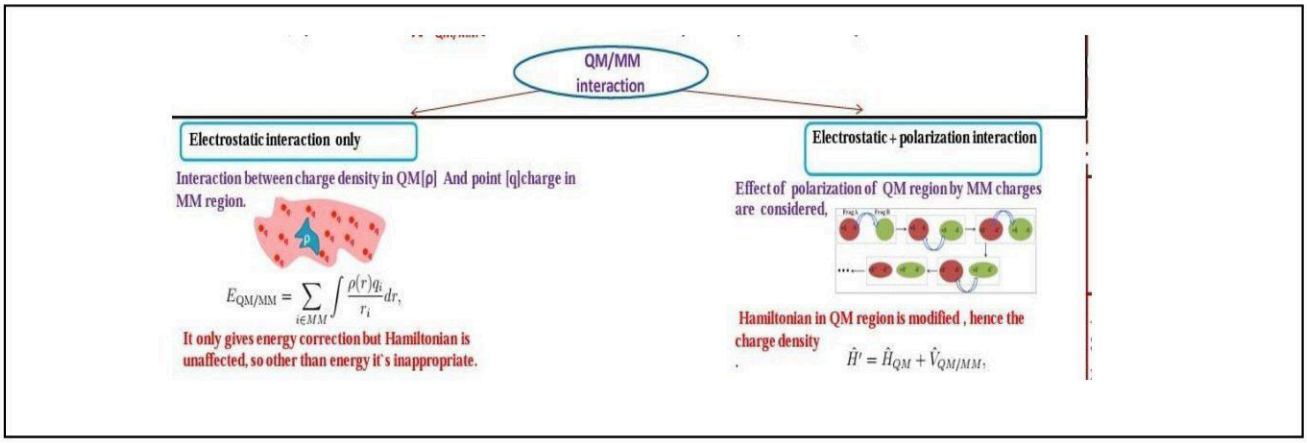
1. SEMI EMPIRICAL METHOD, CALCULATING HAMILTONIAN
2. DENSITY FUNCTION THEORY, TAKING ELECTRON DENSITY AS A VARIABLE INSTEAD OF WAVE FUNCTION
3. MANY BODY METHOD LIKE, MP2,CCSD ETC.

❑**Calculation of MM part:** Here total interaction potential[V_{MM}] is written in terms of total bonded and non bonded interaction.

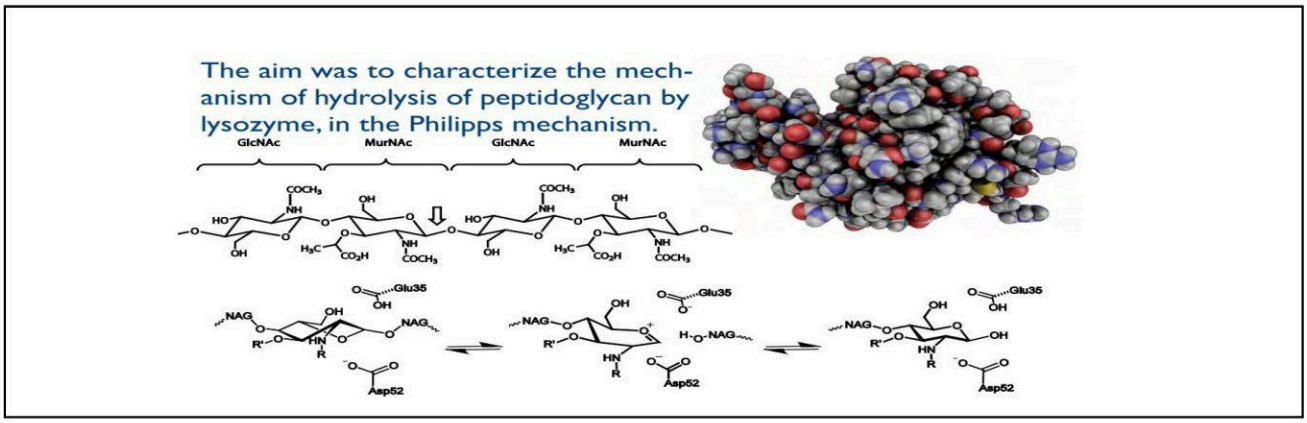
$V_{bonded} = V_{bond} + V_{angle} + V_{dihedral}$ $V_{non\text{-}bonded} = V_{electrostatics} + V_{vdw}$

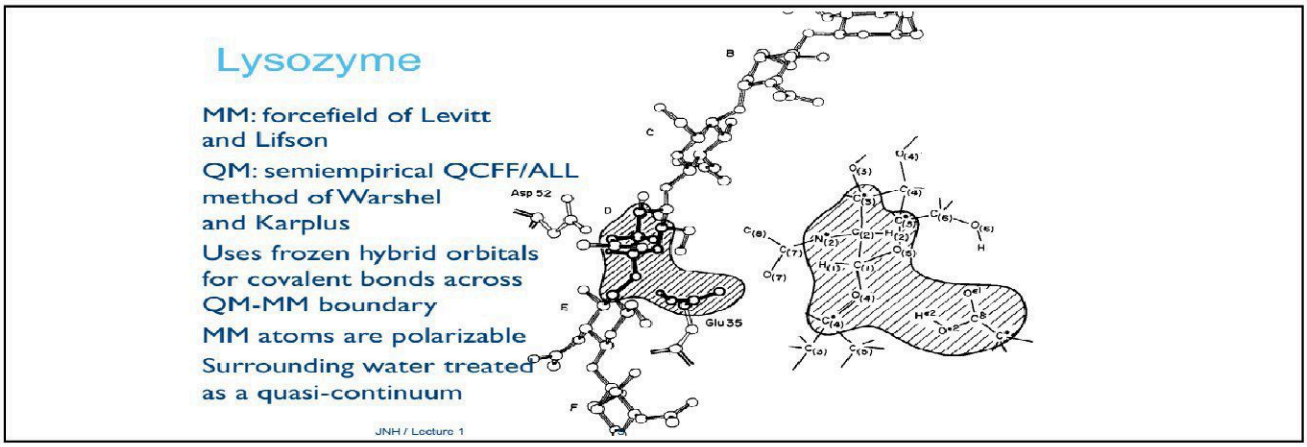
The potential terms contains empirical parameters of motions like bending, stretching etc [r0 ,k, θ 0etc.]. Which is system specific in most of the cases.

❑**Treatmentof QM/MM boundary[HQM/MM]:** It is the most crucial and complicated part. Some techniques are mentioned below:



❑SEMINAL WORK BY WARSHEL-LEVIT:





❑**ACKNOWLEDGEMENT:** I WOULD LIKE TO THANK MY TEACHERS AND ALSO MY BROTHER MR SUBARNA BISWAS ,AS THEY HELP ME A LOT BY GIVING DATA ABOUT THIS TOPIC.

Written By

~ Arkadip Mandal

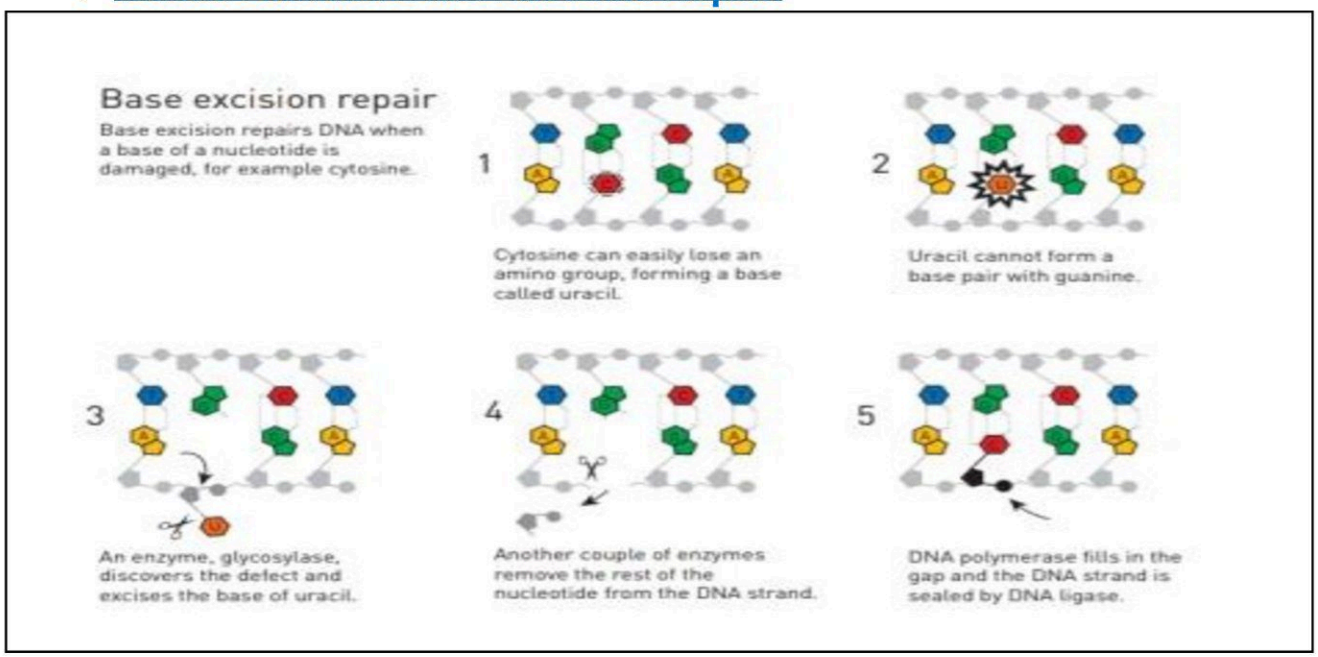
4. DNA REPAIR–FROM ONE CELL TO ANOTHER , FROM ONE GENERATION TO THE NEXT

The Nobel Prize in Chemistry 2015 was awarded jointly to Tomas Lindahl, Paul Modrich and Aziz Sancar "for mechanistic studies of DNA repair."

Tomas Lindahl, Paul Modrich and Aziz Sancar are awarded

the Nobel prize in Chemistry 2015 for having mapped and giving explanations how the cell repairs it's DNA and keeps safe the genetic informations.

❖ Tomas Lindahl: Base Exicision Repair



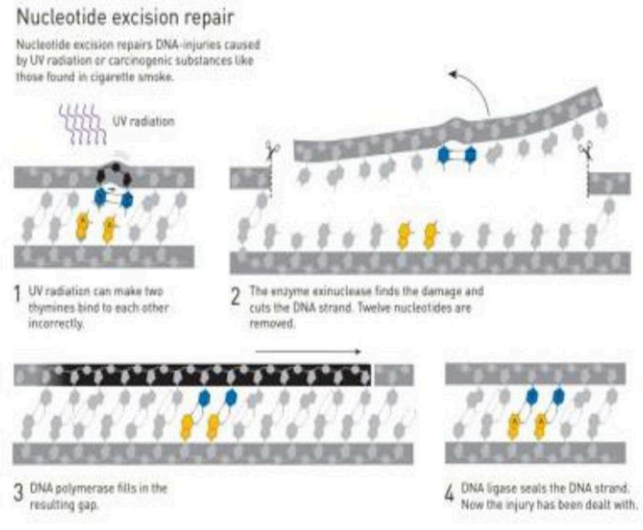
During his postdoc at Princeton University,USA, Tomas Lindahl researched with R.N.A. A question arised in his mind is DNA molecule really be stable for lifetime?Some experiments proved that he was right:

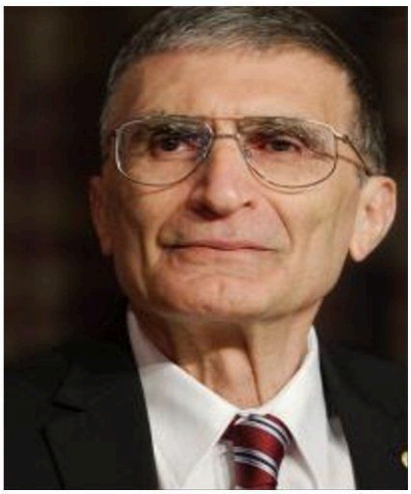
- He found some special bacterial enzymes that remove damage of cytosines from DNA
- He also found that many proteins that repairs DNA.
- Lindahl pieced together a molecular image of how base excision repair functions,a process in which glycosylases are the first step in the DNA repair process.
- Base excision repair also occurs in human beings.
- In 1966, Tomas Lindahl managed to recreate the human repair process *in* .

❖ Aziz Sancar:

The mechanism used by the majority of cells to repair UV damage, nucleotide excision repair, was mapped by Aziz Sancar,(born in Savur, Turkey).He studied that bacteria have two systems of repairing UV damage:

- Light-dependent photolyase
- A second system that functions in dark(by three genetic mutations: uvrA, uvrB and uvrC).





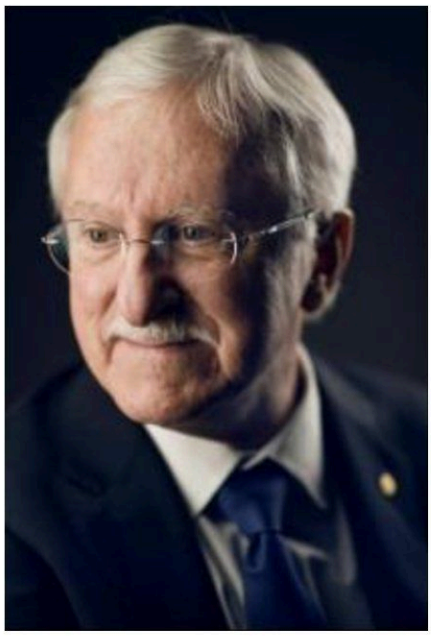
Aziz Sancar

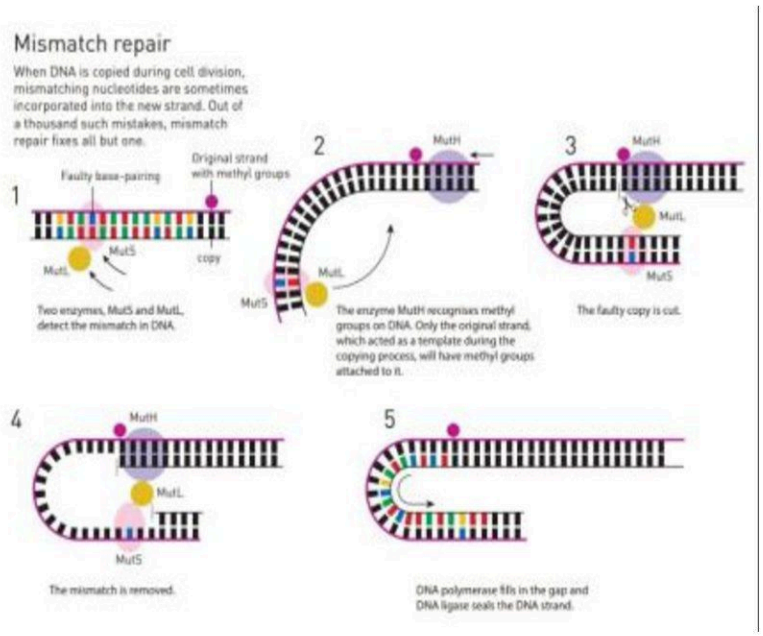
- In ground-breaking *in-vitro* experiments he showed that these enzymes coded by the genes (uvrA , uvrB and uvrC) can identify a U-V

damage,then making two incisions in the DNA strand, one on each side of the damaged part.

- A fragment of 12-13 nucleotides, including the injury,then it is removed.

❖ Paul Modrich:





Paul Modrich discovered the systematic work, cloning and mapping one enzyme after the other in the mismatch pair process.

- He studied the human version of the repair system.
- One out of a thousand errors that occurs when the human genome is copied, are corrected by mismatch repair.
- DNA methylation has other functions our genome to that of bacteria, so something else must given the process.

❖ Defects in the repair systems cause cancer

The exicision repair, nucleotide excision repair and mismatch repair and several other mechanisms that repair damage of DNA, caused by the sun, cigarette smoking and other genotoxic substances.If genome collapses without repair mechanisms,the genetic informations change rapidly and risk of cancer increases.

- Damage to the nucleotide excision repair process causes *xeroderma pigmentosum*.
- *Skin cancer* is developed by UV rays.
- Defects in DNA mismatch repair increase the risk of developing hereditary colon cancer.
- This makes the cancer cells' DNA unstable, so, sometimes cancer cell mutated and become resistant to chemotherapy.
- So the reasearchers attempting to develop new cancer drugs, that will slow down or completely stop the growth of the cancer.

In conclusion, this research will help the scientific community to lead to the development of lifesaving treatments.Or, in the words of Paul Modrich: "That is why curiosity-based research is so important. You never know where it is going to lead…..A little luck helps too."

❖ References:

- Wikipedia
- https://youtu.be/V7nzv1tG5yg
- https://www.nobleprize.org
- https://www.nature.com

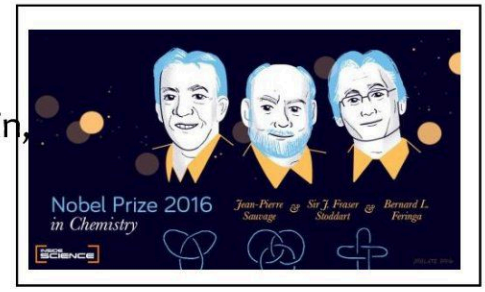
etc

Written By

~ *Sreya Roy*

5.Molecular machine: The work of 2016's Noble Laureates in chemistry

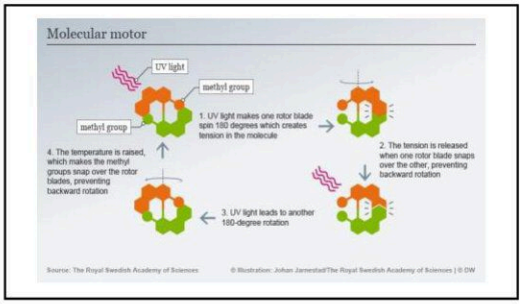
The Nobel Prize in Chemistry 2016 was awarded jointly to Jean-Pierre Sauvage, Sir J. Fraser Stoddart and Bernard L. Feringa "for the design and synthesis of molecular machines."



When Jean-Pierre Sauvage succeeded in linking two ring-shaped molecules together to form a chain, called a *catenane* in 1983, it was the first step towards a molecular machine.

Fraser Stoddart in 1991, developed a rotaxane. Among his developments based on rotaxanes are a molecular lift, a molecular muscle and a molecule-based computer chip.

Bernard Feringa was the first person to develop a molecular motor; in 1999 he got a molecular rotor blade to spin continually in the same direction. Using molecular motors, he has rotated a glass cylinder that is 10,000 times bigger than the motor and also designed a nanocar.



They have taken molecular systems out of equilibrium's stalemate and into energy-filled states in which their movements can be controlled. In terms of development, the molecular motor is at the same stage as the electric motor was in the 1830s, when scientists displayed various spinning cranks and wheels, unaware that they would lead to washing machines, fans and food processors.

Molecular machines will most likely be used in the development of things such as new materials, sensors and energy storage system.

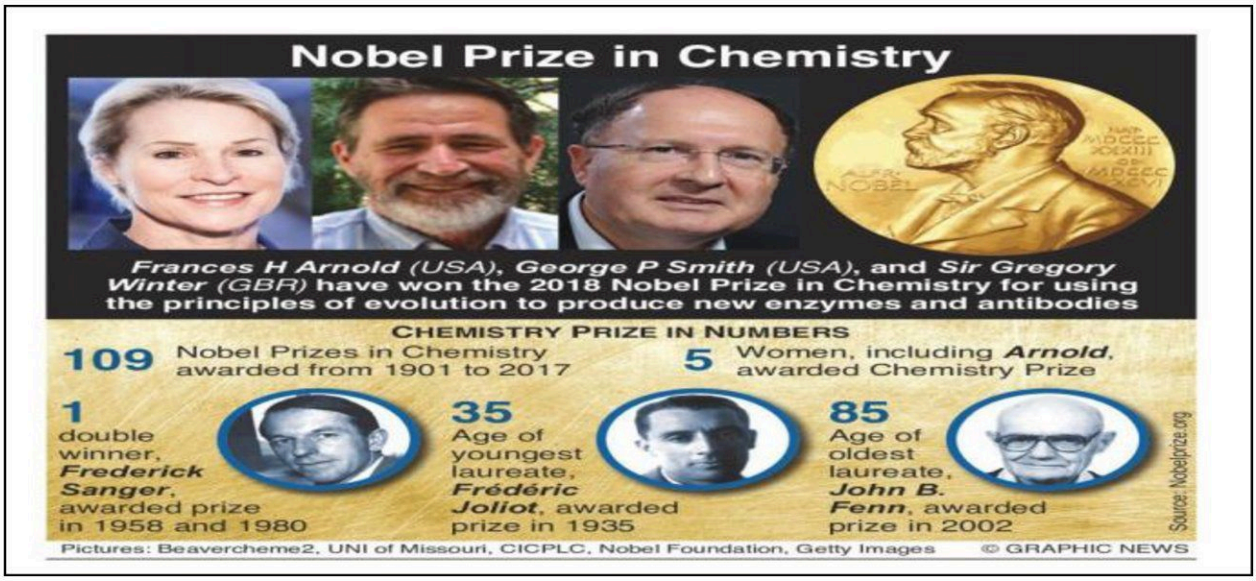
Written By

~ *Aditi Adhikari*

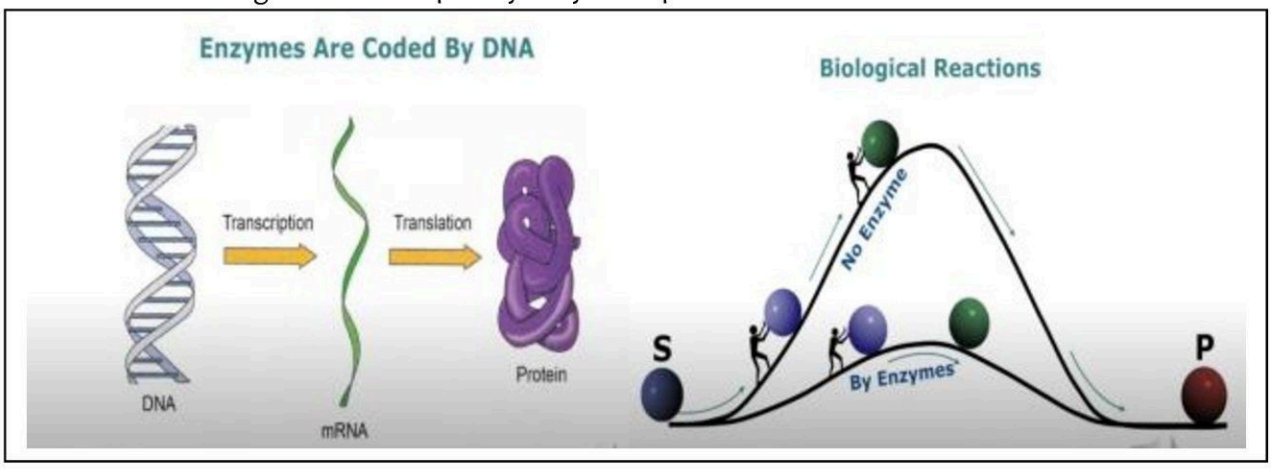
6.Enzyme Brings Up The Nobel Prize in 2018!

The Nobel Prize in Chemistry 2018 was divided, one half awarded to Frances H. Arnold "for the directed evolution of enzymes", the other half jointly to George P. Smith and Sir Gregory P. Winter "for the phage display of peptides and antibodies."

Frances Arnold, George Smith and Gregory Winter had won the Nobel Prize in 2018 in Chemistry. With that Nobel nod, Frances Arnold became the 5th woman to win a Nobel Prize in Chemistry. She is recognized for her invention and development of a technique called "THE DIRECTED EVOLUTION OF ENZYMES".

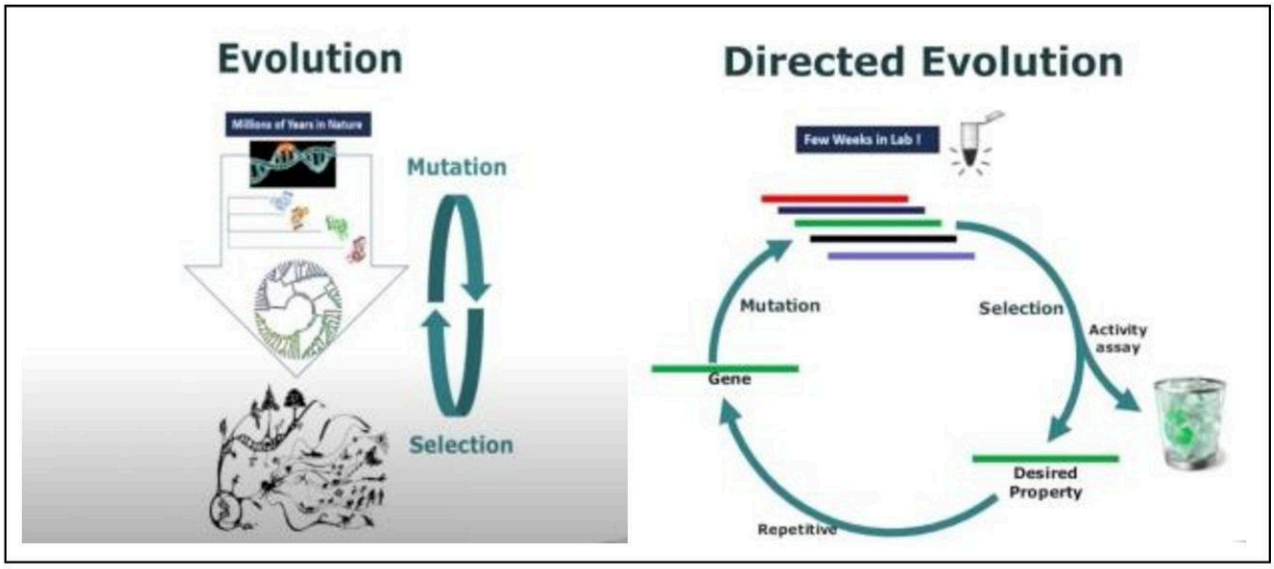


Enzymes are mostly proteins, coming from the translation of m-RNA which are formed by DNA transcription. As biological catalysts, their role is to speed up biochemical reactions thousands of times faster. From digestion of food to the copying of genetic information and millions of other reactions in all living cells are completely enzyme-dependent.

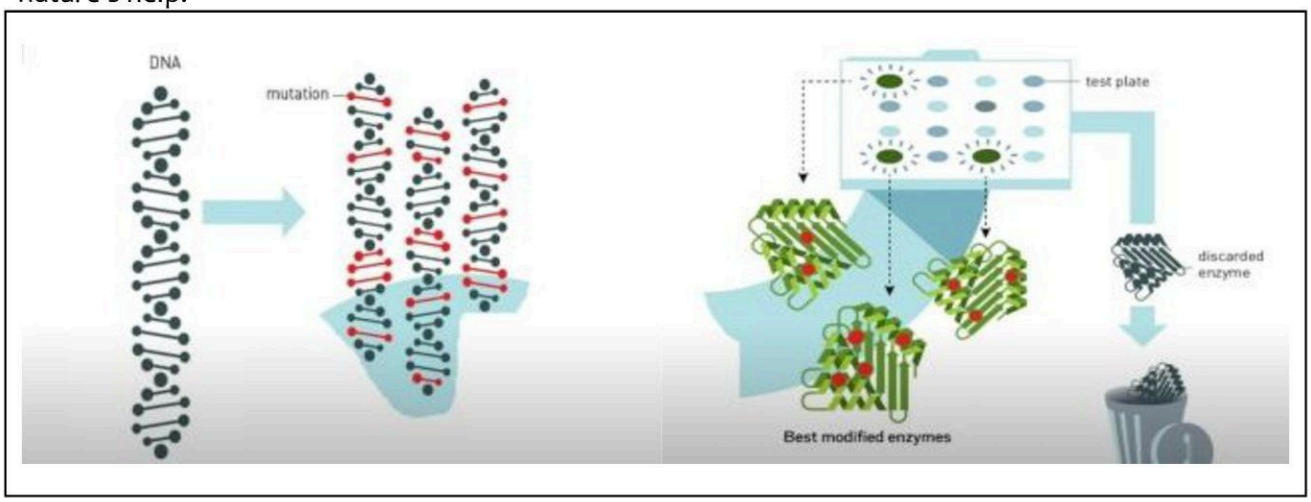


Evolution is a very slow phenomenon in nature and it is a continuous process of mutation in DNA codes and selection of the more adopted organisms in a particular environment.

In molecular biology, directed evolution is a method that remixes the process of natural evolution in a much faster and focused way by creating libraries of variance of a given gene.



Using regular old evolution, nature has made enzymes that work. But there is always room for improvement. Evolution is not necessarily optimal. Realizing this, Chemists have tried to design better enzymes. Enzymes that are more active than their natural counterparts or enzymes that could thrive outside their normal biological environment say in a commercial reactor. Rather than assume Chemists could design the best enzyme on their own. Arnold developed a way to enlist nature's help.



In Arnold's directed evolution, she introduces a variety of these genes into a bunch of bacteria. Using the modified genes, the bacteria make modified enzymes.

❖ Some transcripts from a Nobel lecture by Arnold is given:

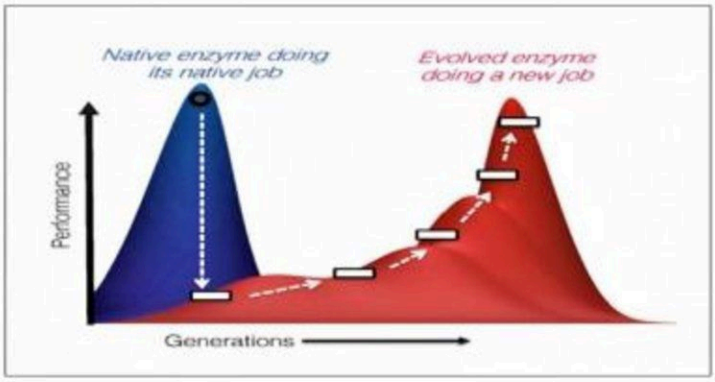


Figure 1. An enzyme whose function is optimized for its native job generally performs poorly in a new role. Directed evolution through rounds of mutation and screening can discover changes in sequence that improve performance, climbing a new fitness peak.

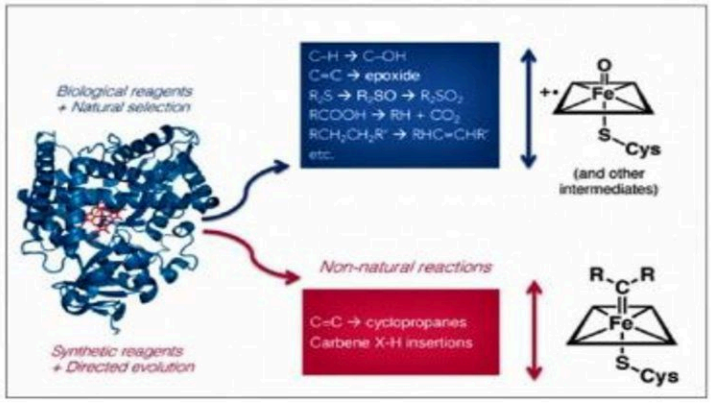


Figure 2. Expanding the scope of P450 chemistry. The cytochrome P450 family, whose members were presumably created by gene duplication and natural selection of promiscuous functions, comprises enzymes that use reactive oxygen intermediates to catalyze a wide range of reactions. We reasoned that we could expand the scope of P450 chemistry by using synthetic carbene and nitrene precursors to drive formation of new reactive intermediates. Directed evolution would be used to mold the enzyme, controlling and enhancing new-to-nature activities.

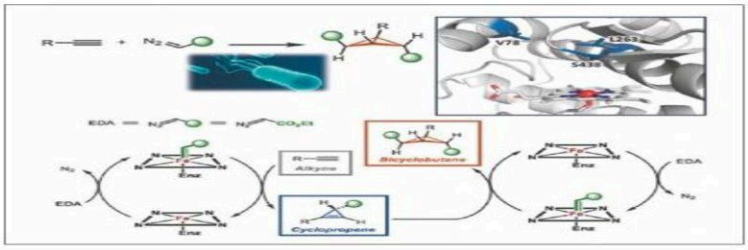


Figure 3. Enzyme-catalyzed bicyclobutanation through two carbene transfers to an alkyne, catalyzed by a serine-ligated variant of a cytochrome P450 [31]. The enzyme must generate the reactive carbene and transfer it to the alkyne substrate and then do it a second time to the cyclopropene intermediate in order to generate the bicyclobutane. Evolved enzymes make a single stereoisomer of these highly strained rings, which indicates a well-defined orientation of the substrates in the newly-evolved active site.

Chemists then test for which of these modified enzymes are best suited for the job we want them to do. Arnold gave a seminal demonstration of this in the 90s by modifying the enzyme subtilisin. Like most of the enzymes, it works in water. But Arnold directly evolved a version that

works in the organic solvent used in industrial reactions. As Claes Gustafsson of the Nobel committee put it, it's like "Darwinism in a test tube"!

Today, directed evolution has produced enzymes that are thousands of times more active than enzymes found in nature.

And it has yielded enzymes that help us create medicines, biofuels and many more useful substances.

Written By

~ *Neloy Kumar Ghosh*

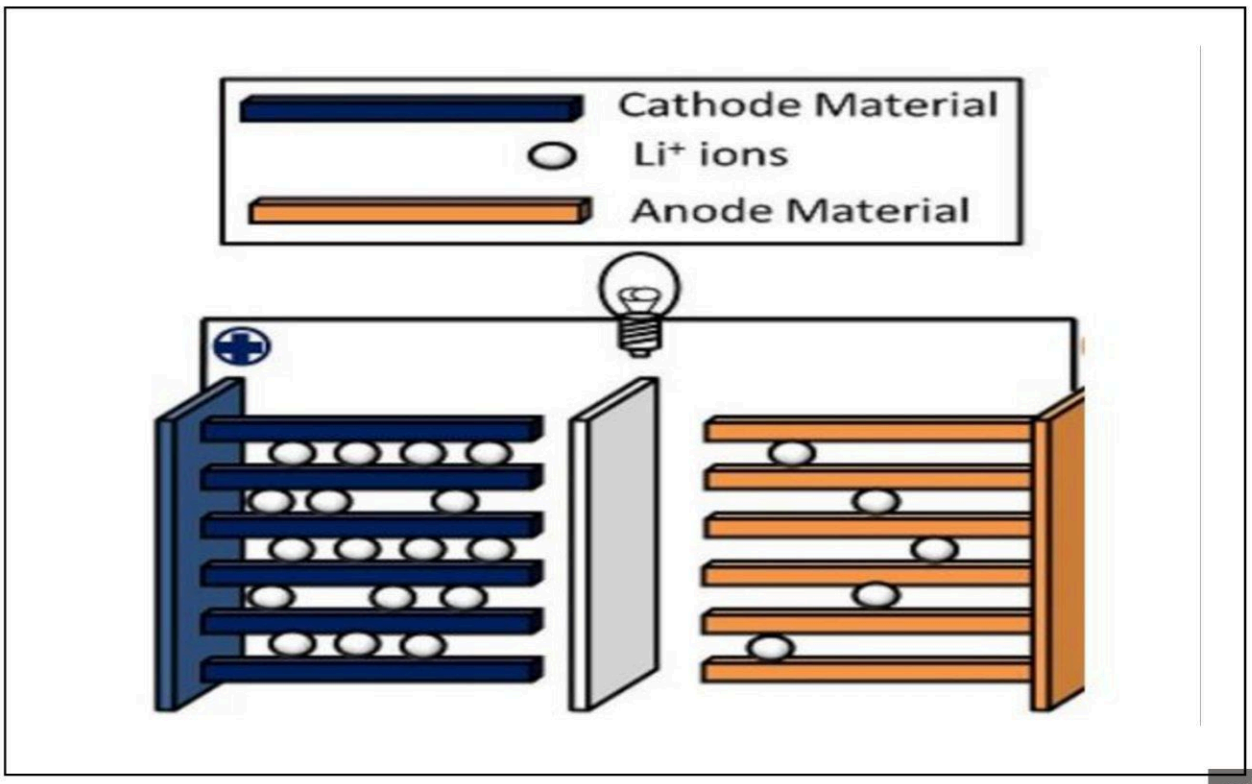
7.Lithium-Ion BATTERY

The Nobel Prize in Chemistry 2019 was awarded jointly to John B. Goodenough, M. Stanley Whittingham and Akira Yoshino "for the development of lithium-ion batteries."

❖ WHAT IS A LITHIUM-ION BATTERY AND HOW DOES IT WORK ?

A lithium-ion battery is an advanced battery technology that uses lithium ions as a key component of its electrochemistry. During a discharge cycle, lithium atoms in the anode are ionized and separated from their electrons. The lithium ions move from the anode and pass through the electrolyte until they reach the cathode , where they recombine with their electrons and electrically neutralize. The lithium ions are small enough to be able to move through a micro permeable separator between the anode and cathode . In part because of lithium's small size (third only to hydrogen and helium), Li-ion batteries are capable of having a very high voltage and charge storage per unit mass and unit volume.

Li-ion batteries can use a number of different materials as number of different materials as electrodes . The most common combination is that of lithium cobalt oxide (cathode) and graphite (anode),which is most commonly found in portable electronic devices such as cellphones and laptops. Other cathode materials include lithium manganese oxide(used in hybrid electric and electric automobiles) and lithium iron phosphate .Li-ion batteries typically use ether (a class of organic compounds) as an electrolyte.

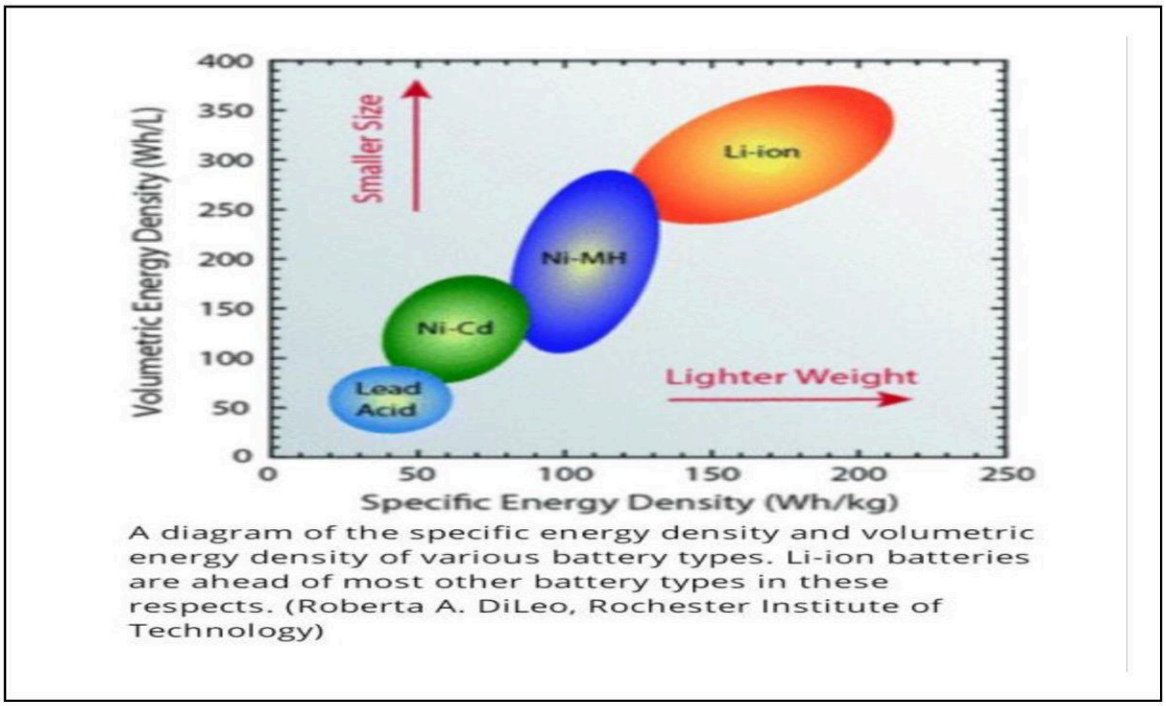


Schematic of lithium-ion battery

❖ What are some advantages of lithium-ion batteries?

Compared to the other high-quality rechargeable battery technologies (nickel-cadmium or nickel-metal-hydride), Li-ion batteries have a number of advantages. They have one of the highest energy densities of any battery technology today (100-265 Wh/kg or 250-670 Wh/L). In addition, Li-ion battery cells can deliver up to 3.6 Volts, 3 times higher than technologies such as Ni-Cd or Ni-MH. This means that they can deliver large amounts of current for high-power applications, which has Li-ion batteries are also comparatively low maintenance, and do not require scheduled cycling to maintain their battery life. Li-ion batteries have no memory effect, a detrimental process where repeated partial discharge/charge cycles can cause a battery to 'remember' a lower capacity. This is an advantage over both Ni-Cd and Ni-MH, which display this effect. Li-ion batteries also have low self-discharge rate of around 1.5-2% per month. They do not contain toxic cadmium, which makes them easier to dispose of than Ni-Cd batteries.

Due to these advantages, Li-ion batteries have displaced Ni-Cd batteries as the market leader in portable electronic devices (such as smartphones and laptops). Li-ion batteries are also used to power electrical systems for some aerospace applications, notable in the new and more environmentally friendly Boeing 787, where weight is a significant cost factor. From a clean energy perspective, much of the promise of Li-ion technology comes from their potential applications in battery-powered cars. Currently, the bestselling electric cars, the Nissan Leaf and the Tesla Model S, both use Li-ion batteries as their primary fuel source.



A diagram of the specific energy density and volumetric energy density of various battery types. Li-ion batteries are ahead of most other battery types in these respects. (Roberta A. DiLeo, Rochester Institute of Technology)

❖ How are lithium batteries different from lithium-ion?

In short, lithium-ion batteries are rechargeable whereas most lithium batteries aren't. Li-ion batteries are able to be recharged hundreds of times and are more stable. They tend to have a higher energy density, voltage capacity and lower self-discharge rate than other rechargeable batteries. This makes for better power efficiency as a single cell has longer charge retention than other battery types.

Benefit Categories	Lithium-Ion (Li-on)	Lead Acid (Water Based) Battery
Maintenance	X	
Longevity/ Lifetime Value	X	
Charging	X	
Safety	X	
Sustainability	X	
Cost		X

Written By

~ *Pushpita Dutta*

8. 2020 Nobel Prize in Chemistry

The 2020 Nobel Prize in Chemistry has gone to Emmanuelle Charpentier and Jennifer A. Doudna "for the development of a method for genome editing."

CRISPR/Cas9 technology has introduced new opportunities in cancer therapies, curing inherited diseases and also in plant inbreeding.

Emmanuelle Charpentier and Jennifer Doudna were awarded the Nobel Prize in Chemistry 2020 for discovering one of gene technology's sharpest tools: the CRISPR/Cas9 genetic scissors.Using components of the CRISPR system, researchers can add, remove, or even alter specific DNA sequences. This technology has introduced new opportunities in cancer therapies, curing inherited diseases and also in plant inbreeding .

❖ Why the name CRISPR/Cas?

CRISPR is an abbreviation for clustered regularly interspaced short palindromic repeats.These sequences are a part of the bacteria's immune system. Bacteria that have survived a virus infection add a piece of the genetic code of the virus into its genome as a memory of the infection. In addition to these CRISPR sequences, researchers discovered special genes called CRISPR-associated, abbreviated as cas.

❖ Introduction

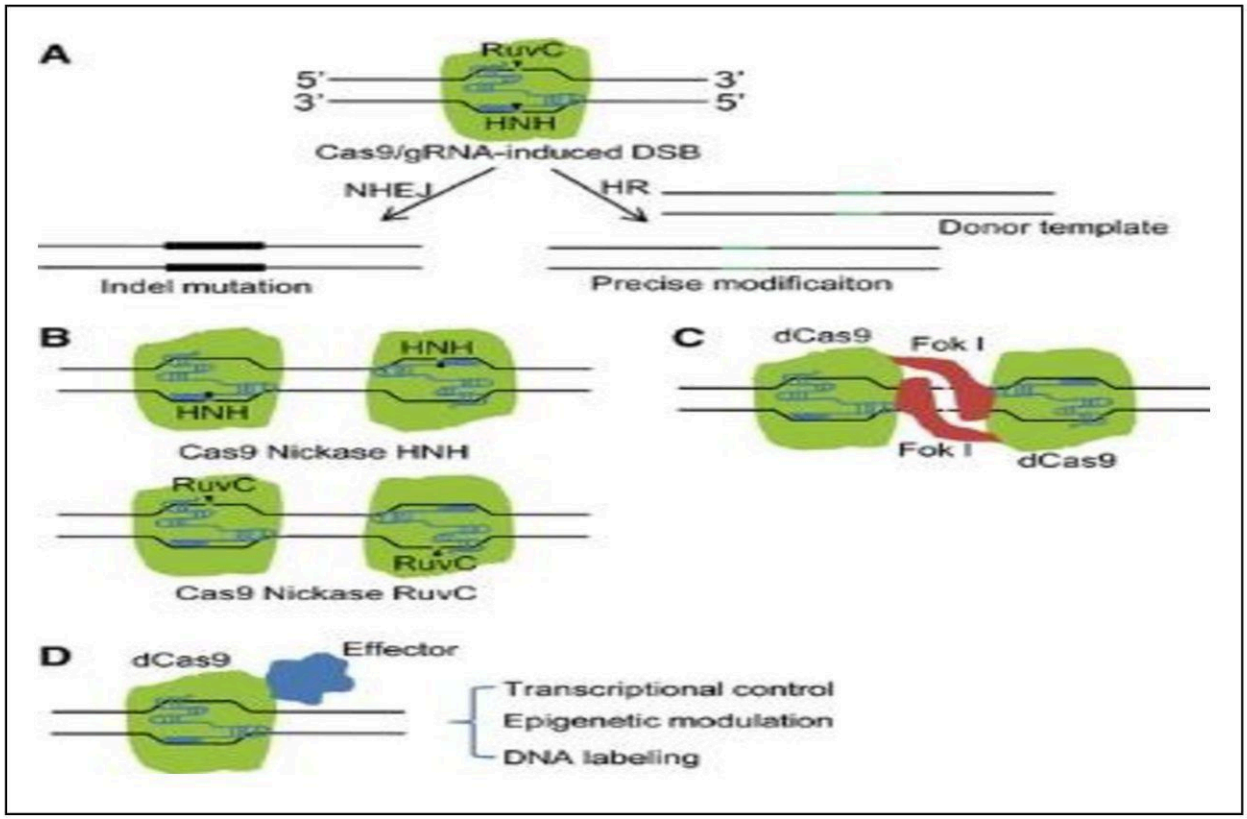
Precise modification of specific sites within a gene of interest is considered to be a standard approach to elucidate gene function, to create disease animal models, and to improve desired characteristics of animals and plants. Targeted gene modification also provides the potential for therapeutic applications. In the past decades, strategies for precise genome modifications using embryonic stem cell-mediated modification by homologous recombination were limited to certain organisms. Recently, engineered nucleases, including zinc finger nucleases, transcription activator-like effector nucleases, and clustered regularly interspaced short palindromic repeats (CRISPR)–CRISPR-associated protein (Cas) have provided a much simpler and more economic method for gene-targeted modification . These engineered nucleases generate a DNA double-strand break (DSB) at the targeted genome locus. The break activates repair through error-prone nonhomologous end joining (NHEJ) or homology-directed repair (HDR). In the absence of a template, NHEJ is activated, resulting in insertions and/or deletions (indels) that disrupt the target loci. In the presence of a donor template with homology to the targeted locus, the HDR pathway operates, allowing for precise mutations to be made

❖ Engineering CRISPR–Cas9 for genome editing

RNA-guided DNA cleavage systems protect bacteria and archaeons against invading DNA contaminants, serving as an adaptive immune system. The process is quite complicated. The invading foreign DNA can be recognized and inserted into a genome locus to form a CRISPR region; the captured foreign DNA sequences are termed protospacers. In type II CRISPR systems, the CRISPR locus is transcribed into a pre-CRISPR RNA, and processed to a matured crRNA with the assistance of tracrRNA. Interaction between crRNA and tracrRNA directs SpyCas9 to recognize the specific DNA sequence complementary with the protospacer. This RGEN target site is usually 20 bp in length and must be immediately adjacent to the NGG motif, or sometimes NAG (with much lower cleavage efficiency), which are known as protospacer adjacent motifs (PAMs). The programmable crRNA and fixed tracrRNA are fused to form an sgRNA, which directs Cas9 to the desired site and catalyzes the cleavage of both DNA strands effectively.

Cas9 contains the RuvC and HNH nuclease domains (Fig. 1). The HNH domain is a single domain, whereas the RuvC domain consists of three subdomains. Single-particle electron microscopy reconstructions of SpyCas9 showed an sgRNA-guided structural change forming a central channel for the RNA·DNA heteroduplex . Later, the high-resolution structure of SpyCas9 in complex with guide RNA and target DNA showed a bilobed architecture including a target recognition lobe and a nuclease lobe . The nuclease lobe is composed of an HNH nuclease domain, a RuvC nuclease domain, and a C-terminal region. The HNH and RuvC nuclease domains

are responsible for the cleavage of the complementary and noncomplementary DNA strands of the target sites.



CRISPR–Cas9-mediated genome editing. (A) Cas9·sgRNA-induced DSBs can be repaired by either NHEJ or by HDR pathways. Cas9 contains RuvC and HNH nuclease domains, each of which is responsible for cleavage of one DNA strand. (B) Paired nickases were used to improve the specificity in the genome editing. Cas9 nickase (HNH) cleaves only the DNA strand (complementary strands of the target DNA) recognized by the sgRNA. Cas9 nickase (RuvC) cleaves the DNA strand (noncomplementary strands of the target DNA) not interacting with the sgRNA. (C) dCas9 (both HNH and RuvC nuclease domains are inactivated by mutation) is fused with Fok I nuclease to improve the specificity of genome editing. (D) dCas9 fused with an effector domain, such as DNA methylases, demethylases, histone acetylases, deaceylases, and kinases, to provide the specific chromatin modifications for desired effects.

❖ Conclusions

In summary, the simplicity and high efficiency of the CRISPR–Cas9 system allows affordable genome editing. In addition, the large sgRNA library will make both drug target identification and function screening more efficient. This RNA-guided genome-editing tool also gives rise to the potential to change the genetic landscape of animals and plants around us to obtain the desired genotypes at will.

The application of this system has been expanded beyond genome editing, to areas such as gene expression regulation and specific chromatin labeling with fluorescent protein. Although great advances have been made in improving the specificity and expanding the application of this technology, there is still plenty of room for improvement and extension.Undoubtedly, the basic research will make its way into clinic practise. Further optimization and development of next-generation CRISPR–Cas9 tools for genome and epigenome editing is expected to satisfy the requirements for therapeutic applications.

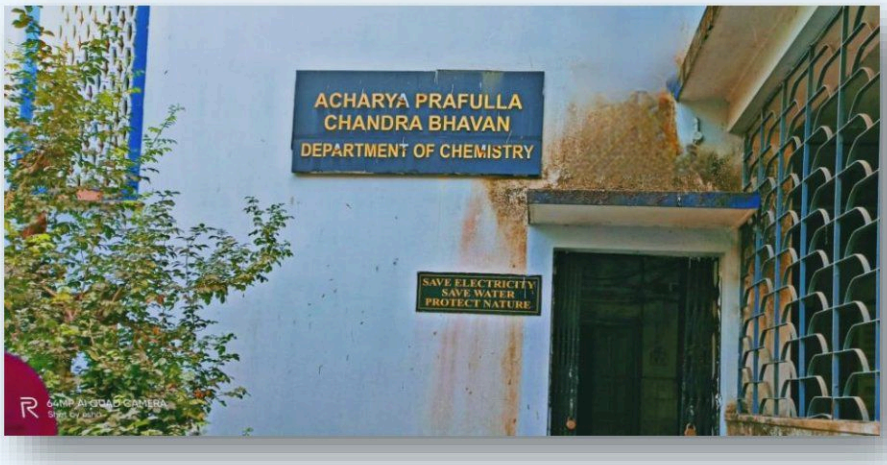
❖ Acknowledgements

We thank Dr Xin Lou from Model Animal Research of Nanjing University for careful reading and editing of the manuscript. We thank the entire Zhang Laboratory and Huang Laboratory for their support and advice. This work was supported by grants from the 973 program (2011CB944301 and 2012BA139B02).

Written By

~ *Sanam Ali*

About the department



The Department of Chemistry set out its journey in 1950 as the Intermediate level under the University of Calcutta. In 1961, the Pass course in the B.Sc level was introduced in the department and in 1967 the department was further upgraded for teaching Honours in Chemistry. The department is enriched with dedicated teachers and well-equipped laboratories.