ISSUE 10

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COGITO-137

THE THOUGHT CAPSULE

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Cogito137
The Thought Capsule

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EDITOR'S WORDS

ARUNITA BANERJEE

In sync with last year, our December 2021 issue has been curated and themed around Nobel winning sciences of this year. We invited individuals who are pursuing dissertation-oriented research in fields associated with the Nobel-winning sciences, or have researched the topic with due personal interest, to write the articles. We are grateful to the students and alumni of IISER Kolkata and others who contributed articles for our December 2021 issue.

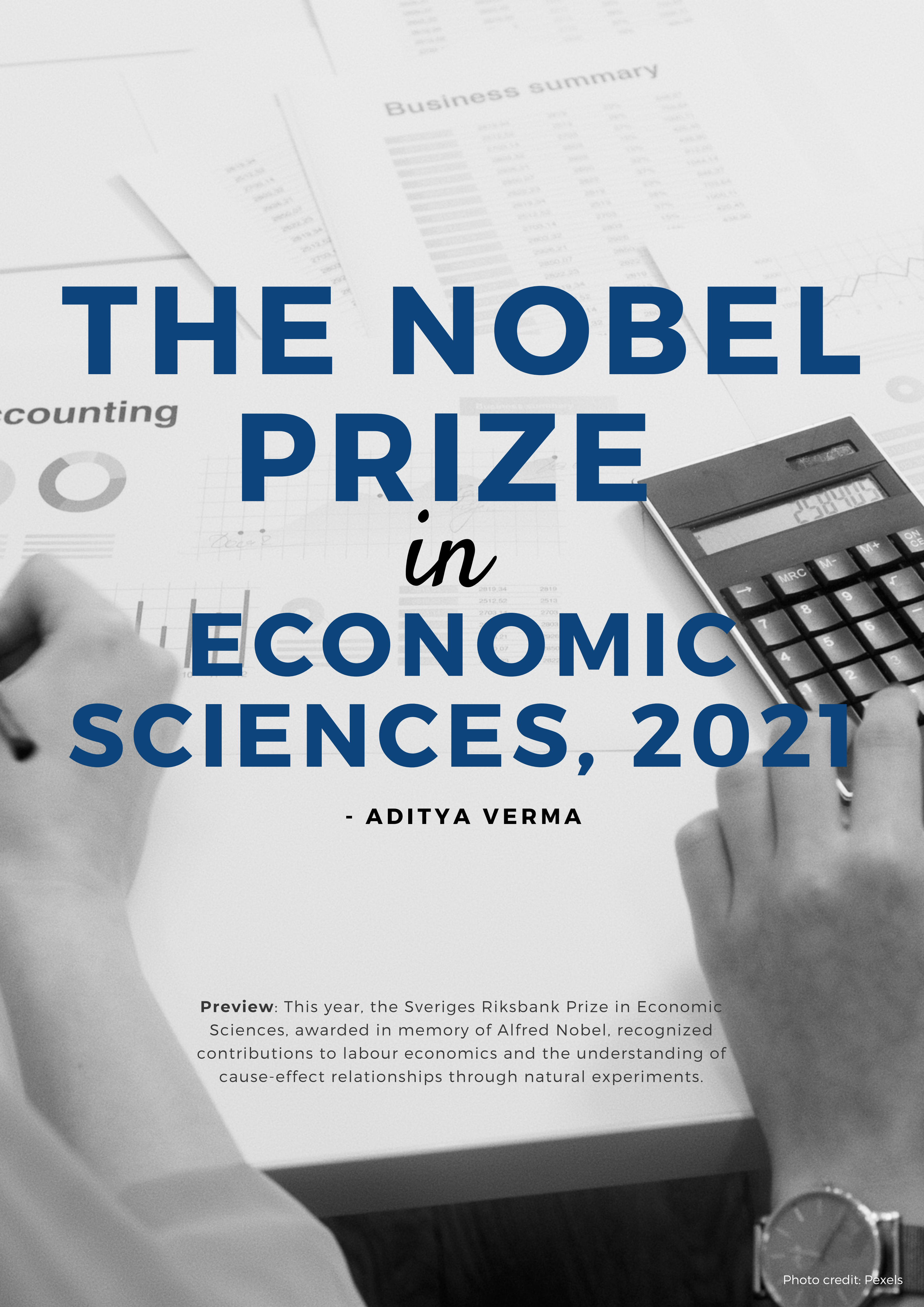
With the hope of broadening our horizons and the scope of Cogito137, we have started venturing into interdisciplinary projects and partnerships. We primarily aim to popularise science and scientific research, but have now begun to holistically tailor our content to encapsulate 'science and society' influences into our work. Alongside articles on the basic science categories in which Nobel Prizes are awarded - Physics, Chemistry, Physiology and Medicine; we have also included articles about the Nobel prizes in Economics and Peace categories, in this issue.

The Nobel Prizes 2021 are a reflection of some of the most prominent concerns and solved puzzles of today's world and it is indeed heartening to see such work receiving recognition of the highest order. The articles in this issue attempt to simplify the complex and state-of-the-art research and processes, which are equally technical and elegant.

This issue also marks Team Cogito's successful functioning for two years. Since our inception in November 2019, we have strived to maintain credibility in our publications across various formats - text/art/videos. We invite everyone who is enthusiastic about communicating science to submit content of their choice, to our platform. Students and alumni of IISER Kolkata are most welcome to join our dynamic team and work with us. Write to us: scicomm@iiserkol.ac.in with feedback, suggestions, regular column ideas, video podcast ideas, collaboration invites or other content ideas.

We will be back with our 2nd anniversary edition in February 2022.
Wishing all of you a merry christmas and a happy new year!
Stay safe and take care!

-Arunita Banerjee
Chief Editor, Cogito137



THE NOBEL PRIZE *in* ECONOMIC SCIENCES, 2021

- ADITYA VERMA

Preview: This year, the Sveriges Riksbank Prize in Economic Sciences, awarded in memory of Alfred Nobel, recognized contributions to labour economics and the understanding of cause-effect relationships through natural experiments.

Photo credit: Pexels

THE NOBEL PRIZE IN ECONOMIC SCIENCES, 2021

Aditya Verma

Photo credit: Boundless Immigration

On 11 October 2021, an official press release issued by the Royal Swedish Academy of Sciences disclosed the names of those who will receive the Sveriges Riksbank Prize in Economic Sciences in Alfred Nobel's honour. One half was awarded to David Card (Univ. of California, US) "for his empirical contributions to labor economics" while the other half jointly to Joshua D. Angrist (MIT, Cambridge, US) & Guido W. Imbens (Stanford Univ., US) "for their methodological contributions to the analysis of causal relationships". This year's laureates have shown how natural experiments can help us understand the conclusions about cause and effect. This new interdisciplinary insight and approach have revolutionized empirical research. They received a prize amount of 10 million Swedish Kronor (or approx. 8.7 crore INR), with one half to David Card and the other half equally distributed between Joshua Angrist and Guido Imbens.

The concept of 'cause and effect' has a critical role in answering some of the biggest questions in the social sciences. For example:

How does immigration influence earnings and employment levels? What is the impact of long-term education on a person's future income?

The uncertainty of completion of one's education and more or less immigration often make the problem more difficult because we've almost negligible examples for such comparisons. However, David Card (born 1956 in Guelph, Canada), Joshua D. Angrist (born 1960 in Columbus, Ohio, USA), and Guido W. Imbens (born 1963 in the Netherlands) have shown the possibility of answering such complex questions with the help of "Natural Experiments". Similar to clinical trials, the situation is used where chance events or policy changes affect a group of people.

David Card analyzed the labor market for effects of education, immigration, and minimum wages, by using natural experiments. His research in the early 1990s challenged traditional thought, leading to new analyses and further insights. Consequence showed that among other things, enhancing the minimum wage doesn't inevitably lead to fewer jobs. The income of people who immigrated at an earlier time risk being negatively affected while fresh immigration can boost the income of those who were born in a country.

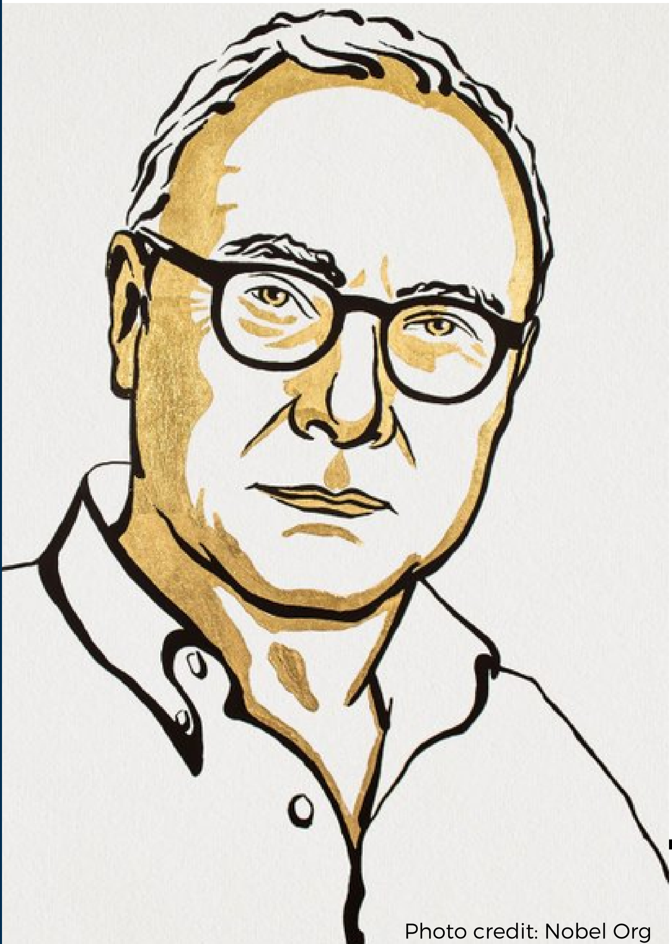
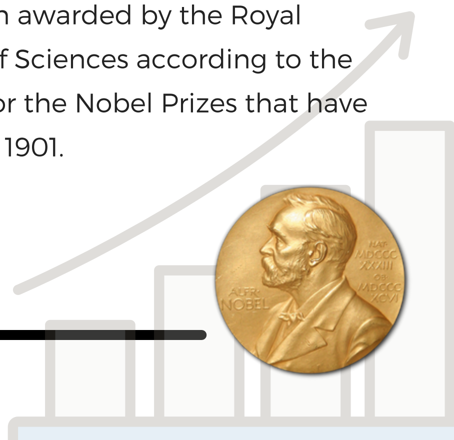


Photo credit: Nobel Org

Card's work led to significant insights, like the realization of the importance of resources in schools so that the success of its students in the future labour market can be ensured. Data obtained from natural experiments are quite complicated to interpret. For example, an extension of compulsory education by group A for a year won't affect everyone in that same group. Some students would have kept studying anyway and the value of education (as perceived by them) is often not representative of the whole group. So, it's hard to draw any conclusion about the impact of an extra year in school. Joshua Angrist and Guido Imbens succeeded to solve this complex methodological problem, by demonstrating how precise conclusions about cause and effect can be drawn from natural experiments, during the mid-1990s.

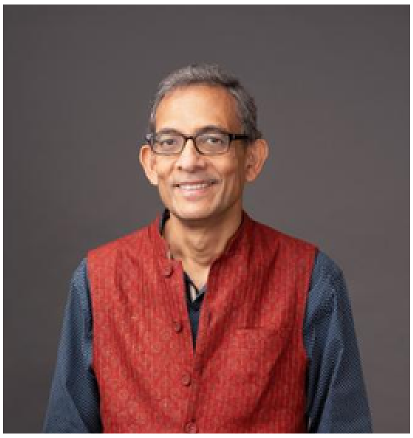
"Card's studies of core questions for society and Angrist and Imbens' methodological contributions have shown that natural experiments are a rich source of knowledge. Their research has substantially improved our ability to answer key causal questions, which has been of great benefit to society,"
says Peter Fredriksson, chair of the Economic Sciences Prize Committee.

In 1968, Sveriges Riksbank (Sweden's central bank) instituted "The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel", and it has since been awarded by the Royal Swedish Academy of Sciences according to the same principles as for the Nobel Prizes that have been awarded since 1901.



INDIAN NOBEL LAUREATES IN ECONOMICS

Abhijit Banerjee



Born on 21 Feb 1961 in Calcutta, India- Award year: 2019- "For their experimental approach to alleviating global poverty".

An India-born naturalized American economist who is currently the Ford Foundation International Professor of Economics at MIT, USA. Banerjee shared the Nobel in 2019 with his wife Esther Duflo (French-American economist) currently Professor of Poverty Alleviation and Development Economics at MIT, USA and, Michael Kremer (American development economist) "for their experimental approach to alleviating global poverty".

Amartya Sen:

Born in 3 Nov. 1933 in Shanti Niketan, West Bengal. Award year: 1998- "For his contributions to welfare economics":

An Indian economist and philosopher, who since 1972 has taught and worked in the United Kingdom and the USA. He's currently a Thomas W. Lamont University Professor, and Prof. of Economics and Philosophy at Harvard University.

WOMEN NOBEL LAUREATES IN ECONOMICS

1. Elinor Ostrom (USA): In 2009 for her analysis of economic governance, especially the commons. Shared with Oliver E. Williamson (USA).
2. Esther Duflo (French-American): In 2019 for their experimental approach to alleviating global poverty. Shared with her husband Abhijit Banerjee (Indo-American) and Michael Kremer (USA).

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- https://youtu.be/nUTRasDkXK0

About the authour

Aditya Verma is an Integrated PhD student in the Department of Earth Sciences, currently in his second year.

The Nobel Peace Prize Awards

Photo by **Engin Akyurt** from **Pexels**

SAYAK DASGUPTA

The 2021 Nobel Peace Prize awards came at a critical juncture amidst the ongoing crackdown by governments and private corporations on the institutions of free press and freedom of expression. This article brings forth the struggles and successes of the two recipients of the award, and also throws light on the importance of the free press in a world where yellow journalism has been evergrowing.

There has been much debate surrounding why Dr. Alfred Nobel, a war profiteer, included the Peace Prize in his will along with the other categories of the Nobel Prize. According to Nobel's will, the Peace Prize recipient should have done "the most or best to advance fellowship among nations, the abolition or reduction of standing armies, and the establishment and promotion of peace congresses."

However, previous recipients of this coveted Prize indicate otherwise. The European Union, one of the largest manufacturers and exporters of weapons, was awarded the Prize in 2012. Abiy Ahmed, the fourth and current Prime Minister of Ethiopia, within a few months after being conferred the Prize initiated military crackdowns on minority groups in the Northern Tigray region of the country, causing grave Human Rights violations. The pro-democracy leader of Myanmar, Aung San Suu Kyi, the winner of the award in 1991, provided immunity to the Tatmadaw or the Armed forces of Myanmar from the international community in light of events associated with ethnic violence against the Rohingya Muslim population.

Winners of 2021

The declaration of the 2021 Nobel Peace Prize winners comes at a critical juncture when freedom of the press and expression has become faint in the light of high profile global setbacks such as the coup d'etat in Myanmar, the reinstatement of the Taliban in war-torn Afghanistan, and also to mention, several incidents of arbitrary killings of journalists in broad daylight by gatekeeping elements of the society and that of the government. Dmitry Andreyevich Muratov from Russia and Maria Angelita Ressa from the Philippines received the Nobel Peace Prize this year for "their courageous fight for freedom of expression" in their respective countries.

Photo by **Nataliya Vaitkevich** from **Pexels**

Having spent decades for his efforts, Dmitry Muratov received the award for fighting restrictions on free press in an authoritarian Russia. In the mid-1980s, he worked as a reporter for *Volzhsky Komsomolets* (Volzhsky Young Communist League), and later moved to *Komsomolskaya Pravda* (Young Communist League Truth). Following the dissolution of the Soviet Union in 1991, he and many other former journalists from *Komsomolskaya Pravda* collectively founded *Novaya Gazeta* in Russia. It is reported that Michael Gorbachev, the former and last President of the erstwhile Soviet Union, supported their establishment with some financial assistance, from the 1990 Nobel Peace Prize award money that he won for ending the Cold War. *Novaya Gazeta* has played a pivotal role through the Russian daily in shedding light on the tumultuous situation in Chechnya and the Northern Caucasus. Muratov is its current Editor-in-Chief, often referred to as the face of the newspaper.

Novaya Gazeta's fight for free press and freedom of expression came with significant costs. In the early 2000s, six reporters associated with *Novaya Gazeta* were killed as they reported on groundbreaking issues like corruption, crime and other alleged abuses. Muratov believes that the Nobel Prize was collectively won by all the contributing factors of his newspaper. In a United Nations News interview on 15th October, the Nobel laureate revealed that he will not take or receive even one single cent of the prize money. He added that the Editorial Board of *Novaya Gazeta*, in a meeting, decided how the prize money will be distributed.

"It will be donated to a health foundation that helps journalists; to a foundation that supports children with spinal muscular atrophy and other serious rare diseases; a part will go to the Anna Politkovskaya Prize Foundation; and, of course, a part will go to the children's hospice in Moscow, the Vera Foundation and the Dmitry Rogachev Clinic, where children with leukaemia are treated," said Dmitry.

Popularly referred to as the "woman who single-handedly confronts tyranny", Maria Ressa was conferred the Nobel Peace Prize jointly with Dmitry Muratov for using freedom of expression to expose abuse of power and growing authoritarianism in her native country, the Philippines. Her notable contributions in exposing fake news on social media and other interactive platforms have attracted the attention of the entire international community.

After moving to the United States of America, following the declaration of martial law in the Philippines, the Princeton attendee, Ressa received a Fulbright scholarship to study in Manila. At the initial stage of her career, she worked as a journalist for ABS-CBN in the Philippines, and later for a government-owned network called People's Television Network (PTV). Eventually, she got recruited by the Cable News Network, popularly referred to as CNN. During her tenure in CNN, Ressa covered news all around the South-East Asian countries. She became the Bureau Chief of CNN in Manila from 1987 to 1995, and in Jakarta for a duration of ten years from 1995.

Ressa co-founded Rappler, which became one of the first multimedia news websites in the Philippines and a major news portal in the country, receiving numerous local and international awards. "Rappler" comes from the root words "rap (to discuss)" and "ripple (to make waves)". It was born to a new world of possibilities – driven by uncompromising journalism, enabled by technology, and enriched by communities of action.

The laureate has been arrested on numerous occasions by the Philippines' authorities. Her latest arrest happened under the pretext of the controversial cybercrime law of the Philippines, also known as "cyber libel". Her arrest is widely referred to as a politically motivated action due to her hardline approach towards criticizing the incumbent Duterte's regime.

The Nobel Committee, in its press release, noted that "Rappler has focused critical attention on the Duterte regime's controversial, murderous anti-drug campaign. The number of deaths is so high that the campaign resembles a war waged against the country's own population. Ms Ressa and Rappler have also documented how social media is being used to spread fake news, harass opponents and manipulate public discourse."

Conclusion :

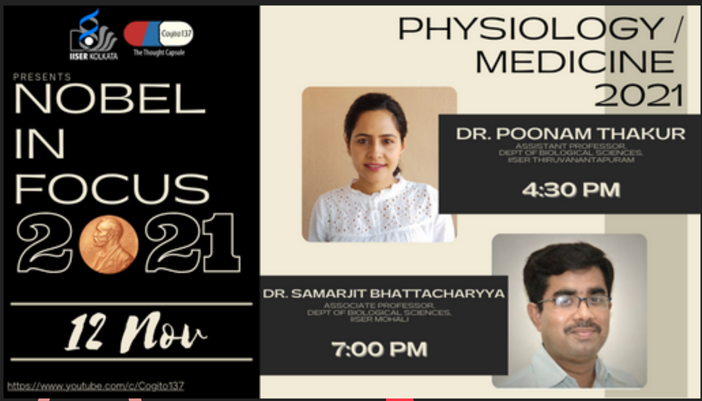
While certain critics of this year's recipients of the Nobel Peace Prize believe that the prizes were a move by the Western Nations in promoting their propaganda, it is true that freedom of the press ensures the safeguarding of the rights of the general people and promotes free and open struggle for dissent.

The two awardees have been instrumental in handholding free and fair journalistic ventures worldwide. In the words of Ressa, the future of journalists and journalism will depend on how well the fraternity carries out its work in the days to come.

Author's Bio - Sayak Dasgupta is a second-year undergraduate student from Jadavpur University. His main interest lies in observing the international political environment, debating, and reading books and commentaries by diplomats on various geopolitical happenings from time to time.

Do you know what we do here at Cogito137?

Watch Episode 1 to learn more about us!



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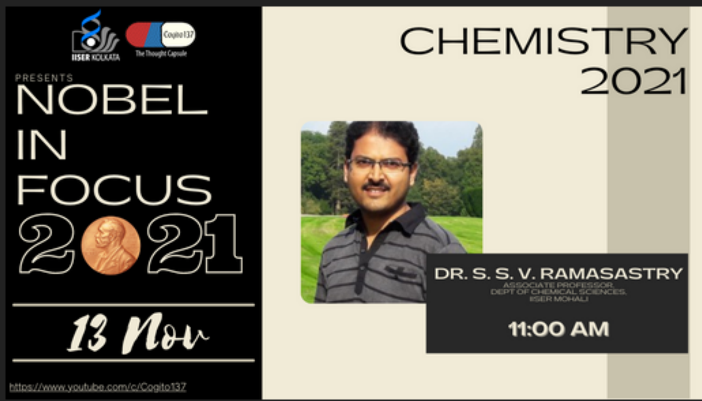


NOBEL IN FOCUS 2021

On Youtube

WRITTEN BY : SAPTARSHI MAJI

THE 'NOBEL' FEELING – UNDERSTANDING HOW WE 'FEEL' THE WORLD AROUND US.

Preview: We all react to touch and heat, but how do we perceive that sensation? This article talks about the mechanism of touch and temperature receptors that won the Nobel prize in Physiology and Medicine in 2021.

Photo credit: Pexels


Photo credit: Live Mint


Photo credit: Envato Elements

The 'Nobel' Feeling - Understanding how we 'feel' the world around us.

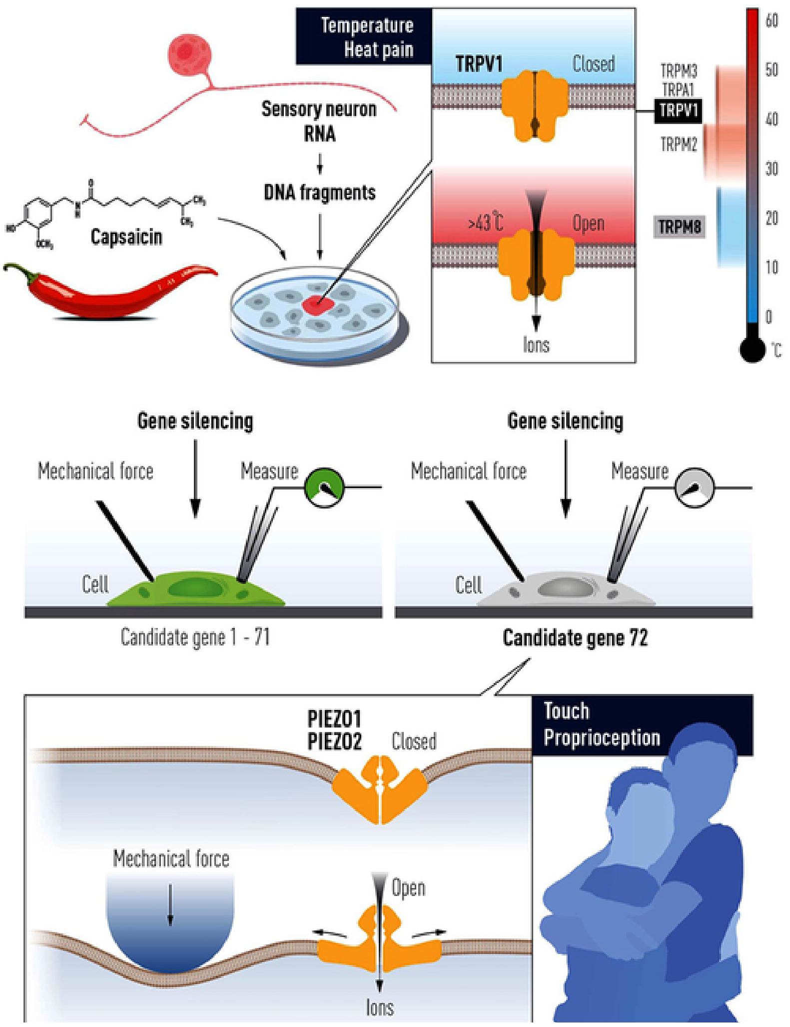
Saptarshi Maji

Vision, smell, taste, hearing, and touch; are the five senses that help us understand the environment surrounding us. These are not only the most fundamental inputs from the environment but also the most important for surviving in one. The basic understanding of how we perceive these senses has always been thought-provoking to scientists.
An in-depth understanding of senses like vision, smell, taste, or hearing was described by scientists much earlier. Hungarian biophysicist Georg von Békésy was awarded the Nobel in 1961 for his discoveries of the physical mechanism of stimulation within the cochlea (a part of the inner ear which enables hearing), which converts the sound wave into electrical stimuli. Six years later,

Ragnar Arthur Granit, along with Haldan Keffer Hartline and George Wald, received the Nobel prize in physiology or medicine for their discoveries in understanding the primary physiological and chemical processes in the eye, that are important for our vision. In 2004, American molecular biologists Richard Axel and Linda B. Buck were awarded the Nobel in the same category for their work on the smell-identifying odorant receptor and organization of the olfactory system.

. Senses like the feeling of touch have always been neglected. Skin, the largest organ of our body, has the highest amount of interaction with the environment and provides us with necessary information about our surroundings like temperature, wind, touch, etc. Back in the 17th century, French philosopher René Descartes proposed the presence of 'threads' spread all over our body which are connected to the brain and are responsible for relaying these messages. Later it was found that these threads are sensory neurons that keep track of changes in the environment. Not only that, but these neurons are also highly specialized in registering different types of stimuli.

To feel any sensation, a physical stimulus is converted into an electrical signal. Only then, our body perceives the sensation. In 1944, American physiologists Joseph Erlanger and Herbert Gasser won the Nobel prize for their work on the specialization of neurons or nerve cells. They confirmed that to feel any sensation, a physical stimulus activates a neuron, results in a voltage difference and secretion of messenger chemical substances which propagates to the next neuron and thus reaches our brain in a relay process. But how heat or a physical force is transformed into an electrical signal in our nervous system remained unanswered for a long time. This year, the Nobel prize in physiology or medicine was awarded to Ardem Patapoutian and David Julius for their work on understanding this question.
In the early '90s, David Julius started his career as faculty at the University of California, San Francisco. His work was mainly on different receptors, necessary for different types of moods that we feel. One of them was to find the receptor for capsaicin, a chemical substance in chili pepper causing burning sensation when touched. From previous knowledge, it was already known that capsaicin causes pain sensation by activating nerve cells. In their quest for the capsaicin receptor, they first made a library of genes in the nerve cells.
Since nerve cells are activated in the presence of capsaicin, one of the genes should be responsible for this activity.



drishtiias.com/Nobel Prize for Physiology/Medicine, 2021

Next, they started expressing the genes in non-neuronal cells one by one and began monitoring their activity in response to capsaicin. In 1997, the quest, which was similar to searching for a needle in a haystack, ended with finding the receptor for capsaicin. The newly found protein was named TRPV1, which was found to be a channel protein. As the name suggests, channel proteins are a group of membrane-embedded proteins that connect two sides of the membrane. Channel proteins are highly specialized in transporting specific or a group of specific small molecules (mostly ions and water molecules). In this case, TRPV1 was found to be a nonspecific cation channel that, when activated, imports cations (positively charged ions) into the cell. In this particular case, mostly sodium (Na+) and calcium (Ca2+) ions are imported into the cell, as their concentration is several fold higher outside of the cell than inside).

This results in a change in the ionic balance inside the cell that stimulates the nerve cell. Surprisingly, they found, this channel is also active in response to heat.

And that is how they discovered the first-ever heat-sensitive receptor that causes a similar painful experience as chili pepper does.

The scientists overcame the main problem in working with heat receptors, that is, stimulating heat sensor-protein using high temperature can kill the cells in a laboratory culture petri dish. Although, the exact mechanism of how heat activates TRPV1 is still not known.

Later, they discovered numerous other heat-sensing receptors in different animals with various temperature ranges for activation. For example, TRPV4, another heat-responsive protein, has an activity range of 27°-34°C and is vital for the hibernation of reptiles. In cold temperatures, the expression of this receptor is reduced in most of the tissues except the skin, which helps in sensing the environmental conditions during the hibernation period.

TRPV8, another cold receptor, was discovered independently by Ardem Patapoutian, the other Nobel awardee of this year. Interestingly, instead of capsaicin, menthol, a cooling substance, was found to activate this specific receptor.

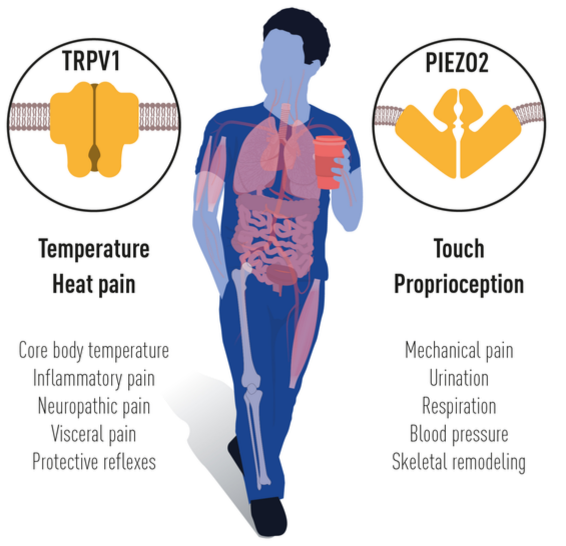
Ardem Patapoutian, assistant professor at Scripps Research in La Jolla, California, was also working on how physical pressure is converted into a nerve signal. Numerous mechano-sensors were already discovered in bacteria but none in higher animals. Patapoutian and his collaborators first identified a specific cell line that produces some electric signal when poked. Similar to the method opted by Julius, Patapoutian also made a library of genes. But unlike Julius, who expressed the genes in a non-native cell line, Patapoutian started deactivating the genes one by one. Through the laborious process, they identified the 72nd gene that, when deactivated, produced no electric signal. This was the first-ever mechano-sensor or mechanical force sensor that was discovered in the higher animals. They named it Piezo1, after the Greek word for pressure (píesi). Later, they found another sensor very similar to Piezo1 which they named Piezo2.

Structural analysis shows that Piezo1 is a gigantic membrane protein that passes the membrane 37 times, which is known as the 'Transmembrane domain.' Three monomers of Piezo1 come together and aggregate to form the giant membrane protein. While one end of the protein forms a channel pore (hole like pathway), the remaining part of the protein is spread far away from the pore center, replicating a three-blade propeller-like structure. The large propeller part is responsible for mechano-sensing. Due to the large spread area of this protein, it can sense membrane undulations very rapidly, which in turn acts as a lever that opens the ion channel.

Piezo1 not only senses external pressure like touch, wind etc, but internal pressure as well, including blood pressure, urinary bladder control, etc. Our daily movement is highly dependent on responses from Piezo2 as it helps us in feeling the presence of ground under our feet and positioning our body accordingly. This process is also known as 'Proprioception.'

Intense research has continued in this field since the discovery of these receptors. Since both are somehow related to pain sensation, scientists are trying to use them for treatments of several diseases, e.g., chronic pain and many more.

Research on pressure and temperature receptors were an excellent addition to understanding the basic fundamentals of our senses and our perception of the world around us. The recognition of the discoveries by the highest scientific accolade was just a matter of time.



Author Bio:
Saptarshi Maji completed his Masters in Life Sciences in 2018 from IISER Kolkata and joined as Ph.D. student. Currently he is working on maintenance of copper homeostasis inside the cell under supervision of Dr. Arnab Gupta.

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SPINNING THE WORLD OF PHYSICS INTO CHAOTIC TERRITORY

PRAJWAL PADMANABHA

Complex systems are exactly as the name suggests, complicated. They are hard to understand and predict, and they are everywhere. This article talks about what makes them hard to understand and shows how scientists have overcome these difficulties, which led to them winning the 2021 Nobel Prize in Physics.

Photo credit: Pexels

SPINNING THE WORLD OF PHYSICS INTO CHAOTIC TERRITORY

Prajwal Padmanabha

Let us start simple. You have seen a bird fly. It pretty much flies where it wants. Maybe if it is a pigeon in Old Delhi, it flies towards seeds thrown by a kind human. Sometimes, you might see two or three birds flying together in formations that you'll find fascinating. On rare occasions, you might even see 10-15 birds flying in a striking formation and you pause to appreciate the beauty of nature.

If you are in a contemplative mood, you might wonder why they fly in a formation. This is where the real beauty appears. Thousands of tiny birds called starlings manage to fly in these incredible swarms that look like they are all being controlled by a supervillain from the comics. Somehow, these groups of thousands of individuals manage to coordinate and pull off this amazing feat. What is even more surprising is that this is not just limited to birds! If you observe closely, you will see this everywhere– in the oceans, on land, in the air, and even at microscopic levels where they amazingly manage to communicate through chemicals. The contrast here is that if a single or few individuals are left on their own, you are unlikely to observe these patterns. This is what lies at the core of complex systems! But this is also what makes complex systems hard to define.

Whenever physicists talk about complex systems, there is no precise definition that everyone uses. This is because we do not yet have an exact idea of what makes something complex. The job of defining complexity is made harder because there are different properties of systems considered to be complex, which may or may not overlap between two different systems. [ref] In certain cases, complexity might arise out of the number of variables that are needed to describe the system. In others, it might be a behaviour that emerges only when a group of particles are present. In some cases like the weather, a small change in the system might lead to large changes down the line, which is called chaotic behaviour.

While there lacks a single definition of complex systems, there are certain properties that occur commonly in systems considered to be complex. These properties are key to understanding a system.

One of the leading features of complexity is that of emergent behaviour, like the one described at the beginning of the article. Phenomena that are absent while dealing with a single component or a small number of components might be visible with larger numbers. These are systems showing collective behaviour in some ordered fashion and parameters usually controlling this behaviour. In models of swarming, this is randomness in the movement of birds. In physical systems, ordering is usually controlled by temperature. Transitions from disorder to order are some of the most important areas of study, which we will talk about again after looking at some more features of complexity.

Complex systems are also typically non-linear. A linear system is one where the effects are proportional to the amount of change a system experiences. Newton's laws of motion are a good example of linear effects of the force on acceleration of a body. But a complex system might exhibit non linear effects, which also ties in with the idea of chaos. An example of this could just be two pendulums connected to each other.

A swarm consisting of thousands of individuals
Picture credits: Unsplash

We pull any one of them to a certain point and release it, and then observe the positions of the two pendulums. If this is a lab experiment, we would repeat it to verify. That what we recorded the first time is correct. But now, if we accidentally shift the initial position of the pendulum even by a tiny bit, the resulting positions are very different! A very small change in the initial position leads to disproportionate change in the later position. This is an example of a nonlinear effect. This effect is commonly known as The Butterfly Effect, referring to how a flap of a butterfly's wing could lead to a hurricane at some point down the line.

Another aspect of complex systems which is important is critical transitions. Transitions as discussed earlier are changes in the state of the system, the most common example of which would be ice melting into water or water boiling to vapour. While transitions can be of many kinds, these are called phase transitions. Disorder to order phase that we discussed earlier is another kind. In our example of water boiling, we could measure the temperature and see that it is increasing steadily and then predict when the water would start boiling. But in the case of complex systems, it can usually be abrupt without any kind of warning signatures. The origin of this can lie in a lot of factors, like the number of elements in the system, the number of parameters that one would need to describe the system with a model, incomplete knowledge of all the processes of the system and so on. But such transitions that occur abruptly are of great importance and are called critical transitions.

A frequent characteristic of complex systems is memory. While this might seem strange, a lot of physical processes are memoryless. An appropriate example for this would be to consider a drunk person on the streets of Paris. While the person is an inherently biological system, for the purposes of our example, they might very well serve as a physical particle. This person has forgotten where they have come from and wanders around the streets trying to find their home. You take a map of the city and start marking where the person goes, and as expected, you notice that they are wandering aimlessly. You can try to think if they are moving in a particular direction and take their average position. You notice that all their wanderings are centered around the bar they exited from! This doesn't give you any information, so you try to see how far they are exploring on an average. You can mark the absolute distance from the bar while ignoring the direction. But an easier way to do this is just to take the distance travelled squared since it is going to be a positive number. You notice a particular pattern here – the longer they wander, the larger "area" they explore. This average displacement squared varies linearly with time. There is no memory associated in this example because it is inconsequential, at what time the person exited the bar initially . But complex systems frequently retain memory! The time at which you start or the parameters of the system at a particular instant become important. If the person is not drunk enough and remembers the positions they visited to find their way, it instantly adds memory into the system making it much harder to calculate quantities like we discussed. Complex systems sometimes have many such particles that retain memory, with the particles interacting between themselves. There are lots of other features of complex systems which can be described but the ones mentioned are some of the most frequent ones.

While the discussion on complexity and the different properties are not strictly necessary to understand the work of the Nobel laureates, it is demonstrative of how difficult the study of complex systems is. It helps us appreciate the breadth of phenomena that is covered by the systems. The work of Giorgio Parisi is fitting in the context of what we have discussed. His contributions to physics range from working on subatomic particles to the theory of fluid dynamics. The Nobel Committee's message for the prize reads- the award has been given to Giorgio Parisi "for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales." [ref] Specifically, the prize refers to his work on systems called Spin Glasses.

Newton's cradle: An example of a system that might look complicated but is simple to analyze and predict
Photo credits: Pexels

To understand this, let us consider a magnet. You remember that the North pole of a magnet attracts the South pole of another. Now imagine magnets pointing in different directions on a sheet of paper. Instead of laying flat on the paper, they are pointing upward towards different points. These magnets are called spins. Sometimes, spins like to point in the same direction as their neighbour and sometimes, they like to point in a completely opposite direction. The first kind of interaction is called ferromagnetic interaction and the latter is called antiferromagnetic interaction.

But it can also be possible that in one part of the sheet, the spins can be ferromagnetic, but in another part, they can be antiferromagnetic. When this happens, all the spins cannot be pointing in the same direction. This is what is called a disordered system.

Imagine three spins on three points of a triangle, all preferring to be antiferromagnetic. If the first spin points up, the second spin would point down. But the third spin is in a conundrum. It cannot point up or down because it would be violating antiferromagnetic preference with one of the neighbouring spins if it does so. This is what is called frustration, because the third spin is basically frustrated with its condition.

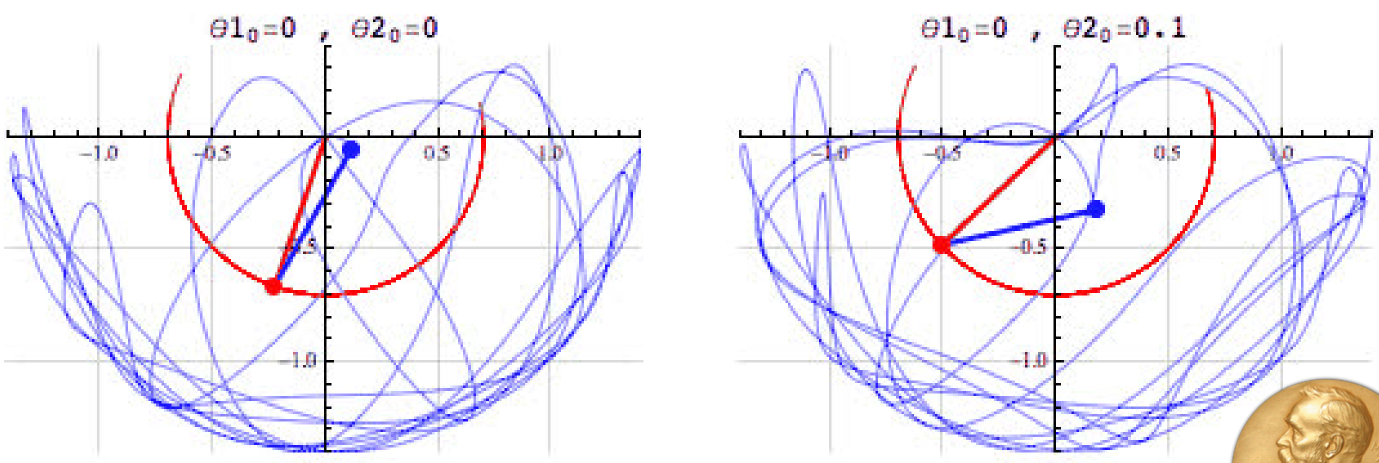
Spin glasses are essentially frustrated disordered systems. Each orientation of the spin would have a certain energy. If the spins are frustrated, their energy increases. Physical systems left on their own always like to have minimal energy. They are like us on a lazy winter morning. Because of this, in a frustrated disordered system, there is no single set of orientations of all the spins on the sheet that would have the least energy. Instead, there are multiple possibilities where the system is frustrated but with the same energy. By nature, all these possibilities are disordered with spins pointing in wildly different directions.

Let us consider the example of ice to water transition again, but now in reverse. If we lower the temperature of a tray of water, it gradually becomes ice. The state moves from free flowing liquid to rigid solid. The order of the system therefore increases because in ice, the molecules of water are arranged in a very predictable manner. The temperature is called the order parameter because it controls the order of the system.

Because of the very nature of spin glasses, it is not so easy to tell if a system is in a certain configuration either due to low temperature or because of the inherent disorder in the system. Giorgio Parisi employed a trick called the Replica Method. As the name suggests, it looks at two possible orientations of all the spins and considers how much they are a replica of each other. By looking at all possible pairs of orientations, he defined a new order parameter which helps us to know when the phase transition happens in spin glasses. Spin glasses are used in a variety of fields [ref]. Some of the few examples are computer science, optimization problems, finance modelling, biological evolution, and mechanism of protein folding. Considering the wide ranging applications of the theory, it is no surprise that a breakthrough in it has been awarded one of the most prestigious prizes in physics.

The second half of the Nobel prize has been awarded jointly to Syukuro Manabe and Klaus Hasselmann “for the physical modelling of Earth's climate, quantifying variability and reliably predicting global warming”.

To begin, some distinctions need to be made. Climate and weather are different. While climate constitutes long term patterns, weather is shorter and is subject to more fluctuations. We have tried to predict both the climate and weather since prehistoric times for agriculture and other purposes. But models of climate started in the 19th century when patterns of wind were mapped and scientists began looking for explanations of it based on very simple models of heated spheres. As time progressed, more complicated models began to appear that took into account more variables and parameters. But, the climate is a chaotic system. Even simple models of weather and climate show chaos.



Chaos shown by the double pendulum with a slight difference in the starting angle of one of the pendulums. The paths are seen to be very different, especially at long times.

So, it is expected that the real system is also chaotic. The system is also quite non linear making modelling difficult.

Syukuro Manabe considered a vertical column of air and mapped the flow of carbon dioxide within that column. He accounted for different processes and variables that have interplay between them. The result of those models? An estimate of 2.3 degrees increase in global temperature when the carbon dioxide concentration doubles. It is impressive to note that the estimate Manabe and his collaborators gave in 1967 with a computer that had only 5 Mb of RAM still remains accurate! [ref]

Weather on the other hand is short term fluctuations. Klaus Hasselmann considered climate to be an evolution of these short term fluctuations over a long time. He incorporated the random walk example we saw into the coupling between climate and weather which resulted in a simple set of equations that anyone could use quite easily. The general idea of including randomness into climate modelling led to stochastic climate modelling as a field. In particular, with stochastic climate models, Hasselman was able to connect his predictions to observations. Once the predictions match with the observations, it is possible to look at the model and start changing what goes into the model. Specifically, he was able to separate natural and human causes to changes in temperature. His work conclusively showed that the increase in temperature of Earth's atmosphere is due to human activity! [ref]

In today's “climate” of misinformation and fake news, it is necessary to have concrete research that attributes the effect of increasing emissions and linking human activity to rise in temperature. Manabe and Hasselman's work does exactly this and provides a base to develop more intricate models to capture more phenomena. Considering the long term impact of their research, it is not surprising that they were awarded the Nobel Prize.

Moore's law predicts that every year, computing power doubles while sizes of computers halve. Though we might be nearing the end of validity of the law, it has certainly proven to be accurate in the last few decades. The eruption of modern computing power has been immensely utilized by complex systems scientists. This is especially true when the models need to incorporate multiple parameters and variables. Having more computing power makes this easier, allowing further complicated models that can try to capture all information about the system. The field of complex systems is truly interdisciplinary. It manages to use tools from mathematics to build physical models that are applicable in biological fields.

Going forward, it will be possible to understand more complex phenomena. The device you are reading this article on is more powerful than anything we used to put humans on the moon. Standing at the precipice of this significant change, we would not be able to see the far reaching impact of what new science will bring us. Going back to safe global temperatures may not be as simple as going back to lower emissions and is likely to need more drastic measures. The knowledge to answer these questions and to chart a path to navigate through these troubled times can only come from more information about these systems. The recent Nobel prize will surely motivate more young researchers into the field and will lead to us unlocking more secrets of the beautiful world around us as long as we preserve it.

Prajwal Padmanabha is a PhD student in Physics trying to understand the applications of statistical physics to biology. Hopefully, by the end of it, he understands something at least.

The Asymmetric World: A Nobel Tale

By Subhajit Chakraborty

Photo credit: Pexels

Photo credit: Nobel Org

CATCH SOME WAVES IN

THE ASYMMETRIC WORLD: A NOBEL TALE

By Subhajit Chakraborty

picture credit - Niklas Elmehed ©Nobel Prize Outreach

This beautiful world and Mother Nature host an alluring interplay of different symmetric and asymmetric objects on the basis of which all life processes, climatic phenomena, and other scientific activities occur. Scientists have been trying to decode this interplay of symmetry and asymmetry for a long, long time now, and it seems there is significant growth in this process.

The chemists were also not an exception; in this case, they had ventured deep into the world where they wanted to define every molecule on the basis of symmetry. This led to the foundation of some of the most significant symmetry related theories, which further led to the foundation of modern organic chemistry. These concepts have been central to modern chemistry for a really long time now, and the importance of this remark was reflected when the 2021 Nobel Prize Chemistry was announced. How is that related to the Nobel prize? Well, fasten your seatbelts and let us dive into the land of asymmetries and some spicy organic chemistry to try to find our answer.

REVIEW

This year, the Nobel Prize in Chemistry was awarded to Prof. Benjamin List of Cologne University and Prof. David Macmillan of Princeton University for their brilliant contribution in "Asymmetric Organocatalysis".

Now, these terms seem pretty complex, so let us first try to understand the primary context of the term Asymmetric Synthesis.
Asymmetric synthesis refers to the preferential synthesis of only one enantiomer(non-superimposable mirror image) in a particular reaction. Below is an example of such a reaction:

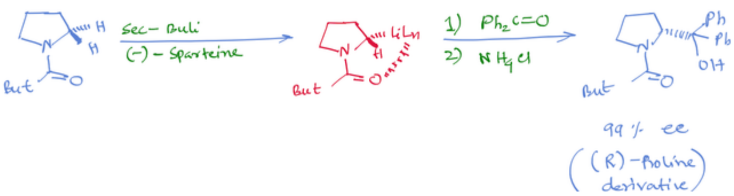


Fig 1: Example of an asymmetric reaction showing the formation of R-Proline derivative in 99% ee.

Now that we are somewhat familiar with asymmetric reactions, then comes the fair question, "What about the catalysts?" Yes, this question has led to the foundation of asymmetric catalysis. Majority of the reactions in the asymmetric synthetic methods used either metal as catalysts or some bio mimetic enzymes for catalysis. These catalysts are highly valuable to carry out these reactions but there are some problems and issues with these catalysts.

Let us talk about the metal catalysts first:

- In many asymmetric reactions, transition metals such as Ruthenium, Palladium, Cobalt and many more heavy metals which may have poisonous effects on nature when released as a waste matter into the surroundings and hence is against the idea of Green chemistry.

- Another factor is that these metal catalysts are extremely sensitive and vulnerable to subtle changes in the reaction conditions lowering their catalytic efficiency.

A famous example in transition metal asymmetric catalysis is the "Noyori asymmetric hydrogenation ", which uses (S/R)-BINAP/diamine Ru complexes as the catalysts.

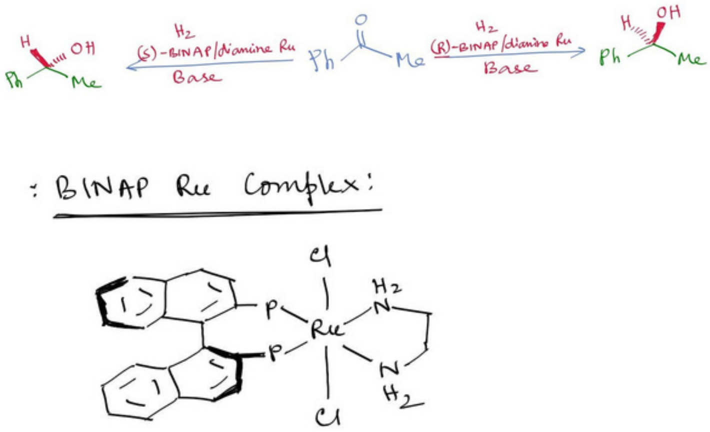


Fig 2: Noyori asymmetric hydrogenation and the catalysts used.

Now let us understand the enzymatic catalysis of specific asymmetric reactions that occur in our body on a day to day basis.

For example, the conversion of fructose-1,6-diphosphate to glyceraldehyde-3-phosphate and dihydroxyacetone phosphate in the glycolytic pathway takes place through an asymmetric nitro aldol condensation in the presence of an enzyme "Aldolase". Now, suppose we want to replicate the exact same reaction in the laboratory conditions. In that case, it might get pretty complicated as the creation of the same Aldolase enzyme from approximately more than 300 amino acid residues will be a challenging task.

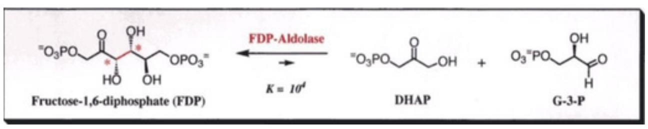


Fig 3: Biological asymmetric Aldol reaction.

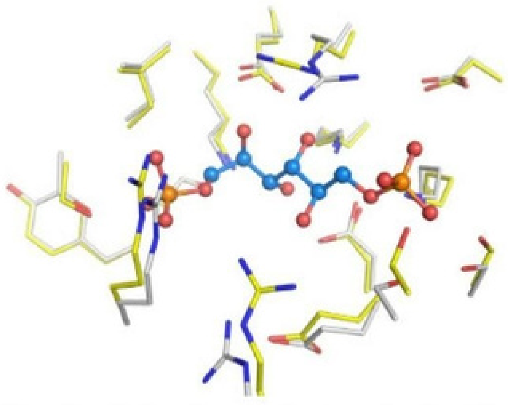


Fig 4: Aldolase enzyme from rabbit muscle cells showing a particular orientation of the amino acid residues.

So, these drawbacks of the catalysts indicated a new discovery, and a brilliant question took birth in the minds of Prof. Benjamin list and Prof. David MacMillan, and it was “What if Organic compounds can catalyze reactions?” or, more specifically, catalyze these asymmetric reactions. They immediately started their independent journey towards a common goal: to find organic asymmetric catalysts and hence "ASYMMETRIC ORGANOCATALYSIS" started its beautiful voyage.
Let us try to understand the independent work that led them to a similar yet very powerful conclusion.

Prof. List worked on asymmetric Aldol reactions. He proposed the first set of “Proline catalyzed Direct Asymmetric Aldol reactions”. And these reactions are found to take place through enamine mechanisms. The first to be studied by them in this regard is the reaction between acetone and nitro-benzaldehyde:

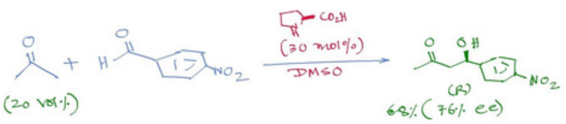
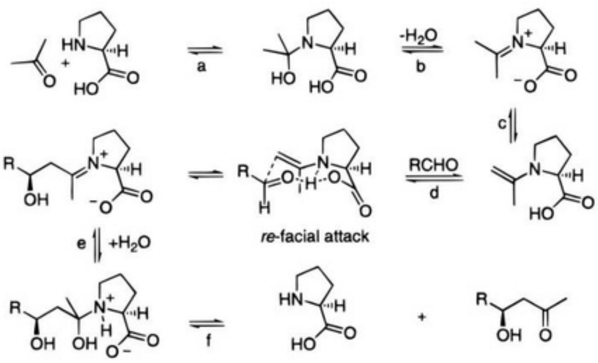


Fig 5: Proline catalyzed Asymmetric Aldol reaction.

The proposed mechanism of the above-stated transformation was reported as follows:



The enantioselectivity of the reaction could be explained using the Zimmerman-Traxler type of transition state that is formed and the re-Face attack of the enolate.

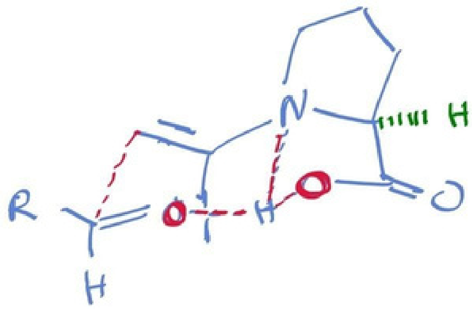


Fig 6: Zimmerman-Traxler type transition state

These reactions were the first reported nonmetallic small-molecule catalysis for direct intermolecular asymmetric aldol reactions. Now, if we ask, what is there so good about organocatalysts like Proline? There are many reasons for this:

- Proline is non-toxic, inexpensive, and readily available in its enantiomeric forms.
- These reactions are at room temperature and need no inert conditions.
- The catalyst is water-soluble and hence can be separated through aqueous extraction.
- These catalysts pose no threat to nature and are hence quite sustainable and green.
- These reactions are found to provide a pretty good yield as compared to contemporary metal catalysts.

Now let us dive into Prof. MacMillan's work. He started to work on one of the most powerful reactions in the field of organic synthesis, the celebrated "Enantioselective Diels-Alder reaction".

As we all know that it is a [4 + 2] cycloaddition reaction between a diene and a dienophile, and these reactions are seen to be catalyzed in the presence of certain Lewis acids. But, Prof. MacMillan gave a new dimension to this reaction and proposed using some particular organocatalysts to accelerate the reaction.
One of these catalysts was “Imidazolidinone” which was an organocatalyst that can get a particular enantiomer in the enantioselective Diels-Alder reactions it was proposed that these reactions involved the formation of certain iminium ion intermediates therough which the reaction proceeds.

The iminium ion that is formed in the reaction activates the LUMO of the diene, and in this way, the reaction is facilitated. But the question was, how did the reaction show such high stereocontrol?

The iminium ion inspection answered these questions:

- Selective formation of the E-iminium isomer to avoid non-bonding interactions between the geminal methyl substituents and the substrate olefin.
- The benzyl group in the catalyst effectively shields the re face and keeps the si face exposed to cycloaddition.

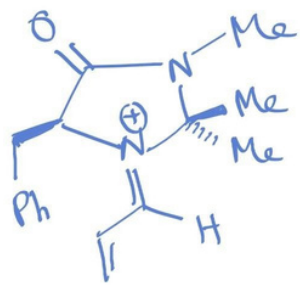
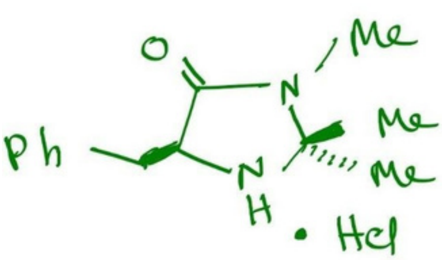


Fig 8: The Imidazolidinone iminium ion formed as an intermediate which provides the stereocontrol.



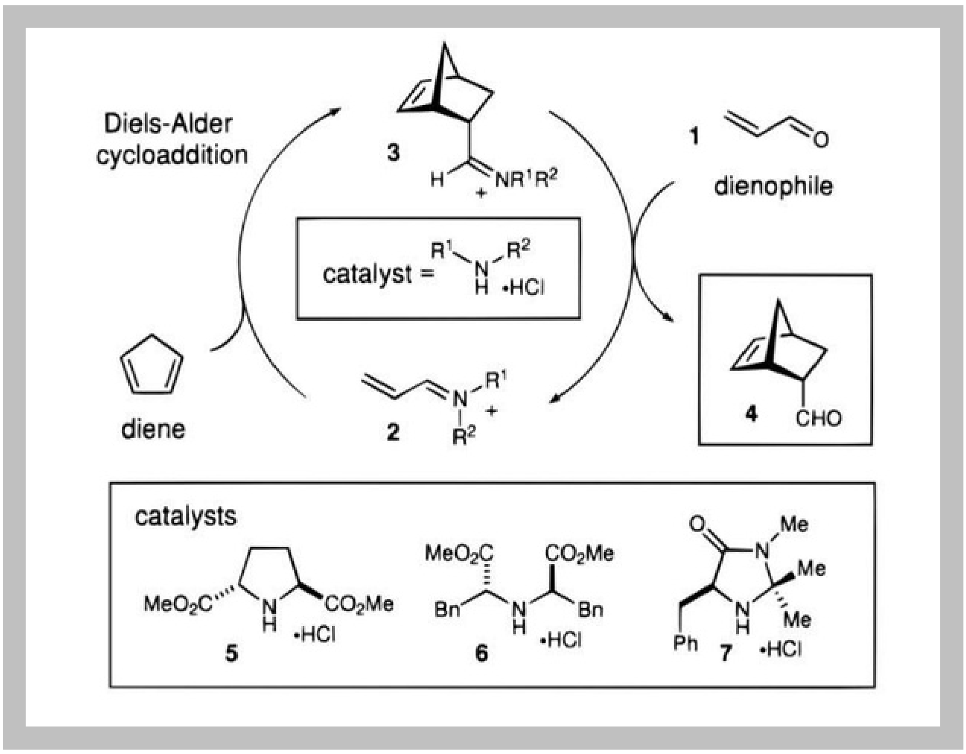
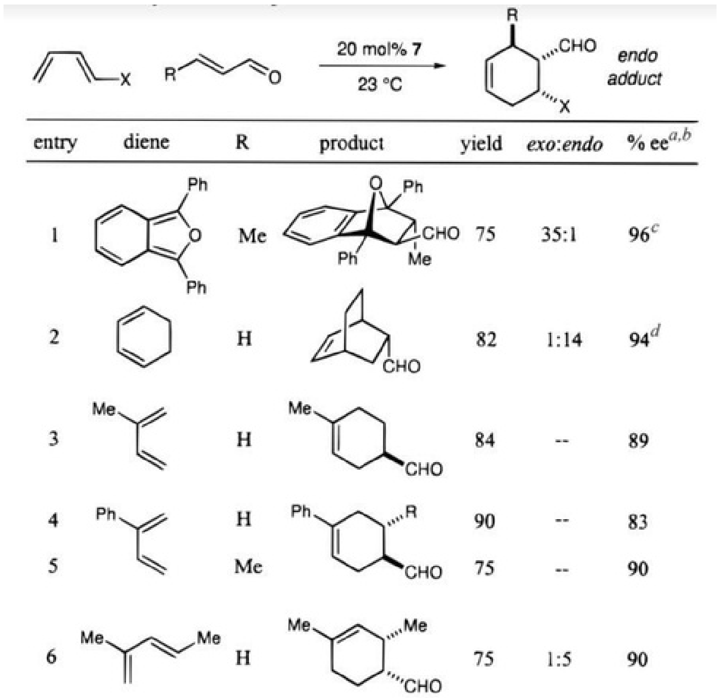


Fig 7: The reaction sequence and imidazolidinone catalyst(drawn).

These organocatalysts were found to be effective in carrying out a large variety of such Diels-Alder reactions when carried out among various substrates.
One such example is shown below:



entry	diene	R	product	yield	*exo:endo*	% ee[a,b]
1		Me		75	35:1	96[c]
2		H		82	1:14	94[d]
3		H		84	--	89
4		H		90	--	83
5		Me		75	--	90
6		H		75	1:5	90

Fig 9: Enantioselective Diels-Alder reaction between Acrolein and representative dienes in the presence of Imidazolidinone catalyst.

How beautiful are these reactions. It is really intriguing to see and feel how both of the legendary chemists started their journey on two different ships and ultimately landed upon the same island. That beautiful island is of "Asymmetric Organocatalysis". This year's Nobel prize reflects how a pretty simple question can lead to significant conclusions and fancy results.
This extraordinary work has now gifted the chemists a new Magic wand to create molecules in a better manner without harming our Mother Nature.
At last, we would bid a farewell to the wonderland of asymmetry for now with a famous quote from Jan Tschichold:

" ASYMMETRY IS THE RHYTHMIC EXPRESSION OF FUNCTIONAL DESIGN"

Photo credits: **Pexels**

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OUCH!
OUCH! OUCH!
HOT!
HOT! HOT !

Naman Agrawal

Preview

On a fine winter morning you wake up with a hangover, and stroll your way to the neighbourhood tea shop. After ordering the steaming cup of fresh ginger tea, you chuckle to your atma, 'Nice beginning to the day, huh!'. In your whimsical dopamine rush, you sip too much of the tea too soon. The seething hot tea simmers and burns your upper palate and tongue! Your pain is sudden, unforeseen and electric, and your atma shouts "Ouch! Ouch! Ouch! Hot! Hot! Hot!".

Photo credit: Pexels

OUCH! OUCH! OUCH! HOT! HOT! HOT !

NAMAN AGRAWAL

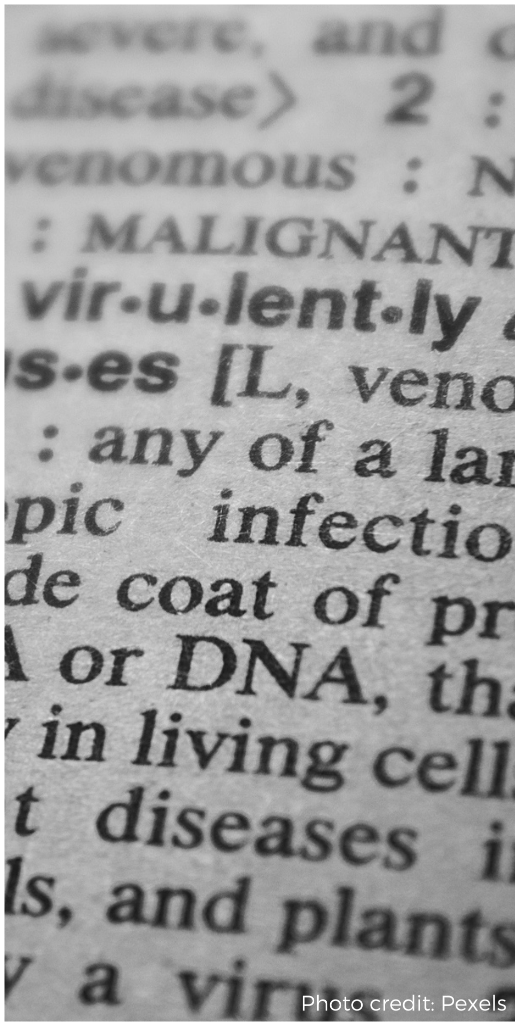
Summary: Understanding how humans perceive the world around them has been a central driving force for most of our scientific endeavours. Two key pieces of the puzzle, namely temperature and touch sensors, were discovered by Dr. David Julius and Dr. Ardem Patapoutian for which they were awarded the Nobel prize in 2021. This article aims to elucidate the methodology followed by the nobel laureates for their discoveries.

Okay, alright, this article is supposed to be the explainer for the Nobel Prize in Physiology and Medicine 2021 which was awarded to Dr. David Julius and Dr. Ardem Patapoutian for their discovery of sensors of heat and touch in the human body. Let us begin by travelling back in time to an unknown grocery store in San Francisco. David Julius, a professor at University of California was busy shopping with his wife. He looked at all the rows of spices and remarked to his wife "This is such an interesting problem!", to which she replied "so do it ! " [1]. Thereafter how Dr. Julius followed through with the problem is simple, and yet so remarkable that it once again bolsters the power of simplicity and elegance in scientific methodology. . Let us try to follow the line of thinking of Dr. Julius.

Question - How are the spices sensed in the body ?
Hypothesis - Spices need a "Spice Sensor" which would detect the spice's presence and convey that information to the brain through the nervous system.
How do we find that "Spice Sensor" ?

Any sort of pain - noxious, thermal or mechanical - is sensed by the human body through a specialized group of neurons which are called nociceptor neurons. Incidentally, these nociceptor neurons also react to Capsaicin, which is an active component in spices like capsicum. Is it possible that these neurons might have the elusive "Spice Sensor" on their surface which enables them to react to Capsaicin?
Dr. Julius and his students made a DNA library of the genes in sensory neurons that they thought might be responsible for making the spice sensor on the neuron surface.

Photo credit: Pexels



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They artificially expressed these genes in kidney cells which natively do not respond to Capsaicin. After going through 16,000 of such candidate genes, finally he found the one which codes for the receptor of Capsaicin. Further research on this led him in figuring out that this receptor is actually a temperature sensing receptor! The receptor would open on temperatures that were perceived as “painful”. They named this gene TRPV1 (transient receptor channel protein). The elusive “Spice Sensor”, which turned out to be a temperature sensor, had been found alas![2]

The road to discovery of mechanical sensors by Dr. Ardem Patapoutian was not very different. Dr. Patapoutian, working at Scripps Research in La Jolla, California, identified a particular cell type which upon mechanical stimulation produced miniscule but measurable electric currents. Similar to Dr. Julius, he made a DNA library of the candidate genes that he thought might code for the receptor that senses mechanical pressure in these cells. He then inactivated (silenced) these genes one by

Question - How are the spices sensed in the body ?

Hypothesis - Spices need a “Spice Sensor” which would detect the spice’s presence and convey that information to the brain through the nervous system.

one. Silencing of one particular gene, which they later named Piezo1, made the cells insensitive to mechanical stimuli, and hence led to the discovery of the gene responsible for mechanical sensing. [3]

It is very easy to see why these discoveries are so important. TRPV1 channels are important in detecting not just thermal pain, but also important in regulating internal body temperature and reflex actions. Similarly, Piezo channels are important not only in sensing touch, but also to have an internal sense of body parts' location and regulating run-of-the-mill body functions that depend on crucial processes like respiration and blood pressure regulation. These discoveries are also highly valuable from a pharmaceutical point of view. If one can specifically silence the pain receptors in a particular body part, we might find new directions towards chronic pain treatment and a plethora of other related health issues.

Our bodily pain and temperature sensing mechanisms have evolved over millions of years to protect the body from damage and ensure its survival. Thus, these discoveries as great as they are, encompass a caveat, and one needs to be cautious in perturbing such receptors which are optimized and are indispensable for our survival.

Reviews

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Author bio :

Naman finished his integrated BS-MS in 2020 with BS from IISER Kolkata, India and MS project from CAESAR in Bonn, Germany with Dr. Bettina Schnell. Thereafter, he took a one year break because someone ate a bat. He joined YLab in Fall 2021, where he will be looking at how the internal state of flies affect their interaction with their environment and the underlying neural circuitry for the same. In his free time, he reads some poetry, does some theatre and sends his friends obscure memes.

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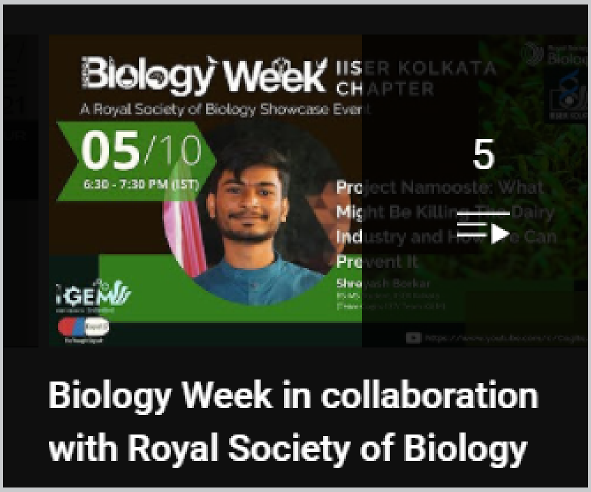

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