EXHIBIT

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THE SCIENCE NEWSLETTER

In this issue:

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Interview with Dr Ravi Maruthachalam

Earlier this month, Anvesha got the opportunity to interview Dr Ravi Maruthachalam of the School of Biology here at IISER TVM. Dr Ravi works on various topics including genome stability, plant centromere biology, minichromosome biology and aneuploidy. Here are some excerpts from Dr Ravi's (R) interview with Akshita Mittal of BSMS batch '19 and Gokul Prabhu (G) of BSMS batch '17:

G: Before we jump into some very technical questions, why don't we talk about where it all started? What was your inspiration to become a scientist?

R: I grew up in a farming community. Naturally, I became fascinated with plant diversity surrounding me. After my 12th, I opted to do B.Sc in Agriculture because I wanted to add some scientific value to what we did on our farm. Then I went on to do my Masters in Agriculture at the Tamil Nadu Agricultural University, Coimbatore where I specialised in Plant Breeding and Genetics. Plant breeding, as you know, is where improved cultivars, hybrid plants are bred and given to farmers finally for cultivation. Subsequently, I did my PhD with Dr Imran Siddiqi in Plant Reproductive Biology at CCMB, Hyderabad working the plant model, *Arabidopsis thaliana*, a weedy relative to cultivated Mustard. I did my post-doctoral research focussing on Plant Centromere Biology at the University of California, Davis. I worked with Prof Simon Chan whose lab interests are to understand how centromere is specified in plants. We know that centromere is specified epigenetically by CENH3 protein. So, in order to understand the structure-function relationship of CENH3 protein we did several experiments and stumbled upon finding that by simple manipulation of CENH3 protein, we can control chromosome movement whereby we can selectively eliminate one of parental chromosome sets after successful fertilisation and thus instead of producing a diploid hybrid progeny, you end up producing a uniparental haploid progeny exclusively from one parent.

G: Your research involves an accidental discovery of producing haploids in-vitro. How did it happen and why was this discovery considered to be crucial back then? What are its applications in recent times?

R: In sexually reproducing organisms, the resulting progeny contains nuclear chromosomes equally contributed from both the parents. Whereas, in case of haploids, the progeny contains genetic material exclusively from only one parent— either from the mother or the father.

A chromosome imbalance leading to aneuploids or haploids is not a welcome trait in animals, but believe it or not, in plants, generating a haploid progeny is a multibillion-dollar business for the reason that it is the fastest way of generating pure breeding lines. If we want to create superior hybrids in any crop species, you need pure-breeding parents. The conventional method of producing such inbred/pure lines is to cross two desired parents of interest to produce an F1 progeny and propagate them for several generations (F8 or F9 generations) through selfing or inbreeding until desired level of homozygosity is achieved. But no matter how many generations you go through, you cannot attain 100% homozygosity. On the other hand, by producing haploids and subsequently doubling its chromosome number, such pure breeding genetically homozygous parents can be generated within 2 generations there by saving several years of pure line development and thus improved cultivars can be released for cultivation in a short period of time.

Considering the importance of haploids in crop improvement, plant breeders constantly make efforts to generate haploids in agronomically important crops of their interest mostly by exploiting in-vitro tissue culture mediated approaches such as anther/microspore culture and ovary/ovule culture. However, the drawback of tissue culture mediated haploid induction approaches are that it is highly species and genotype specific and most of the economically important crop species respond very poorly such that it is difficult to achieve large scale production of haploids. *Arabdiopsis thaliana*, despite being the most well studied plant on our planet has proven to be highly recalcitrant for tissue culture mediated haploid production methods. In addressing a basic science question of how centromeres are specified in plants, we serendipitously discovered that by simple manipulation of a chromosomal protein CENH3, we can induce conflict between the parental chromosomes during embryo development triggering selective elimination of either mother's or father's chromosome ending up in creating a uniparental haploid progeny instead of diploid hybrid progeny. Thus we have discovered an improved in vivo method of haploid induction, which, if successfully extended to other crop species can in fact revolutionise plant breeding. Here at IISER TVM, we are trying to understand the molecular and genetic basis of this uniparental elimination with an aim to develop tools that to improve plant breeding. In this regard, we have an ongoing project with the ICAR - Central Potato Research Institute, Shimla to translate this methodology of haploid production in potato to breed potato through haploids.

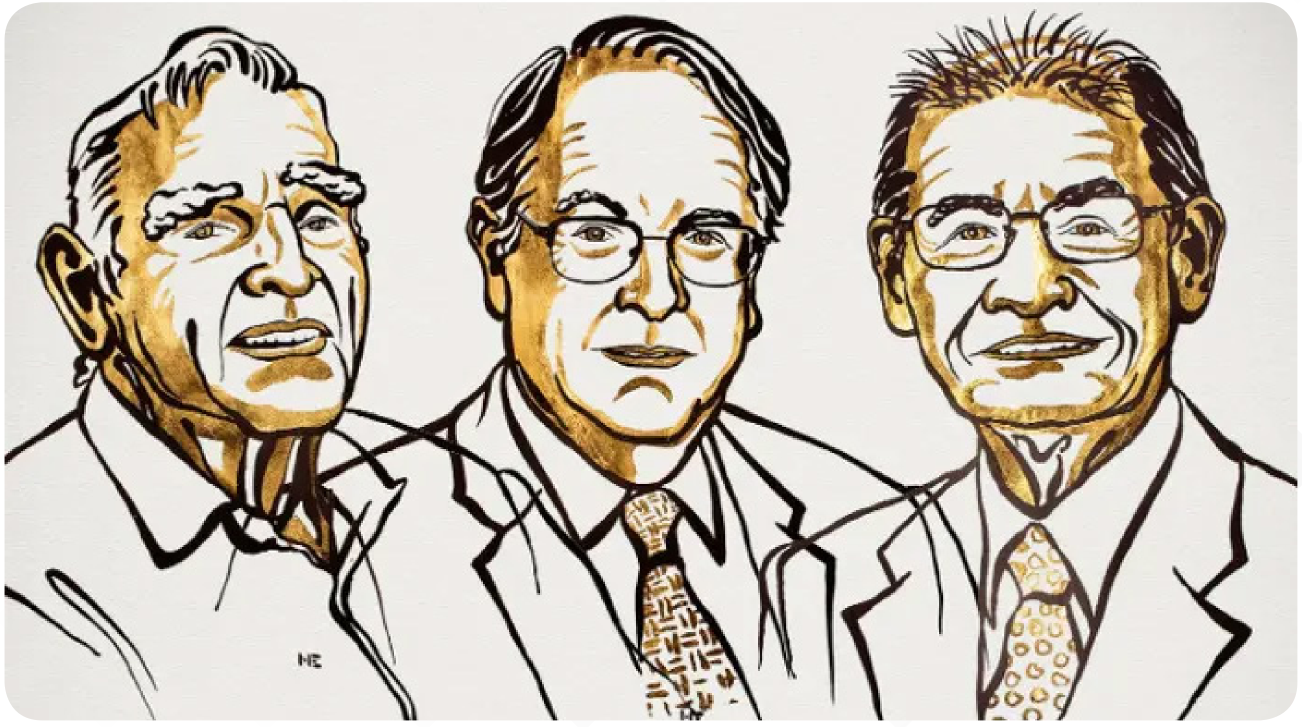
G: Over the last decade, scientists have been perfecting this gene-editing technology called CRISPR-Cas. Do you think CRISPR-Cas can revolutionise the way genetics has been done?

R: Definitely. In the coming years, I believe that the discoverers of this genome editing technology will be awarded the Nobel Prize. It has now been employed in several organisms across kingdoms. In plants, targeted mutagenesis was practically impossible till the discovery of CRISPR-Cas technology. Now with the advent of this technology, you can edit any gene of your interest. Targeted mutagenesis is now possible and a lot of advances have happened and a lot of gene manipulations have been done not only in the model plant *Arabidopsis* but in other plants as well. In animals also, if you want to correct a defective gene, genome editing is possible using CRISPR-Cas technology. Due to ethical reasons, it has not been implemented in human systems. But for certain diseases, efforts are on to apply this technology.

G: If you could give some advice to students like me, doing research in an institute like IISER, what would it be?

R: IISERs were started with the mandate to integrate basic science research with undergraduate education, which facilitates students to access labs from their very first year. Students should have a defined interest, which area they want to specialise in. Accordingly, they have to look into who the faculty working in that area are. Approach them, talk to them. Once started working in the lab, students have to be committed to their work and to follow up with the experiment. The other thing is that they should have a lot of perseverance and patience. At times, they may not get their expected results based on their predefined hypothesis. I generally see students getting frustrated when their results do not go the way as expected. Even if they do not get their hypothesised outcomes, they should be in a position to explain why. Something interesting might be happening. Keeping up to date on literature in your field of interest is very important. So, you'll have to read a lot of research papers, pertaining to your area of research and try to integrate your research with the recent developments in that area. A very important insight is that science depends on reproducibility. Just for the sake of getting published, you shouldn't falsify or fabricate the data. And finally good luck.

The Nobel Prizes



Chemistry

The 2019 Nobel Prize for chemistry was awarded to John B. Goodenough, M. Stanley Whittingham and Akira Yoshino for working towards the development of lithium-ion batteries. These rechargeable and lightweight batteries can power everything from portable electronic devices to electric vehicles. They also provide a way to store energy from renewable (but transient) energy resources like sunlight and wind. This battery has made a dramatic influence on society.

Alessandro Volta demonstrated the first-ever electric battery in 1800, and scientists have been trying to produce better batteries ever since, mostly by seeking anode materials that can release more electrons and cathode materials that can better attract the electrons.

Whittingham, in the 1970s, created the first lithium battery which flaunted 2-volts. In the early 1980s, Goodenough sought to improve the battery's cathode, and his innovation doubled the voltage of lithium batteries to 4 volts. In 1985, Yoshino used petroleum coke as an anode to store lithium ions when charged. When this was paired with Goodenough's cathode, it resulted in a safer, durable and rechargeable 4-volt battery. This basic design was used in the first commercially available lithium-ion batteries in 1991.

Lithium-ion batteries now perform much better than those on the market in 1991. Today, you can recharge these batteries a thousand times, and they have also gotten safer and cheaper. Scientists are now developing different types of rechargeable lithium batteries.

-- Nikitha S., BSMS B'17

Image source [credit: Nobel Media]

Economics

In an era of colonising the outer worlds, it is disheartening to know that more than 700 million people on earth still live in extreme poverty. The efforts to solve this crisis, however, are in full motion. This year's Nobel Prize for Economic Sciences was awarded to Abhijit Banerjee, Esther Duflo and Michael Kremer for their 'experimental approach to alleviating global poverty'. Their innovative way of segregating broader issues of poverty into smaller and more manageable questions, and seeking answers in real-life field experiments have made a remarkable change in the approach to alleviating poverty. For example, these researchers found that just providing more textbooks, meals and teachers did not do much to help students learn (which was the typical way of dealing with lower literacy rates among the poor). Instead, they found, through their field experiments, that making school-work more relevant to students, working closely with challenged students and holding teachers accountable to be more beneficial. This revolutionary way of experimentation has had a definite impact on policies and keeps improving our ability to alleviate global poverty.

-- Megha, BSMS B'19

Image source [credit: Nobel Media]

Physics

The Nobel Prize in Physics 2019 was awarded 'for contributions to our understanding of the evolution of the universe and Earth's place in the cosmos' with one half to James Peebles 'for theoretical discoveries in physical cosmology', the other half jointly to Michel Mayor and Didier Queloz 'for the discovery of an exoplanet orbiting a solar-type star.'

James Peebles is recognized as the principal architect of physical cosmology and is regarded as the most celebrated living cosmologist. He was one of the first to theoretically predict microwave background radiation, dark matter, and dark energy, which gave birth to the field of observational cosmology. He is at present the Albert Einstein Professor Emeritus of Science at Princeton University.

Michel Mayor and Didier Queloz were the first to discover an exoplanet (51-Pegasi) orbiting a sun-like star, 50 light-years away from Earth in 1995 by the radial velocity method (Doppler spectroscopy), starting a revolution in astronomy. Over 400 exoplanets have been discovered since then.

-- Ravikiran, BSMS B'19

Image source [credit: Nobel Media]

Biology

The Prize in Physiology/Medicine is shared by three brilliant minds, William G. Kaelin Jr, Sir Peter J. Ratcliffe and Gregg L. Semenza 'for their discoveries of how cells sense and adapt to oxygen availability'. They worked out the genetic mechanisms of cells sensing falling oxygen levels, and responding by making new blood cells and vessels. We are aware of just how vital oxygen is, but too much or too little of it can also be deadly. Lack of oxygen triggers an adaptive process called the 'hypoxia response', and can influence the creation of new blood vessels or an increase in red blood cells. A key physiological response to hypoxia is the rise in levels of the hormone erythropoietin (EPO), generating an increase in red blood cells.

Drs Semenza and Ratcliffe separately showed that specific DNA segments located next to the EPO gene manage the response to hypoxia and how this was available across all types of tissues in the body, including the kidneys – where EPO is typically produced. Going a step further, Dr Semenza wanted to be able to identify the cellular parts of hypoxia response element (HRE). Using liver cells grown in his lab, he discovered a protein complex that pairs itself to a particular DNA segment, seeking out oxygen. He called this the hypoxia inducible factor (HIF).

Around 1995, the Nobel Assembly described Prof. Kaelin Jr.'s research focusing on an inherited syndrome, von Hippel-Lindau's disease (VHL disease). 'This genetic disease leads to dramatically increased risk of certain cancers in families with inherited VHL mutations. Kaelin showed that the VHL gene encodes a protein that prevents the onset of cancer.' Prof. Ratcliffe then demonstrated in 1999 that there was an association between VHL and HIF-1α, one of the two DNA-binding proteins discovered by Prof. Semenza.

These discoveries demonstrate that the response through gene expression and changes in oxygen is directly coupled to oxygen levels in the animal cell, which allows for an immediate cellular response. This answers a lot of existing questions about ecological adaptations in high-altitude regions and has opened new avenues in the treatment of anaemia, cancer, and heart disease. It is described as a 'textbook discovery', a phenomenon that students would begin learning at the most basic levels of biology.

-- Shreya, BSMS B'19

Image source [credit: Nobel Media]

An Evening of Philosophy

On October 19, Prof. Deepak Dhar, notable Indian theoretical physicist and Distinguished Professor at IISER Pune, was invited to give a talk at IISER TVM as part of Anvesha's activities. His talk was on the relationship between mathematics and physics, particularly when the latter uses mathematics as a language to describe the universe. He began with the question, "Did the number pi exist 100,000 years ago?" Most of us might answer this question in the affirmative, especially if we think of mathematics as a subject of discovery, where we find patterns and relations with our imperfect senses. Plato argued that mathematical forms exist independently of our limited senses and have their own existence in the ideal world outside, and mathematicians applied their senses to discover them. Non-platonists, however, argue that mathematical forms are just useful mental constructs that humans create with their imagination and don't exist in reality.

To put this in perspective, Prof. Dhar explained two interesting viewpoints, that of Eugene Wigner who wrote an influential article titled "The Unreasonable Effectiveness of Mathematics in Natural Sciences", and Derek Abbott's more recent article titled "The Reasonable Ineffectiveness of Mathematics". Wigner's viewpoint is pretty standard by now and mostly Platonist, and subscribes to the view that it is miraculous that mathematics can describe the real world with so much accuracy and that it was something he could not fathom. However, Abbott claims that it's not miraculous and goes on to explain why. Abbott used the description of the Platonist and non-Platonist viewpoints to make his case. He says that mathematics can meaningfully describe natural phenomena only in a small subset of problems mostly related to physics. To support this claim, he brought up the example of biological systems which are usually mathematically intractable.

Similarly, social behaviour and economics are also difficult to model mathematically. Even in the case where mathematics is useful, the mathematical models are only approximations and idealisations, models which are close but don't describe actual reality. One simple example is of elliptical orbits in the study of planetary motion. In reality, orbits aren't exactly elliptical.

These discussions were of course entirely philosophical in nature, and it was Prof. Dhar's hope that with this talk, he would encourage young scientists to philosophise more, rather than stick with the currently held notion among scientists that philosophy is mostly irrelevant and a misuse of terminology.

It is also worth noting that a lot of physical theories, including Einstein's work on relativity, came about only after much philosophical enquiry was made on the nature of reality and the scientific method, something that a lot of contemporary physicists refuse to acknowledge.

-- Hari Krishnan, iPhD B'18

Quantum Theory and Gravity

The 20th of October, 2019 saw students from diverse fields in science filling the seminar hall in the Physical Sciences Block, bringing with them an atmosphere of excitement and anticipation. Prof. Spenta Wadia was scheduled to deliver a talk on Quantum Field Theory.

Prof. Spenta Wadia is a renowned theoretical physicist, a distinguished professor at the Tata Institute of Fundamental Research (TIFR), and the founding director of the International Centre for Theoretical Sciences (ICTS), Bengaluru. He is a pioneer in the field of Quantum Field Theory and is one of India's leading scientific personalities.

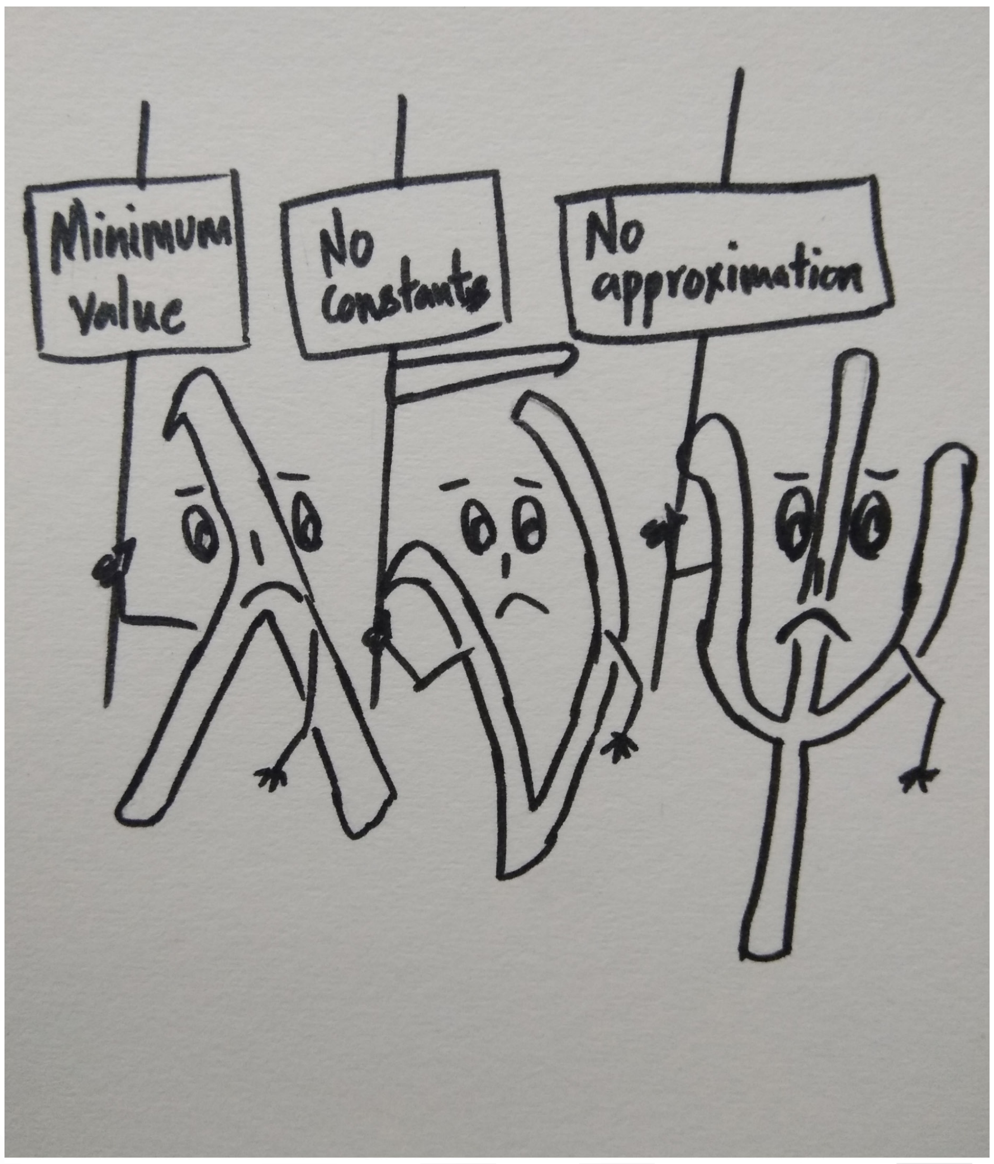
The organisers from Anvesha were initially worried that the talk might be too technical for the audience, many of whom were unfamiliar with Quantum Field Theory. All such fears were put to rest when they realised that Prof Wadia had prepared a lecture that was interesting and quite intuitive.

He started with the history and developments in the field of physics thus far, and took a moment to appreciate the work of thousands of researchers who gave us the understanding we have today. After this, he introduced the Standard Model of Cosmology and Cosmic Microwave Background (CMB), at which point he observed that the fluctuations in the image were elegantly explained by the idea of Quantum Gravity. He proposed that such fluctuations of density became the seeds for the uncountable number of galaxies in the universe today. He argued that precision experiments on CMB indicated that, for a fundamental theory for the large scale structure of the universe, a theory of Quantum Gravity which reduced to Einstein's theory of relativity at low energies was required. Furthermore, he went on to discuss a bit about string theory and also presented the beautiful idea of Holographic Conjuncture. Everyone present could easily follow the logic Prof Wadia presented, and there were several questions from the students that allowed for a lively interaction that satiated everyone's curiosity. Prof Wadia's politeness and humility struck a chord with all who met him. Always carrying a gentle smile on his face, he dined and spoke with the students post his talk.

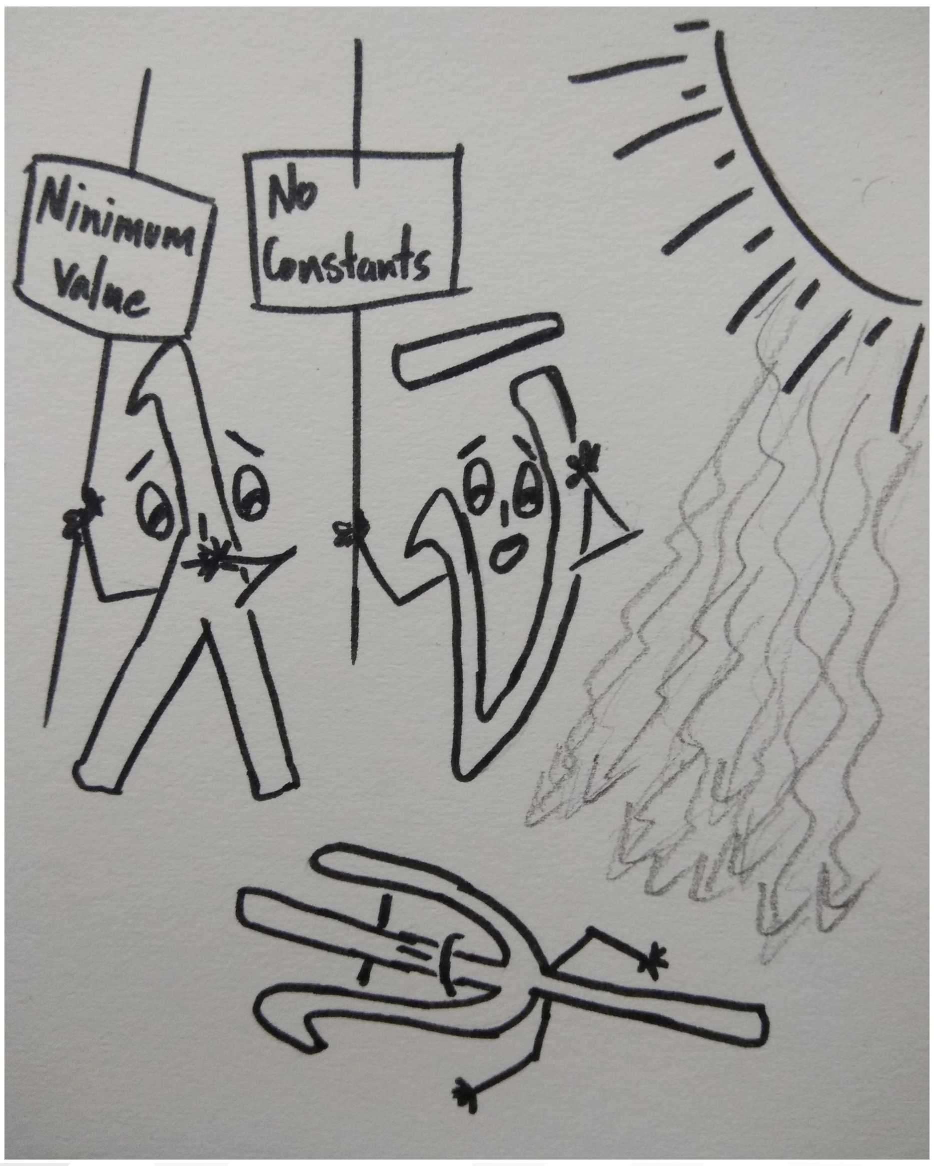
-- Adarsh K., BSMS B'17

Wavefunction Collapse

-- A comic by Dheeraj C., BSMS B'17



One day, wavelength, wavenumber and wavefunction started a protest in public against their unfair treatment by physicists.



Due to the intense heat, wavefunction 'collapsed' mid-protest.

Physicists 'observed' wavefunction collapse, but there was little they could do; they found its position, but couldn't find its momentum.

We hope you enjoyed this month's edition of Exhibit: A!

If you are interested in contributing any content, artwork, or want your research featured here, please get in touch with us at:
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Send your suggestions to: https://forms.gle/pBzJW7GSv7bC5r7RA

Have any science-related questions you'd like answered? Send them to us and we'll get our best minds on it!
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