AWSAR AWARDED
POPULAR SCIENCE STORIES
By Scientists for the People

WSAR
Augmenting Writing Skills for Articulating Research
AWSAR Awarded
Popular Science Stories
By Scientists for the People
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AWSAR AWARDED POPULAR SCIENCE STORIES: By Scientists for the People

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FOREWORD

India has made phenomenal progress in the area of Science and Technology (S&T) in the past two decades. However, science promotion activities in the country are randomly organized and are mostly restricted to the boundaries of scientific institutions. Scientific outcomes generated from these establishments should reach masses in popular language to initiate scientific thinking and awareness among people of the country.

As per statistics given by the All India Survey on Higher Education, Ministry of Human Resource Development (MHRD), Government of India, 34,400 students were conferred Doctor of Philosophy from various higher education institutes and universities in 2017-18. The number of degrees awarded in the area of Science, Engineering & Technology were 8880 and 4907 respectively.

Popular science stories are best conceived and told by practitioners for effective communication. As PhD Scholars and Postdoctoral Fellows (PDFs) are considered the backbone of scientific ecosystem across the globe, their latent potential therefore, must be tapped towards communicating their own research work to ‘common’ person. In this direction, the Department of Science and Technology (DST) initiated a unique programme called “AWSAR (Augmenting Writing Skills for Articulating Research)” to encourage these young researchers towards popular science writing. The well-organized exciting stories from these researchers would help people at large thus, facilitate connect to the larger concern of both science and society.

AWSAR, as the name suggests, is a distinct effort of DST, to enhance writing skills through capacity building and process of recognition. A National level competition was organized last year to invite stories from research scholars and postdoctoral fellows thus strengthening the ecosystem of science communication and science reporting to public. AWSAR received accolades from print, social and digital media and was highly appreciated by students pursuing PhD. An overwhelming response was received last year, with more than 2600 submitted stories and the participation is expected to gain momentum in years ahead. This initiative anticipates adding yet another dimension of deeper understanding of research and its relevance to the authors.

I am pleased to learn about the compilation of best AWSAR stories. I am confident that this would be of great value to the students, researchers and public at large and would provide motivation to others to come forward and participate in this endeavour. I compliment National Council for Science and Technology Communication (NCSTC) Division and Vigyan Prasar for having put sincere efforts to bring out this publication.

9th September, 2019

(Ashutosh Sharma)
Augmenting Writing Skills for Articulating Research (AWSAR) is a new initiative conceptualized by Department of Science and Technology (DST) for effective outreach and communication of their own scientific research conducted by young scholars to common people. AWSAR envisage to bridge the existing gap in communicating research by utilizing the latent potential of PhD Scholars and Post-Doctoral Fellows (PDFs) in an interesting manner. This program is being supported and coordinated by National Council for Science and Technology Communication (NCSTC) along with Vigyan Prasar, an autonomous institute of DST.

AWSAR provides an opportunity to foster, strengthen and create scientific temper through popular science writing and creating a culture of science dissemination & popularization among the research scholars. Under this initiative, Ph.D scholars and PDFs in science and technology streams are encouraged to write popular science article during the tenancy of their scholarship/fellowship and the best stories are awarded through an annual competitive process.

The prime objective of the “AWSAR” program is to propagate Indian research in Science, Technology, and Innovation being pursued by young scholars in popular science writing format. A series of workshops on popular science writing were also conducted for capacity building of aspiring young scientific writers all across the country. An encouraging response was received for participation in workshops and story submission process. Out of 2629 stories received, 124 stories from different science stream are incorporated in book format. Top three stories in PhD category and one outstanding story in PDF category were awarded during the National Science Day (NSD)-2018 celebrations. This book will provide a purview of science communication through popular science writing, which will help to strengthen the ecosystem of science popularization and inculcate scientific temperament in society.

This book on ‘AWSAR Awarded Popular Science Stories by Scientists for the People’ is a compilation of AWSAR awarded stories submitted in the year 2018. It exemplifies the effort of many researchers and investigators who had put in countless hours for their research. I want to thank them for their scientific contributions.

Dr Nisha Mendiratta
Head & Scientist G
National Council for Science and Technology Communication
Department of Science and Technology
Government of India
INTRODUCTION

It has been observed that most of the research in the field of Science & Technology remain confined to institutional boundaries or at the most limited to scientific fraternity through publications of articles in peer-reviewed journals. There is a yawning communication gap that exists at the science-society interface. Bridging this communication gap between scientific fraternity and the common citizenry is still a challenging task. Communicating science to a common man in a simple way without the use of technical jargon, that too, without diluting the scientific content and the accuracy is not only an art but a skill which developed over the time. Today, science & technology communication is an emerging field of academic inquiry. Many institution and universities are offering professional courses at various levels in S&T communication. Unfortunately, during the period of research, researchers did not find an opportunity to communicate or talk about their research at a public forum, though they have many exposures on how to write a technical research paper and present in a seminar or conference before their peers.

Considering the above scenario, and with an aim to strengthen the ecosystem for science communication in the country and to bring science closer to society, the scheme “Augmenting Writing Skills for Articulating Research” (AWSAR) was conceived and conceptualized by National Council for Science & Technology Communication (NCSTC) Division, Department of Science and Technology (DST) in collaboration with Vigyan Prasar (an Autonomous Institute of Department of Science & Technology). The specific objective of the scheme is to encourage youths pursuing higher studies to write about their research in a popular or easy to understand format. The initiative hopes to disseminate Indian research stories among the citizenry in a format that’s not only easy to understand but generate and sustain interest about S&T in a lay reader. It is expected that the outcome of this scheme will help in fulfilling the objectives of our constitutional mandate as enshrined in Article 50 A(h), i.e., Fostering, strengthening, and nurturing scientific temper among the people of the country. This concern has also been reiterated in The Science, Technology and Innovation Policy (STI) 2013.

The scheme AWSAR was launched in September 2018 by giving wide publicity through print and electronic media and conducting workshops in different parts of the country. The workshops provided an opportunity for the researchers to have direct interaction with some of the best-known science writers and journalists of the country. The scheme also has a monetary incentive in the form of prizes which include three best entries with a cash prize of ₹1,00,000/-, ₹50,000/- and
₹25,000/- in PhD category in addition to 100 best entries along with Certificate of Appreciation. Under Post-Doctoral Fellows category the cash prize is ₹1,00,000/-, for an outstanding story. In this category twenty other best stories are also selected.

A comprehensive web portal www.awsar-dst.in was developed for giving detailed information about the AWSAR scheme and inviting the stories from the researchers. In total 4128 researchers got themselves registered on the portal. On the closing date of the entry, 455 and 2174 stories were received respectively under PDF and Ph.D. category. After the initial review, 1755 stories were sent to two experts for evaluation. The authors of the top 10 entries under Ph.D. Category and three top entries under PDF category were invited to interact with the expert panel. Finally, the winners were announced.

The present compilation of the selected stories from different labs and research institution of the country covers a diverse sphere of R&D activities where researchers have attempted to connect science with people to enhance their understanding of science. Ultimately, AWSAR envisages bridging the existing gap in communicating research to common man by utilising the latent potential of PhD Scholars and Post-Doctoral Fellows (PDFs).

Dr K B Bhushan, Scientist D, VP
Dr Gaurav Jain, Jr Scientific Officer, VP
Dr B K Tyagi, Scientist F, VP
I take this opportunity to express my sincere gratitude to all PhD Scholars and Postdoctoral Fellows (PDFs) across the country who have submitted their research stories in popular format under AWSAR programme.

As this was a new programme launched in 2018, the process of implementation involved capacity building of the PhD Scholars and Post-doctoral fellows (PDFs). I would like to thank our key resource persons Shri Biman Basu, Former Editor Science Reporter, Shri Dinesh C. Sharma, Managing Editor, India Science Wire and Shri Chander Mohan, Former Head NCSTC Division, DST. All were kind enough to take time from their busy schedules for contributing in this unique endeavour since beginning of this expedition to guide and mentor.

My sincere thanks to the members of ‘Expert Committee’ and ‘Expert Panel’ who have constantly guided the ‘AWSAR team’ with their knowledge and experiences. Their contribution in the entire process is immense and is highly appreciated for timely completion of the evaluation process.

As this was a collaborative effort between DST and Vigyan Prasar, I am grateful to Dr Nakul Parashar, Director, Vigyan Prasar for keeping our morale high and facilitate the entire process effectively and efficiently. All my colleagues in NCSTC Division, DST and Vigyan Prasar who have helped and encouraged throughout and rendered their support and motivation are acknowledged. Special thanks to all the team members who have worked at the back-end day and night to meet the deadlines. Last but not the least I thank media for being part of this journey since its inception until the day AWSAR awards for popular science writing were conferred upon PhD Scholars and PDFs for the first time.

Dr Rashmi Sharma
Scientist-E
Department of Science and Technology
Government of India
We, The Mallik Lab, at Tata Institute of Fundamental Research are working towards understanding how tiny cellular material moves over large distances inside a living cell. Cellular environment is extremely crowded and busy. Cells have several smaller compartments called organelles and various biomolecules, each of varying shape and size. If we put a live cell under a microscope, we see that there is constant exchange and movement of material from one part of the cell to the other. This trafficking of biomolecules, or “cargoes”, as we call them is required for various life processes, such as cell division, uptake of nutrients, and migration of cells to the site of wound healing. Defects in transport of key molecules can often result in death or manifest in a number of diseases such as Alzheimer’s and Huntington’s.

We study the transport process with respect to infection. In our day-to-day life, we encounter a variety of infectious agents. Our body has developed defense mechanisms to fight disease-causing agents without affecting our normal functions. When a foreign particle infects our body, our immune cells ingest these particles and trap them in a double-layered membrane structure, which is called a phagosome. This process is called phagocytosis. Phagosomes eventually move to the centre of the cell for degradation. Motion of a phagosome from the site of engulfment to its site of killing is extremely important for effective clearance of the pathogen.
How does this motion of phagosome or other cargoes occur in the cell? This is brought about by the action of cellular “motors”. Motor proteins walk along pre-existing roads to deliver cargoes at their required locations. For simplicity, let us imagine the cargo as a cart, which requires a motor—say a horse—to drive its motion in one direction. There are two main types of motors that carry out long distance transport like the horse and the bullock, which are Kinesin and Dynein. Both Kinesin and Dynein motors walk on same kind of tracks. However, they are quite different in their size, structure, as well as the direction in which they walk. Kinesin motors move cargoes towards cell periphery (a horse-cart moving in one direction) while Dynein generally moves them towards the centre (a bullock-cart in the opposite direction).

To add to the cellular complexity, a large number of cargoes have both kinds of motors and actually move back and forth. So, we now imagine a cart with horses on the one end and bullocks on the other, both pulling back and forth to drive its motion in opposite directions. How these opposite motors work together to bring about molecules to the right place at the right time is hotly debated. We have recently addressed this question in our manuscript published in “Current Biology” in May 2018.

In our study, we examined the motion of phagosomes in their early stages of phagocytosis. These Early Phagosomes (EPs) display bidirectional back and forth motion due to presence of both Kinesin and Dynein motors. To study motor function on EPs, we extracted them from immune cells using well-established protocols and made them walk on artificially constructed tracks. We analyzed their motion outside the cell using a special kind of microscopy called optical trapping. This technique provides tremendous amount of information as to how far motors can walk; the land forces exerted by each motor type their speed. Such experiments allow us to decipher properties of motors at a single phagosome level, a resolution that cannot be achieved when looking at an entire cell.

We investigated how could we explain back and forth motion of EPs? Do opposite motors depend on each other or do they pull against each other like in a tug of war? To make sense of how opposite motors behave on an EP, we specifically removed Dynein motors from the EP membrane. Surprisingly, upon Dynein removal, Kinesin neither performed better nor did it become worse. This suggested that both types of motors act independent of each other and do not require the opposite motor for their function. If motors function independently, what governs the choice of active motor when do horses pull and when do bullocks pull the cart? Is there a pattern these motors follow to bring about motion?

To answer this, we analyzed a number of events where pulling force was generated by Kinesin (horses) and Dynein (bullocks) motors. We focused on even pairs, for instance, a KK pair where Kinesin was followed by another Kinesin event, or KD pair where a Kinesin was followed by a Dynein event, DK pair where Dynein was followed by a Kinesin event and DD pair where Dynein was followed by another Dynein event. On performing statistical analysis of these pairs, we found that the number of each type of event pair is more or less similar. This suggests that all four types of event are equally likely to occur. This is similar to tossing of a coin where the probabilities of getting two heads (HH) or one head and then a tail (HT) or two tails (TT) or one tail and then a
head (TH) are more or less equal. Thus, once a pulling event occurs, the choice between Dynein and Kinesin for the next event is a random process. The system does not have any memory of the first event and thus, activation by either type of motor is equally likely.

We next asked whether this random choice of active motor explains bidirectional EP motion? If this is random, can we simulate this motion using modeling? Interestingly, we found that the back and forth EP motion is accurately explained by mathematical modeling when we take into account motor numbers on EP, their binding and unbinding rates and the geometry of phagosome where motors bind the track. These parameters somehow ensure that both Dynein and Kinesin events are equally possible resulting in back and forth EP motion. Such motion allows EPs to sample more intracellular space and interact with other organelles for exchange of components.

Thus, from our studies we have obtained basic parameters that make choice of motors a fair process. This may also be true for many other cellular cargoes. Further levels of regulation such as change in membrane composition; motor numbers or organization can bias this fair coin and accordingly change motion properties of phagosomes in the later stages. Our work, in general, addresses some fundamental questions by using a variety of approaches we employ biological methods, biophysical force measurement techniques as well as mathematical modeling. Our work provides a holistic view in understanding of bidirectional cargo transport during early stages of phagosome motion as well as in situations when things go awry and result in infections.

*Cartoon depicting a coin toss between Kinesin and Dynein motors on the phagosome*
The Mystery Behind Unconventional Protein Secretion and Secretory Autophagy

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Proteins, one of the building blocks in every organism, are synthesised inside a cell in a compartment called Endoplasmic reticulum (ER) and gets targeted to different regions within and outside the cell based on their unique “zip-code”. Some proteins get secreted out of the cell for several physiologically important reasons. This can happen via a conventional mode or an unconventional mode. The canonical secretory proteins follow the strict protocol route of ER-Golgi and to the exterior due to the presence of the specific zip-code called the leader peptide whereas the unconventional secretory proteins lack this code but still secretes out of the cell and is called the unconventional protein secretion (UPS), mostly under cellular stress such as inflammation, nutrient stress, ER stress, mechanical stress.

Research reports suggest that there are multiple routes the unconventional secretory proteins take up to get out of the cell and are classified as Type I, II, III and IV. Based on this recent classification, type I is a pore-mediated translocation across the plasma membrane, type II is an ABC transporter mediated secretion, type III is an autophagosome/endosome-based secretion and the type IV is a Golgi bypass mechanism. Our lab is interested in understanding the type III system where there is a crosstalk between the unconventional protein secretion (UPS) and a process known as autophagy. Autophagy, as the name suggests, is a self-eating process. Autophagy machinery

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can be compared to a vacuum cleaning system that clears the damaged or redundant organelles, proteins and other cargoes. This homeostatic machinery works by encapsulating these defective items in double-membrane vesicles called autophagosomes and then ferried via microtubules to the lysosomes, the compartment containing acidic hydrolytic enzymes where they get chewed up. In the lysosomes, the proteins and other cargoes are broken down into simpler forms and the nutrients are recycled back. This form of autophagy is called as degradative autophagy (see Figure 1).

Besides degradative autophagy, there is another type of autophagy called the secretory autophagy (Figure 1). The involvement of autophagy machinery in UPS of a small subset of proteins has been reported (secretory autophagy). We try to understand the crosstalk of secretory autophagy with unconventional protein secretion in a detailed manner using multidisciplinary approaches. We are interested in identifying the molecular players involved in this process. Many UPS proteins are found to be pivotal and are detected in pathophysiological conditions with dysfunctional autophagy such as neurodegeneration. Thus, autophagy intersects with protein trafficking and secretion thus playing a broad role in the constitutive biosynthetic pathway, regulated exocytosis and alternative routing of integral membrane proteins to the plasma membrane.

In the conventional protein secretion (marked by orange arrow), the proteins synthesised from ER containing the leader peptide undergoes post-translational modifications in Golgi apparatus and gets secreted outside the cell whereas in unconventional protein secretion (marked

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Figure 1: Secretory pathways in cell involving autophagy process.
by black and blue arrows), the proteins bypass the Golgi route or get trapped in CUPS near the ERES (ER exit site) and gets secreted outside that are mediated by autophagosomes (blue arrow) and multivesicular bodies (MVBs; black arrow). The process of degradative autophagy involving phagophore expansion, autophagosome formation, lysosomal fusion and degradation are showed using white arrow.

In a neurodegenerative disease like Parkinson’s, the aggregation of proteins such as alpha-synuclein forms the main cause of the disease. This protein misfolding also affects many other PD-linked genes such as parkin, PINK-1 etc., compromising their function at different stages. The gene mutations in alpha-synuclein, by which the protein association with Lewy bodies happen, are the main pathological observation in these diseases. It is reported that dysfunctional lysosomal functions promotes secretion of such aggregates outside the cell. We are interested in understanding the secretory modes and the molecular machinery involved in the secretion of such aggregates using various biophysical methods. Exosomes, small-sized vesicles ranging between 30 and 200 nm are found to be one of the modes of secretion. The main caveat in the field is to identify potent UPS cargoes and also in delineating their molecular machinery in the protein trafficking. Unravelling the close nexus between autophagy and UPS in aggregate clearance pertaining to neurodegenerative diseases mediated by exosomes has potent therapeutic interventions. We are also employing a theoretical approach to determine/classify the UPS cargoes based on context dependence of the specific ‘DE’ motif (Sreedevi P et al., https://www.biorxiv.org/content/early/2018/01/18/250076.1)

In layman’s language, an analogy can be drawn of a cell with a utopian kingdom “Cellpuria”. In the distant microland of cellpuria lives the emperor DNA in the palace of Nucleus. He is closely associated with his consort histone. The bond between the emperor and the queen is inseparable. The kingdom is ably run by his eminent ministers heading various departments Home affairs minister (ER), mitochondria (power minister), communication department (Golgi), department of law and justice maintenance (lysosomes), foreign

Figure 2. Depiction of protein trafficking in a healthy and diseased cell.
affairs (endosomes). The palace is surrounded by two giant layers of fence (nuclear membrane) where trespassing is prohibited. The atmosphere (cytoplasm) is clean, free of pollution. The kingdom is maintained nicely with well-paved roads (cytoskeleton) and well-defined boundaries (plasma membrane). All the basic amenities are taken care by the government (homesostasis) (Figure 2a).

In the ideal prudent kingdom of Cellpuria, when there is a stroke of evil spirit (mutation)/natural disasters (environmental cues), outburst of plague (aggregate formation and spreading), it collapses the entire kingdom. Faulty production/revolt of young men such as alpha-synuclein, huntingtin, and amyloid set-up outbursts in many parts of the kingdom. These eruptions, as huge explosions (Lewy bodies), cause havoc in the kingdom (Figure 2b). The vesicles which are like envoys may get (secreted) out of the kingdom via different routes as suggested earlier (Type I – secret door; Type II – ABC transporter, ATP-power driven catapults; Type III – Autophagy machinery; Type IV – Golgi bypass).

The figure (2a) is of a healthy cell with proper homeostatic machinery while (2b) is a diseased cell affected with neurodegenerative disease causing aggregate such as alpha-synuclein.

Our interests have been in understanding these routes and probable way to clear these aggregates and thereby stop the spread the transmission of aggregates that are mediated by secretory autophagy. Future work should reveal selectivity of the unconventionally secreted vesicles and identification of critical modulators of this underexplored unconventional secretory pathway that would pave a way in treating the disease specifically.

As rightly said by the famous American poet, Robert Frost,

“Two roads diverged in a wood, and I
I took the one less travelled by,
And that has made all the difference.”

UPS is also one such journey of the intracellular proteins that is non-canonical which would pave way to understand its nature of secretion in a comprehensive manner.
Sitting on the sides of river Sessa (a tributary of river Brahmaputra) and enjoying the cool breeze, she wonders will the river water be transparent as before? She recollects the rendezvous of walking along the river banks when she was a kid to greet the water. She reminisce the tradition of worshiping river Brahmaputra and its tributaries by her forefathers as the lifeline to protect their civilization and socio-cultural aspects. Meanwhile glancing the pages of the newspaper, she finds the tragic tale of the river Sessa dominating the headlines over last fortnight. She continued reading and found a report by the Dibrugarh Fishery Co-operative Society stating an abrupt rise in the fish death in river Sessa leaving the rest of the fishes unhealthy for human consumption. The report advocated that the discharge of the untreated toxic wastes from the polymer factory nearby has resulted in sudden increase in the number of polluted stretches in this river, leaving the livelihood of the fishermen at stake. This problem of water pollution is of recent vintage with the heralding of the industrial revolution in the city. It is pretty apparent that the immediate aftermath of the polymer factory faced severe episodes of environmental change. As she completed reading the column of the newspaper, she felt the mute atrocities faced by the river water and a twilight seeking a raise in voice for the same. While the denizens of Assam were waking up with zeal to celebrate ‘Namami Brahmaputra river festival’, the trumpet of the gala kept playing in her dreams as if seeking a voice for the silent violence faced by the river. She speculated how ‘Namami’ symbolizing ‘worship thee’ be complete without paying heed to the agony behind silence of the river water. The

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need of the hour is to grapple the problem with vigor. On this note, the obvious question of who hasn't dreamt of bringing forth the renaissance of the river with effective abatement of pollution looms over the mind. A hope against hope!

Additionally being a researcher, she had a different set of responsibilities starting from teaching, proposal writings to lab work. She worked in a lab where the group worked towards establishing ‘catalyst bank’ employing metals the multitasking champions, which intended to provide the scientific community immeasurable application across domains. She pondered that she had the right tools at hand- the metals, in tackling the hurdle of wastewater problem. She felt as if the river water begged for alchemy for revival of its lost phoenix. Being a chemist, she knew that she could effectively modulate the chemistry of metals and search out a possible solution in this milieu. She discussed the matter with her mentor, Prof. Pankaj Das, and he suggested on unlocking the potentials of the metals and probe into multifunctional attributes in this vein. Armamentarium of the metals at her disposal, she decided to move forward with gleam in her eyes. Just as springtime heralds hope, the receipt of financial grant from DST SERB made her feel that her step towards her ‘magic catalyst’ won’t remain a dream anymore.

Moving with a train of thoughts, she aimed to develop her ‘magic catalyst’ that would satisfy 3R approach namely recoverable, robust and recyclable. However, an uncertainty regarding the choice of metals kept revolving in her mind. Next day at morning meal, her mom questioned her younger brother what does your breakfast cereal and steel spoon has in common? While her brother kept pondering the answer, she got inkling about her starting tool- that is iron, which would endow magnetic properties and assure the three distinct features of being robust, recoverable and recyclable. Another cue that she had drawn from the mom’s question was that alloying of metals as in steel can activate and bestow multifunctional and superior performance as compared to the individual counterparts. But however the hunt for the second metal still marched on in her mind. The task to adorn the second metal with iron which would confer wastewater remediation properties seemed to be an arduous challenge. Suddenly she recollected her grandma’s stories narrating the use of noble metals in water treatment and pharmaceuticals since ancient times. Before tinkering with her metals, she decided to opt for an in depth study in this context. She found that the significance of the noble metals could be clearly seen from historical perspective and especially in the contemporary times. She finally felt as if her squeaky wheels have got the grease to move. She than decided to pull a second leaf out of her toolbox that is to go with palladium- the noble metal at her doorstep. She harnessed the powers of iron and palladium and weaved them into her ‘magic catalyst’. The two metals rearranged their electrons to exhibit profoundly different properties. Seeking to stride a chord with the sustainability concept, she tamed the functionalities of the two metals using water as the solvent. Just as the doctors use ‘vital signs’ such as blood pressure to gauge the wellbeing of people, she as a chemist used different analytical tools to characterize her prepared catalyst. After she was ascertained about the preparation of her catalyst, she moved on to screen the toxic effluents present in the river water. She found 4-nitrophenol and chromium toxins top listed her search of effluents in the river water. She continued ahead to check the efficacy of the catalyst in removal of the same. Finally the vital findings of her study showed the removal
of the toxic effluents of the river water within 5 min of incubation of wastewater with the catalyst. To toe the analysis, she repeated her experiment several times to check the reproducibility and recyclability of the catalyst. To her delight, she could spell magic and repeatedly recover her catalyst by using a magnet. She reported her findings to her mentor and he further suggested her to check the multifaceted potentiality of her catalyst. Surprisingly, the catalyst was found to show potency in bridging two carbon atoms by a bond in the synthesis of organic chemicals. She was enlightened to prepare a clean and environmentally benign ‘magic catalyst’ which was instrumental in destruction of the toxic effluents of the river water and construction of organic chemicals. She was delighted to share her work amidst the scientific society and finally published her findings in ‘ChemistrySelect’ journal.

Going back to the title question “will the river water be transparent as before?”, the answer seems to be yes in part. Although the designing of her ‘magic catalyst’ irked her curiosity to extend some therapeutic ailment to the diseased river, she has many more extra miles to move on to return the lost glory of the river. The pursuit to achieve the complete vision for ‘Swachh Bharat Mission’ borders on the surreal and calls for a holistic approach. Hope this ‘magic catalyst’ raises some flags to imbibe inquisitiveness in young minds to blend science with innovation and make the ball to start rolling in the right direction.
One summer night, Joseph Meister, a nine-year-old boy terribly mauled by feral dogs, was brought to the laboratory of a scientist named Louis Pasteur. Pasteur, already a public figure, had been struggling to develop a vaccine for rabies for quite some time. He used a weakened form of the virus potion, called attenuated virus, that he had prepared by serial passage of the virus through rabbit hosts, to treat the boy. Joseph never developed any symptoms and the ferocious rabies virus had met its match. This epochal incident occurred 133 years ago. One would believe that 133 years would be enough to eradicate a deadly disease, but rabies still continues throw its weight around with a global death burden of 59,000 deaths a year, or about 160 a day, according to a study published in 2015 in the scientific journal ‘PLoS Neglected Tropical Diseases’. India, with its ingloriously large stray dog population, has the most rabies deaths almost 21,000 a year.

Largely eliminated from developed nations and island states, rabies kills thousands in Africa and Asia. Dogs, the anti-heroes of this story, account for 99% of rabies deaths in India. This has major implications for a situation that is unique to India we harbour a largely free-ranging, ‘stray dog’, population that occurs at high densities throughout the country. A whopping 58 million dogs (~6% of the global dog population) inhabit our country, for a comparison, the size of tiger population in India is 2,226. While international efforts now focus on achieving a global target of zero human deaths from dog-transmitted rabies by 2030, public health experts believe that India

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is far away from accomplishing this task. We do not even have the data to know the extent of the disease in spite of the serious public health threat of rabies in India.

The world’s most abundant carnivore, dogs, thrive in big cities, small towns, and villages across the Indian landscape. Human-dominated urban and semi-urban areas support very high densities of dogs as most Indian cities have extremely poor garbage management and disposal system an endless food supply for these scavengers. In addition to being a public health concern, stray dogs pose a major threat to local wildlife. Research work suggests that outbreaks of rabies can severely endanger wildlife. Studies have shown that the Ethiopian wolf population in the early 1990s in Serengeti National Park declined due to successive outbreaks of rabies. In the Indian scenario, stray dogs roam freely, unvaccinated, posing a huge threat to the wildlife in rural areas. Rural areas in India have thriving populations of several animals of conservation importance, such as foxes, jackals, leopards, snow leopards, lions, tigers, and wolves, that come in regular contact with dogs. Currently, we have no idea of the extent of danger that rabies transmission poses to this wildlife that shares the landscape with stray dogs. Stray dogs form the apex of the dog-wildlife-human rabies triangle that we urgently need to study to estimate the extent of this complex problem in India.

When biologists encounter a complex phenomenon, they like to develop models that capture the essence of that particular phenomenon. Models are abstractions of the real world that can give important insights. For example, Google Maps application on our smartphones provides us with a simplified model of an area, desirable for navigation. It would not be useful to construct this map with all the information about every tree, animal, and house. Similarly, to understand complex phenomenon of how rabies might spillover from stray dogs to wildlife and humans, scientists build models to simulate rabies spread in a virtual space and over imaginary time. Existing models of understanding the spread of rabies are not supported by field data and lack mechanistic details, meaning the details of how the spread might occur. For example, models are not able to accurately predict if the spread of rabies occurs through several long-distance dog movements or through a slow spread from an epicentre of the disease. Currently available models are too simple and inadequate in explaining how rabies is being transmitted and maintained in dog populations. With advancement in computational methods, researchers studying spread of diseases have started using a class of sophisticated models called ‘individual-based models’. In these models, researchers define a set of rules for individuals (in this case, animals) to live and interact in a virtual world and then record emergent properties of this ‘virtual world’. In my research work, I am building such models of rabies spread using the current best understanding of the system.

At our main field site in Baramati (Pune district, Maharashtra), work carried out to monitor stray dog population densities suggests that dog densities are higher in urban areas and there is risk of spillover of disease into adjacent rural areas. Rural areas of Baramati have thriving populations of foxes and jackals that overlap with human habitations. Our research team has put tracking devices (GPS collars) on 35 dogs, 18 foxes and 8 jackals to monitor animal movement. GPS collars are really neat devices. Based on the Global Positioning System technology (that is also used in our mobile phones), these devices record the animal’s exact location and store the readings at pre-
set intervals. These locations get logged and can be downloaded remotely sitting in our office in Bengaluru. From our work, we now know that foxes, jackals and dogs use the same area (degree of spatial overlap) and come in direct contact (contact rates) with each other. Interestingly, the animal tracking data shows that dogs, jackals and foxes utilise the human-modified landscape in their own peculiar ways. When humans modify the landscape by building roads, railway lines and residential colonies, animals respond to these changes in the landscape. For example, we found that a pair of jackals that we were tracking never cross the railway tracks to enter other’s territory. The important role of geography in disease spread was also showed in a study published in 2018 in the scientific journal ‘Molecular Ecology’ where scientists showed that while rivers could act as potential barriers to rabies transmission, roads acted as facilitators for the same. In my research, I use the information from animal movement data from Baramati to build the simulation models of rabies outbreak.

The great advantage of modelling disease spread using simulations (such as ‘individual based models’) is that one can tweak this model to test the performance of different kinds of rabies control methods that policymakers might employ. In my research, I test efficacy of different control methods, such as 50% and 100% dog vaccination coverage, reducing dog densities through animal birth control (ABC) programs, restricting dog movements in fox-jackal habitats, or fox/jackal vaccination. This information is extremely valuable for environmental/ wildlife managers and policymakers to make informed decisions to contain the spread of rabies.

The current strategy for the control of rabies in India is based on studies that were not conducted in India. To reduce the spread of rabies in the dog population, we rely on the World Health Organisation’s guideline of vaccinating 70% of the dog population annually. Dog-catchers, risking dog-bites, continue to vaccinate and sterilise dogs as part of animal birth control programs. Over a hundred years have passed ever since Louis Pasteur developed the rabies vaccine, but rabies remains. India’s rabies problem is unique to her and policies and strategies based on scientific evidence through such studies conducted in India alone can tackle the problem of rabies.
The Backstage Story of
My Auto-Reusable Fluoride Receptors

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Before going to the depth of my story let me offer you a tour to my world (even if you don’t want to). I am a 28 year old researcher (age is important). Currently I am in Indian Institute of Technology (IIT), Bombay working as a Post-Doctoral Fellow (PDF). I did my PhD in Chemistry from Tezpur University, Assam in 2017 and this is a story from my PhD time about a publication, which changed my perception towards research.

19 March 2015. A foggy morning. A very pleasant one for someone who can sleep upto 9 am and enjoy the slightest cold left after the winter. However, not a very enjoyable one for someone like me a so-called researcher who has to wake up at six in the morning to leave for UV slots. Oops, I forgot I may have to describe what an UV slot is, right? An UV-visible spectrometer machine is an instrument that helps us to understand about the energy levels of a molecule and how it interacts with other molecules (do not tell me that you don’t know what a molecule is!). Now in our department we have only one UV-visible spectrometer, which runs without any tantrum (I mean error). So, particularly for that UV instrument crowd is always higher (see, PhD is not only about how you perform. It is also, about how the instruments perform). Today I got slots from 7 to 11 am. Anyway, sadly today is my birthday and it sucks. Who on this earth goes to work before time on his/her birthday?

I reached my lab at 7 am and started working. It has been two years since I have joined here and untilnow, I got no publishable results. My guide himself is a confusing person or he...
only confuses me on purpose that I have never understood. After I joined PhD, I initially worked on metal-organic frameworks (MOFs). One and half years passed and I got no results. Then my confusing supervisor became more impatient than I did. He thought if I change my topic I might get results. Therefore, here I am working on fluoride recognition. Now a day anion recognition is an interesting field to invest on because after the discovery of crown ether compounds and their interaction towards anions, recognition of anions has become a vast area for researchers. From the green chemistry point of view also it is very exciting to study the different interactions of toxic anions (here I am considering fluoride as the anion and I hope you know that excessive intake of fluoride has many severe health implications such as fluorosis and osteofluorosis etc.) with receptors. A receptor is like a crab and anions are its prey. It catches the anion which is suitable from all the conditions such as size, pH etc. A more specific receptor is always a better one because that is how we can recognize a specific anion.

Fluoride receptors work via different mode of interaction. Among them hydrogen bonding is the most common and desired one (hydrogen bonding is like a complicated relationship where an electronegative atom like N, O, F (I hope at least you know the meaning of these letters) etc. of a molecule are not directly attached to a hydrogen but attracted towards a hydrogen atom of another molecule or the same molecule from a different part and develops a relationship lesser intense than a direct bond). I have already synthesized four molecules containing an oxime bond and trying to find out their interaction with nine different anions including fluoride. An oxime is a group having the bond pattern NOH.

Knock knock. Someone opens the door. It is Monica. We joined in PhD together in same lab. But, I bet my supervisor likes her thousand times more than me. Do you know why? Because she has already published one article in Chemical Communication (it is a very highly acknowledged journal).

“Sir is asking for you Suchi”-she said
“Okay, coming in a minute”

Among the four receptors, two of it is showing good results. One receptor is highly active towards fluoride. One is totally inactive. I can explain why. There is difference in pattern though the structures are almost same. But, that is not the tough part. Problem is, results of the other two receptors are not conclusive.

“May I come in Sir”
“Please come in”
“Sir you called me?”

“Ooh yes. I wanted to know what is the result of your receptors. It has been 6 months since you have started working on these receptors. Clock is ticking Suchi. You don’t have your whole life for PhD.”

Whenever my sir start talking about time, I wonder he has already forgotten his own struggle or he just pretend to forget that. “Manjhi the mountain man” PhD trailer spoof released few days back. They said it right “Don’t wait for your guide. Who knows he is waiting for you”

“Suchiiii.…….?"
“Yes sir. I have already started writing manuscript for the first two receptors. However, results for the next two are inconclusive. I think they are not very good receptors. We should discard these two”

My supervisor is not very aged. He still has the urge for results and publications unlike few other faculties in my department. His eyes are more notorious than deep. He looked at me for few seconds.

“PhD is not only about working hard blindly and getting publications. It is about learning how to make strategies, schemes and proceed systematically. It is also about learning how to observe your results from different angles, which I don’t think you have learned yet. Write the first manuscript quickly and figure out what you want to do about the other two. Now, go.”

Uuuggghhh. Why doesn't he understand that these two mysterious compounds are good for nothing. I came out of his chamber, went to the lab, sat on a chair and started thinking. Whenever a good colorimetric receptor recognizes an anion, it changes color. For example in my case it is colorless to yellow. After recognition, color remains days after days, months after months. It is like the crab’s claw, it doesn’t release its prey once caught. If you want to release it you have to put external force to get it back from the crab. In case of reversible receptors, you have to add external agents to get the receptor back. However, in my later two receptors, the color fades away after half an hour and become colorless automatically. I don't know Why! Why? Why? Ooh may be because it doesn’t need any external force for reversibility. All the UV data before fluoride addition overlaps with that of the receptor after half an hour of fluoride addition. Which means the attraction between the receptor and fluoride is not very strong as like the previous one. The presence of mild attraction force, suitable solvent works as the driving force for the receptor to release fluoride anion and thus gains its original structure. Therefore, when fluoride is added to the same used receptor solution for the second time, it regains color or we can say it detects fluoride again.

Yes. I may have found some logic behind the strange phenomena. I want to tell about it to my sir immediately. However, it is 5.30 already. I ran towards his chamber. He was closing.

“Sir, I need to talk.”
“Can we talk about it tomorrow?”
“No.”
Staring at me he said “Okay..go on.”
I explained to him whatever understanding I had. He was quiet for a moment. Then he said-
“I think you have found the answers. We can name your special compounds auto-reusable receptors as they function on their own without any external agents. Gather all the information to support your claim and manuscript is all yours.”

“Thank you sir.”
Today I am the happiest person on earth. Not a very bad birthday I guess. Today I could also realize why our supervisors push us beyond our limits because they know we can do better. In PhD, you cannot stop trying because you will never know at what point success will come and touch your feet. Everyone has a different clock. So, keep trying.
In next four months, I collected all the data including UV-visible, FT-IR, Single crystal XRD etc. and completed writing the manuscripts. My paper containing the first two auto-reusable compounds got published in November 2015 in RSC Advances.

Your muscles and Fruit Fly stem cells

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For about 60 years we have known about stem cells that repair muscles in mammals. We were sure insect muscles don’t use stem cells to repair themselves. But no one showed if and how insect muscles do repair themselves. This article discusses how the discovery of adult muscle stem cells in Fruit Flies was made.

We all get hurt from time to time. You might bruise a knee, break a bone or burn a finger. Our bodies possess the marvelous ability to largely repair these injuries. The ability to repair body tissues is not limited to just humans.

In multicellular life-forms, like ants and elephants (and us too), there are mechanisms by which one cell senses injury in its vicinity (Doğaner B et al, Trends in Cell Biology 2016). Once this cell and other cells near the site of injury sense that there is a wound and it needs repair, they often proliferate to make the number of cells to replace damaged cells (Duscher D et al, Gerontology 2016).

Not all cells can multiply if there is a cut. In adults, cells that can facilitate repair are called Adult Stem Cells (Clevers H, Science 2015). When they divide, they give rise to two cell types. One cell takes the characteristics of the tissue which the stem cell came from. This change in characteristics is called differentiation. The other daughter cell remains a stem cell. This daughter stem cell can again divide to give rise to another differentiated cell and a stem cell. In this way, adult stem cells maintain and repair the tissue to which they belong.

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Cells within a body must coordinate growth and metabolism. Cells coordinate and communicate with each other at various distances through chemical signals. These signalling molecules can be small organic molecules like hormones or larger protein molecules. They can either be freely circulated in the body or attached to cell surfaces. Most often, a signalling molecule can bind another molecule on a recipient cell called a receptor. The combination of a signalling molecule bound to a receptor, triggers changes in the receptor-bearing cell. This signal receptor combination is akin to a word that cells use to communicate in. If you injure yourself, say cut a finger, other cells in your finger sense the injury through such word(s). The signals trigger changes to repair the cut (Oda Y et al, Journal of Steroid Biochemistry and Molecular Biology 2016).

A tissue most of us pay little or too much attention to is muscle. Muscles form 40-60% of our body weight. Skeletal muscles, the ones we use to move our bodies, are essential for quality of life. Imagine anything you did out of bed today. Now, picture doing these things without using muscles. Skeletal muscles are very different from other cell types in one important way. Each mature muscle cell, also called a muscle fibre, has thousands of nuclei. Each mature muscle cell comes to contain thousands of nuclei through the fusion of thousands of individual muscle cells with single nuclei. Several mature muscle cells together bundle up, like wires in a cable, to form what we all think of when we hear the word “muscle”. These muscles contract and relax a lot. Movement damages muscles. The group of cells necessary for skeletal muscle repair is called ‘satellite cells’.

Satellite cells are crucial to muscle repair. When muscles are damaged by severe motion or a physical injury, satellite cells divide over and over and their progeny fuse with muscle fibres (Collins CA et al, Cell 2005). If satellite cells are lost in adults, as can happen over time in certain genetic diseases, muscles lose mass and the ability to contract. Such patients can lose much of their ability to move objects or even their own body.

It turns out, these ‘words’ that cells communicate use with each other during repair, are also the same ones used during development from a zygote to an adult. Even more amazingly, these words are very similar between different species. In fact, we learnt the molecular nature of signalling mechanisms from the humble fruit fly.

Fruit flies are a great species to understand signalling mechanisms and the development of an organism. Of course, a fruit fly egg cannot develop exactly like and into a human being. But decades of studies have shown that the basic principles of tissue formation and function are very similar. We know now that the signalling and cellular mechanisms that breakdown to cause diseases like cancer in human beings, are very similar in fruit flies. In fact, many of them were first discovered in fruit flies.

So, to return to adult muscle stem cells or satellite cells: Through electron microscopy, scientists have seen this cell population in mouse muscle since 1961. These are muscle cells with single nuclei that are positioned right next to muscle fibres. If you take away satellite cells from mammalian muscle and injure the muscle, the injured muscle does not get repaired. In this way, we know that satellite cells are required for muscle repair. These cells can be identified inside a muscle because they have the protein Pax7 (Chang NC, Stem Cells in Development and Disease. 2014). Mature muscle fibres do not have this protein.
Up until 2017, satellite cells were thought not to exist in fruit flies (Rai M et al, Mechanisms of Regeneration 2014). Some researchers have said that satellite cells do not exist in insect muscles. Though strange things happen in nature, this was particularly curious.

Therefore, in the lab of Dr K Vijay Raghavan at NCBS, we looked for satellite cells in fruit fly muscle. Unless you have very clear experiments and unquestionable data, it is hard to overturn a belief in science. The great thing about science though is that new and compelling evidence can change beliefs.

Dr Rajesh Gunage, from the same lab, had found a group of cells needed to form adult Drosophila flight muscles, called adult muscle progenitors. Based on what we know about muscles from fruit flies and mammals, it followed that the cells that Rajesh had identified, would/should give rise to Drosophila Satellite cells. He showed very clearly that the daughters of adult muscle progenitors become a part of adult flight muscles and also become cells with single nuclei right adjacent mature muscle fibers. The physical similarity to mammalian satellite cells, even as seen in electron micrographs, was striking. He also found which ‘word’, technically called a signalling pathway, which these cells use to communicate with their surroundings. This is the Notch pathway.

To convince researchers like us, that a new group of cells has been identified, especially one that is completely unexpected, we had to provide a unique feature of these “satellite” cells, much like Pax7 in mice. This makes complete sense. If I am given a bunch of cells, I have no way of studying specific cells in the collection without a ‘marker’. Imagine identifying one person on a bustling crowded platform at a railway station. You need something specific (like a blue shirt and white pants), about one individual to observe what they do.

So, I looked for one protein that is found only in fruit fly satellite cells. If this protein is expressed in satellite cells, it had to be necessary for muscle formation. Logic dictates that if it is found in satellite cells in fruit fly flight muscles, it would also be in cells that contribute to mature muscles, say in larvae or pupae. Though, the requirement of a number of proteins is known for muscle formation, guessing which one would be only in satellite cells was non-trivial. I checked and found only one of the many proteins was seen in adult muscle progenitors and in satellite cells in adults. We even found a small time window in which the cells that will become satellite cells in adults keep this protein, but others lose it. This protein is called Zfh1.

If cells with Zfh1 are like mammalian satellite cells, they would increase in number if the muscle is injured and help with repair. We used a simple pin prick to damage flight muscle in adult Drosophila. We then quickly showed that daughters of cells with Zfh1 in adult Drosophila flight muscles divide and might help with repair after injury.

So, at Dr Vijay Raghavan’s lab in NCBS were the first to identify cells in adult Drosophila flight muscles that maybe functional equivalents of satellite cells in mammals (Chaturvedi D et al, eLife 2017). This opens up new possibilities to answer fundamental questions about muscle maintenance. We now have a way of studying their behaviour in living tissue inside an animal. That had been difficult so far. We sincerely hope our findings about muscle maintenance and repair in fruit flies will someday help patients with genetic muscle diseases. In scientific terms, this information changes how we think about muscle formation and muscle repair in the tree of evolution.
The Andes Flight Disaster is a unique incident of what human beings can do when faced with ultimate threat to survival. In 1972, when a plane crashed on a high altitude glacier in the Andes and no help was likely for several days, the crash survivors ate others in order to live. This may not be common in humans but our lab discovered that this happens routinely in bacteria. When they perceive conditions of starvation, they start eating each other. Many adaptations and characteristics of several genera of bacteria have specifically evolved the abilities to do so and this adaptation has shaped bacterial evolution to a large extent. This work is a long and difficult series of experiments of which I was fortunate to be a part, but only a part, because it was necessarily a team work being pursued for over a decade.

Predatory bacteria are not new. Some forms of bacteria such as *Bdellovibrio* and bacteria are known to be predatory in nature. But what we found was much beyond that. Many bacteria that we normally know as saprophytic and happily grow on many of the commonly used media can suddenly start eating each other if they are exposed to habitats where other nutrients are almost absent. Environments such as the nutrient media that we prepare in the lab are exceedingly rare in nature. Over 70% of earth surface is water which is a very dilute environment. Most of the rest is soil where again soluble nutrients are at a very low concentration. When we grow bacteria on media that have 1 or 2% of protein digests or sugars or other extracts they are face varying unnatural conditions. So studying pure cultures of bacteria on such artificial conditions tells us very little.

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about their life in nature. Our lab is more interested in looking at how bacteria live out there rather than what they do in petri-plates and test-tubes.

While I was exploring how the aging response in bacteria works in dilute environments, in 2011 a former PhD student of our lab and my contemporary, Charu Kumbhar demonstrated that *Streptomyces* are predators of bacteria ([https://www.youtube.com/watch?v=5OwWfkgr9-8](https://www.youtube.com/watch?v=5OwWfkgr9-8)) in soil and that they seem to use antibiotics as their canines to kill prey. Here, we define predation as the ability to kill other bacteria and grow by consuming them when no other source of nutrition is available. In oligotrophic, i.e. nutritionally extremely dilute conditions or during starvation predator attacks the prey using secondary metabolites and enzymes to kill them, break the cell open and enjoys the contents as a meal. We also had several reasons to think that antibiotics might have evolved primarily for predation. All predatory bacteria that kill their prey from outside are rich in secondary metabolite genes. We tested the reverse hypothesis that all antibiotic-producing bacteria should be able to survive by predatory existence and that is turning out to be largely true for most genera that we tested from soil and the marine environment. The classical belief that antibiotics evolved for competition does not sustain because antibiotics are not produced during growth phase when competition should be the highest.

Predators and prey are known to have a co-evolutionary arms race. If predators evolved chemicals and enzymes to kill prey, prey should evolve resistance. It is simple to conceive that resistance to antibiotics would evolve in nature and be extremely common. But, the advantage of resistance is not limited to escaping predation. Resistance may also be a strategy for obtaining nutrients without energetic cost associated with production of antibiotics and extracellular enzymes. If you have a predator and prey in the neighbourhood, let the predator kill the prey, you only absorb nutrients released from the kill. This way you can do better than the predator because the predator has to invest in making and secreting the chemicals and enzymes. You don’t invest in this effort but only skim the benefits.

To understand the mechanism of predation better, we studied marine isolates which show good predatory activity against different prey. By this time, I was a post-doc in the same lab shouldering the responsibility of coordinating a project to understand what actinomycetes and other bacteria associated with marine sponges do in nature. Now our team was bigger and two project assistants Ketaki Holkar and Anagha Pund had joined me in exploring predation by marine actinomycetes. The team studying marine microbiota consisted of more researchers including Uttara Lele, Srinu Meesala, Neha Shintre, Tejal Gujrathi, Avantika Jakati, Ruby Joshi and Harshada Vidwans who contributed to our understanding of the microbial community in shallow sea and intertidal pools. They kept on supplying us many interesting strains. During screening, we found that *Streptomyces atrovirens* isolated from a sponge showed excellent predatory activity against many species of bacteria. One unique property of this strain was that it had the ability to eat the spores of *Bacillus species* which no other predator has shown so far.

A typical experiment goes this way. You make a plate with water and agarose, devoid of any nutrient and spread a lawn of washed live cells of the potential prey on it. After placing *S. atrovirens* at the center of prey on water agar plates, the plates are incubated for several days at 30°C along
with controls. The plates are monitored for the growth of predator and zone of clearance around the predator. In a few days, you see the predator growing and the making a clear zone around it whose diameter keeps in increasing for several days. Since there are no other nutrients, only predation can enable growth. This is simple but does not let us know what is actually happening at the level of the cell.

To watch things happen under a microscope, a water-agarose bed was prepared on a slide to view live predation using a 100X objective with differential interference contrast microscopy. Here, if you observe patiently, you can observe individual prey cells being lysed and the tips of predator mycelium growing. After a while we see that the density of prey cells decreases near to the predator and remains high away from it.

More fun and high drama started when we thought of observing interaction between more than two species. In two species, interaction different combinations for co-culture of *Staphylococcus aureus* and *Proteus vulgaris* showed susceptibility to predation, while *Escherichia coli* is resistant. In all combinations whenever *S. aureus* was present, it was lysed first. When *E. coli* was present with *S. aureus* and *S. atrovirens*, *E. coli* grew most luxuriantly although it could not kill any one when in pairs. This appears to be because when *S. atrovirens* kills *S. aureus*, *E. coli* benefits the most. In paired interaction, *P. vulgaris* can be preyed upon by *S. atrovirens*. But, in the presence of *S. aureus*, *P. vulgaris* was spared by the predator presumably because a more favourite prey was there.

On a different line, we tried to isolate compounds involved in predation. This job was too tough since they are produced in extremely minute quantities and are not produced in liquid media at all. In fact, predation is a strictly surface phenomenon and does not happen in submerged cultures. For *S. atrovirens*, after extracting from 3,000 experimental plates, we got 4mg of purified...
compounds whose expression was specific to predation. Interestingly, this compound did not kill any of the prey bacteria in conventional MIC assays, but proved to have biofilm inhibitory activity against gram positive as well as gram negative bacteria. We hope we will be able to explore the nano-chemistry of predation and expect a number of novel compounds to surface, but it is going to be a tough job indeed.

This work is never-ending. We have just begun probing into how different species of bacteria interact in nature. We take commonly known bacteria to see how differently they behave when grown under conditions more closely simulating natural environments. Today, research in microbiology has compulsorily gone genomic. You can’t publish papers in high-impact journals unless you generate large volumes of genomic, epigenomic, proteomic or any other omic data. But this does not necessarily give us an understanding of the life of bacteria. An attempt to understand the life of bacteria is both sentimentally and intellectually more rewarding than publishing papers in high-impact journals.
An ‘AWSAR’ to Devise a Protocol for Laser-based Excision of Microscopic Woody Apple Bud Meristem for Tissue-Specific Expression Analysis

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Apples from the hills of Shimla region of Himachal Pradesh are freighted nationwide and abroad. Being a resident of the hills, it had always been figurative as well as exciting for me to see that how this local produce is moved from hills to the plains. Therefore, it is a common sight on Shimla-Chandigarh National Highway-22 to see the trail of trucks carrying the apple-packed cartons from orchards to other parts of the country. But, this time these were apple buds packed in dry ice instead of fruit cartons, which were being carried by me from these hills to National Institute of Plant Genome Research (NIPGR), New Delhi as part of my DST-SERB N-PDF research project work.

Apple (Malus × domestica), being a major temperate fruit, is consumed as a rich source of phytochemicals worldwide. In the remote hill areas, where the transport facilities still remain poorly developed and income sources are limited, this fruit is the only source of income for some local and adjoining communities involved in maintenance, harvest, packaging and transport. Apple tree is a temperate woody perennial. It does not bear any fruits for the first few years of its life which is known as the juvenile phase of its life. After the completion of juvenility, the reproductive events which involve setting of flowers and bearing of fruits take place perennially for the rest of its life. The tree undergoes various developmental reprogramming according to change in seasons. Being smart enough to cope with the harsh winter conditions, standing snow-covered at an altitude

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of 2276 meters above sea level and still managing to serve a visual-delight to onlookers, these temperate trees plan their lifecycle wisely and undergo developmental reprogramming to bear the environmental changes. This involves slowing down of the metabolic events and shedding leaves to conserve energy for the next vivacious phase of their life. This vivacious phase, known as the reproductive phase, embraces setting of flowers and fruits and is initiated consecutively after breaking of dormancy. The appropriate onset of the aforesaid reproductive event encompass dormancy only if the chilling, light and temperature parameters are properly met by these trees. Apart from the rest of the tree organs instrumental for life, a bigger responsibility to contrive this tendency is mostly controlled by the self-perpetuating microscopic units of life on the apical and axillary shoot buds, called the shoot meristems. The meristems are basically niches of actively dividing cells which are capable of giving rise to different cell types.

I was in constant touch with one of my MSc Professor, now heading the ICAR-NBPGR, regional station Shimla to kindly keep me informed about sample stages of apple I needed to collect. Since the trees are very much sensitive to environmental signals, they bloom early if summers onset early. This time the summers arrived early and it was the time to pack the bags and head to the queen of hills, Shimla to collect the apple buds. Looking at me amazed and curious for why I was collecting the small pieces of wood (apple bud samples), I had a brief conversation with a few local people collecting forage for their livestock and wood for fuel from nearby apple orchards. These people following a lineage of worshipping local deities said in surmise in their local dialect, ‘lagam reo devta naraaj ho ryan, hyun kam pad reo, ta karin ye baar garam jhik ho ryo ta seb ne lag ryan’. Being a native, I somehow managed to understand what they were saying. They meant that there has been a substantial reduction in snowfall since last some years because the deities have been furious and, therefore, apple production was getting affected due to prevalent scorching temperatures in the hills. Scrupulously, they were not wrong since these are wisely planned means by ancestors to conserve natural resources and forests in name of the fear of local deities and Gods. Throughout the year, all the major festivals of these tribes tend to fall around the seasonal environmental changes for celebrating the local temperate produce. Being a part of the research community of a country where roughly 70% of population resides in small remote villages, alongside studying the effects of global temperature elevation on staple food crop production, it is of utmost importance to understand the effects of global climate changes on the regional temperate commercial crop production. Apple is a crop accounting for 90% of the total commercial horticultural production of the hill state of Himachal Pradesh and is consumed as a major temperate crop worldwide. This temperate horticultural crop serves as an appropriate model for studying the molecular events encompassing this seasonal reprogramming in the woody apple buds, which are the heart of meristematic activity.

The abovementioned events of dormancy breaking are initiated after perception of environmental signals and accordingly a particular gene is switched off or turned on to modulate the overall protein expression of the plant cell as per the needs of plants. In this process, apart from mRNAs which code proteins, the small non coding miRNAs play important regulatory roles by cleaving their mRNA targets or rendering a protein non-functional. We are interested
in deciphering the role of small non-coding miRNAs in regulating bud dormancy release in the 
meristem tissue of apple. For this, firstly we were required to devise a protocol for excision of the 
microscopic meristematic tissue from apple bud. But, apple has a woody bud containing a woody 
meristem, so devising a protocol for its excision was the first hurdle. We could have carried out the 
studies in easy to grow model plants like Arabidopsis for which some protocols of tissue specific 
excision are already available but it was impossible to replicate and investigate the seasonal events, 
which we are particularly interested in studying, in these annual species.

The first step was fixing the sample’s molecular details in the stage at which they were excised. 
This was done using various organic solvents. After bringing them back to host lab at NIPGR, 
New Delhi, aldehyde-based reagents were used for crosslinking of the proteins. This was followed 
by removing the traces of water from tissue by dehydrating and infiltrating it with gradients of 
alcohol-based reagents. The next step was embedding the buds in wax and making wax blocks 
using specific molds which could facilitate sectioning of the buds for making fine thin micrometer 
thickness chips of the tissue. For this, firstly the tissue was acquainted with wax infiltration for 
some days at an ambient temperature which could facilitate wax infiltration without damage to 
cellular components and the overall cell morphological details. The buds were cut to fine sections 
using a microtome, a tool used to cut extremely thin slices (sections) of a material.

We deployed Laser Capture Microdissection (LCM) for the excision of cells of interest from 
the apple bud sections. LCM involves excision of cells from a particular mixed population of cells 
using a laser beam. The LCM excised apple meristem tissue was utilised for total RNA isolation. 
Since the host lab of my N-PDF research project headed by Dr Ananda K Sarkar at NIPGR, New 
Delhi is quite experienced in working with LCM of plant tissues, some empirical hit-and-trial-
worthy modifications and availability of the related materials, chemicals and equipment in the lab 
helped in devising a protocol which could facilitate the process for woody apple buds. Till date, 
none of the research work addresses isolation of miRNA from microscopic cell/tissue types of tree 
species. We have placed a protocol in place for this kind and similar related analysis of a hard to 
excise microscopic woody tissue.

The protocol would also help in overcoming the hurdle of immediate unavailability of stage-
specific samples throughout the year due to their perennial lifecycle. Because now the tissue can be 
fixed and sectioned, the cells of interest can be excised from a mixed population using LCM, the 
nucleic acids and other cell components can be isolated, preserved and analyzed as per the need of 
the experiment at any time of the year. The research is likely to help in elucidating the role played 
by miRNAs in regulating the events of dormancy breaking in temperate woody perennials.

The time is apt to address the effects of global warming on temperate woody perennial plant 
crop productivity which are subject to maxim adverse effect of global warming. You are able to 
understand the problems of a particular geographical area very well which you have been rooted to. 
This research project is an absolute ‘AWSAR’ for me to get a scientific insight into the modulation 
of gene expression during bud break process and helped me to put a tissue specific excision and 
RNA isolation system in place for further expression analysis.
Who doesn’t love puzzles? You begin life learning to put together big pieces into a simple jigsaw. With time, it gets more complex, the pieces get smaller and the journey to complete this challenge gets more exciting. We scientists are basically kids with our puzzles. The only difference is, a lot of times we do not have the whole picture. We come in with pieces of our own to try and solve the mystery. But no one person has answers to all puzzles, so we have to work in a team.

That is what biomedical research is today. A story of collaboration to solve riddles of Why? How? When? And quite possibly, Where?

The story of my research begins much like it did for many others - wide-eyed and awed by the magnitude of questions yet unanswered. To continue along my meandering path of analogies, cancer (the primary field of my research) is akin to the many headed mythical Hydra. Cut one head off and two others pop up! Every cancer researcher essentially has a Herculean task ahead of them.

But the picture is not all bleak. The truth is that researchers have made excellent progress in understanding this disease and are much closer to viable therapies. A world where the word ‘cancer’ does not fill you with dread? We have not gotten there yet! And ‘that’ light at the end of the tunnel is one of the many reasons why I, just like many others before me, stepped up to the plate, determined not to strike out!

In the ensuing paragraphs, I will try to explain to you my contribution to the jigsaw puzzle of our fight against oral cancer. I also hope to debunk unreferenced (scientific shudder), non-researched (mini heart attack), half-baked information that is shared between many in the form of long tirades on social media. If you have ever shared ‘cancer cures and big pharmas’ conspiracy

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theories, this slow, disappointed head shake is for you… You know who you are?

The basic premise of my research was to understand the effect of chronic smoke or chewing tobacco exposure on oral cells. Do these oral cells start to play truant? Do they begin to show signs of cancerous transformation? “Smoking causes cancer”, apparently everybody knows that! In fact, anyone who has ever seen poor ‘Mukesh’ in theatres before their movie viewing knows all about how tobacco smoking or chewing can cause major trauma/ disfigurement.

But here is the question. How/Why do they cause cancer? This is like the subtle difference between knowing Lex Luthor could kill Superman and Lex Luthor could kill Superman because of Kryptonite! The devil is in the details. That is what I set out to find. Kryptonite… or the devil… depending on what you believe in.

My professor and I believed that though both cigarettes and chewing tobacco are products with similar origins (the tobacco plant) both these forms of tobacco differ in many ways - from their processing stages to their final mode of intake. If they are inherently different, wouldn't they cause the same type of cancer in a different molecular way too?

The benefits of identifying molecular mechanisms by which cigarette smoke or chewing tobacco cause cancerous changes in normal cells are manifold. Different “molecular markers” that change due to smoke/ chewing tobacco exposure could help segregate individuals based on their differing tobacco usage habits. These molecular differences imply divergence in the essential makeup of cancers. This equals distinct vulnerabilities or dependencies in these cancers. The end goal of this puzzle is we detect/identify malignancies before they manifest as a full blown cancer in an individual? Can we also treat them effectively with customized drugs based on their distinct molecular profile?

For the story to begin, one must start with the protagonist. Our protagonist was a normal cell from the mouth of a healthy individual. These cells from the mouth were altered in the lab to grow continuously - “immortalized”, but not cancerous. These cells were now divided into three sets –one group was exposed to cigarette smoke, another group was exposed to chewing tobacco extract and a third set that were grown unaffected by any exposure. All three sets were grown in these conditions for up to 8 months. This was done to mimic long term exposure to cigarette smoke or chewing tobacco that an individual might experience in real life.

The cells were then made to undergo some tests do smoke/ chewing tobacco exposed cells grow faster than normal, unexposed cells? Do they have any other cancer cell-like qualities? Long story short yes, they did. This was the first step in the right direction our normal cells seemed to have transformed towards cancer due to cigarette smoke and chewing tobacco.

Now, most of you are aware of the importance of genes in the human body. Cancer has a strong genetic component so we were curious to see changes at the genetic level in these transformed cells. We performed ‘next generation sequencing’ (NGS) of DNA from these cells, a technology that has opened up a whole world of opportunity in understanding organisms and diseases. Think of NGS as one of the techniques that made Jurassic Park (1, 2 and 3) possible. See what I mean? Indeed, we saw there were changes in DNA that were different for smoke exposed cells and chewing tobacco exposed cells. Yes, these two different forms of tobacco may transform cells differently.
The next step involved employing the exciting technique of mass spectrometry based-proteomics a method to simultaneously query the entire set of proteins in a living system. Why proteins? Because they are the ‘functional readout’ of every cell they are the cogs in the machinery that keep cells functioning and ‘alive’. Our aim was to see whether some proteins had changed their expression pattern in the smoke exposed or chewing tobacco exposed cells compared to unexposed cells (normal cells from human mouth). This would be a problem because “too many cooks spoil the broth”.

In addition, we wanted to know were such proteins different between smoke and chewing tobacco exposed cells? What we observed was interesting yes many proteins were seen to be increased or decreased upon smoke or tobacco exposure, some of them were also different between the two forms of tobacco exposure AND these changes were seen as early as two months of exposure! A lot of these proteins are known to be affected in various other cancers and this indicated that we were on the right track our cells were transformed and proteins affected in our cellular models are known to be altered in cancers.

The second part of my PhD study was to understand whether cancerous transformation because of chronic cigarette smoke exposure resulted in cells which became dependent on some internal machinery for their survival. Did some protein or proteins become absolutely essential for the survival of smoke exposed transformed cells? The answer is Yes! We observed that in cells exposed to smoke for up to 12 months, suppressing a protein called protein kinase N2 (PKN2) caused cells to lose their cancer-like features. What’s more exciting is that the same phenomenon was observed in established cancer cells taken from smokers. So does this make PKN2 the new golden ticket? I would hope so, but this needs much more validation and confirmation, especially in animal cancer models and then in clinical trials before the efficacy of targeting this or any similar protein can be established.

I would like readers to take away some key messages from my story. Basic research of this kind takes years and requires hands-on and intellectual input from a number of scientists and researchers. Multiply this with the number of institutes around the world that are involved in similar research. Years of dedication and scientific integrity go into piecing together such puzzles. The most promising results from such research are then taken forward to identify the most efficient and fool-proof ways of tackling different cancers. Many promising targets never make it to the summit. The tenacious few that show continued promise are then tested in larger, genetically diverse populations.

Now, not all drugs are ‘one size fits all’. This is the age of customization - in designing clothes, in designing drugs. Pharmaceuticals and researchers work together for the end goal of finding the right drug for each individual. So let’s not dismiss the precious work that scientists do with incomplete knowledge and flippant texts. I urge you to read more and educate yourselves on today’s science. Share facts, not fiction!

For now, I have placed my piece in this mega-puzzle. I now move onwards to tackle the next piece and explore new paths. But every path leads us to the same destination defeating a formidable opponent.
Wood Protectant from Coconut Shell: New Biobased Product for a Safe Future

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Long lasting coconut shell

Have you ever noticed shells of coconut surviving the test of time? Have you ever wondered why the coconut shells remain intact in soil, long after it's thrown out? When I came across a piece of coconut shell in my garden withstanding the adverse effects of weather and attack of microorganisms, long after it was discarded, I pondered on the reason. When all other biological materials like leaves, wood and kitchen wastes disappeared in no time what makes coconut shell unique. What could be the reason behind it? What makes it so much durable? There is surely something which is protecting it from biodeterioration.

Coconut shell oil to protect wood

Being a Keralite whose life revolves around coconut, it came naturally to me that if I can utilize this property of coconut shell to develop a wood preservative it will definitely be a boon to the wood industry as the wood science researchers are under pressure to find a biobased wood preservative.

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Coconuts are the most auspicious among edible fruits with multiple utilities and products made from its kernel. Coconut shells are usually thrown out from kitchen though a few use them to burn as fuel for cooking. The shells are not eaten by insects or decayed by microbes and remain intact for a very long time. This was the thought behind the Post Doctoral project proposal which I submitted to KSCSTE, Govt. of Kerala, and I was fortunate to receive funding for the proposal.

The idea behind the proposal was to find out whether coconut shell oil can be used as a wood preservative. Coconut shell oil is produced as a result of pyrolysis of coconut shell i.e., burning the coconut shells under no or limited supply of air. Coconut shell oil is a bye-product of charcoal industry, so utilization of coconut shell oil as a wood preservative will be a value addition by increasing income sources of such industries. A good wood protectant should protect wood from all wood deteriorating organisms like termites, wood decay fungi and wood borers.

A set of standard procedures as prescribed by Bureau of Indian Standards, termites (IS 4833), decay fungi (IS 4873 Part-I) and wood borers (IS 4873 Part-II) were employed to test the effectiveness of coconut shell oil as a wood preservative. Treatment methods adopted were brush coating, dipping and pressure impregnation. The results indicated that coconut shell oil could impart significant level of protection to the treated wood blocks against termites, decay fungi wood borers. But the disadvantage of coconut shell oil was that, due to its dark colour and viscous nature it can be recommended only for outdoor applications.
I decided to improve the nature and efficiency of coconut shell oil so that I can recommend it for indoor applications also. I prepared a proposal with this in mind and got funding from DST under the Fast Track Scheme for Young Scientists. Improving Coconut shell oil to pick up its aesthetic value and efficacy as a wood protectant was the subject matter of the proposed work. I wanted to modify the texture and colour of the coconut shell oil and it was a big task due to its tar like consistency. Coconut shell oil was subjected to separation techniques like extraction, fractionation and dialysis. Finally I managed to get different fractions of coconut shell oil like water extract of coconut shell oil, dialysate of coconut shell oil, distillate of coconut shell oil and steam distillate of coconut shell oil. All these fractions were colour less which was one of my requirements for the intended use. Now I wanted to test how efficient these fractions were in protecting the wood. Standard procedures of Bureau of Indian Standards were followed and distillate of coconut shell oil gave best results. I wondered what gives distillate of coconut shell oil the efficiency to protect wood. Hence, I analyzed the composition of this colour less distillate using gas chromatography mass spectroscopy technique, and found that it essentially comprises phenol and phenolic compounds.

**Marketable product and a patent right**

The efficiency of the distillate of coconut shell oil had to be improved to get a commercially feasible biobased formulation for wood protection. As of now, all the products available in market for wood protection are salts of inorganic ions like copper, zinc and boron. So to improve the efficiency of distillate of coconut shell oil, copper, zinc and boron ions were incorporated by refluxing the solution with their respective salts. The resultant formulations were again tested for their efficiency as wood preservative using Standard procedures of Bureau of Indian Standards. The results showed that, the formulation of copper ions and distillate of coconut shell oil gave best results protecting the wood from termites in the field for three years. It also gave protection to the treated wood against the attack of wood decay fungi and wood borers. I published the results of the studies in reputed international journals with good impact factor and presented my work in various international and national conferences. The outcome of the study gave me confidence to file a patent for the formulation I developed from coconut shell oil as - Ecofriendly wood protectant from coconut shell oil.
Protect and conserve wood

The objective of wood protection is to preserve and prolong the life of non-durable wood. Wood protection is mainly the art of preserving non-durable timbers against the agents of degradation. Preservative treatment reduces the pressure on more naturally durable, rare and higher value species. Protective treatment of timber, therefore, forms a very important part of the national effort to conserve the material resources. If protected from fire, insect and fungal attack, timber structures can survive for extremely long periods may be 2000 years or more. The long lifespan of timber, in particular, can substantially reduce the depletion of forest resources.

Protecting timber is a global need to mitigate climate change

Timber formed by the trees is the major sinks of carbon and known to sequester carbon for long time. Increased carbon emission is the major reason for the climate change. Utilization of protected wood is one of the simplest, most effective and best ways to store carbon and mitigate the carbon emission. Removing the carbon and storing it for a long time is a global need to mitigate climate change. Wood, the natural renewable material has the capacity to do both. By wood preservation we are increasing the service life of wood, thereby reducing the adverse effects of climate change indirectly.

New biobased product for safe future

Current scenario in the wood protection research is not promising. After the phasing out of chemical wood preservatives like Chromated Copper Arsenate (CCA) due to environmental concerns, scientists have not come across any good quality wood protectant that protects wood under both indoor and outdoor conditions. All the commercially available wood preservatives that give good results are of chemical origin. Wood is to be protected with environmentally friendly, naturally renewable substances, so that the treated wood is fit for the purpose, has a safe life cycle and eventual disposal. In this context, the prospects of coconut shell oil formulation as an effective biobased wood preservative holds good, as coconut shell is an abundant, cheap and renewable bio resource. It is now up to the entrepreneurs and industries to produce and market this technology for the benefit of the society. It is a clarion call to all those nature lovers and environmentalists to come forward and use this technology to ensure a safe future for all.
And who has greater mastery over sophistication than Nature herself? One finds it hard to believe that the golden cubes in panel A can be natural formations of something as mundane as iron and sulphur, that simple water can freeze into something as intricate as the snowflake in panel B, or that the shapely prism in panel C despite how it looks is not carved out of ice. The ancient Greeks made exactly this mistake, describing blocks of quartz as *Krustallos* (*Kruos* = icy}

* Dr Shaunak Chakraborty, Post Doctoral Fellow from Indian Institute of Science, Bangalore, is pursuing his research on “Cocrystals.” His popular science story entitled “Designer Crystals” has been selected for AWSAR Award.
cold) out of the mistaken belief that they were looking at everlasting ice sent from Heaven. Thence came the word crystal, which in every day vocabulary is any stone which, irrespective of its colour, is clear and symmetric. A crystal is an object of purity and beauty with a very special place in ancient lore be it as a conduit into the afterlife or as the cure for various physical and metaphysical imbalances.

What a crystal really is, however, is a highly ordered arrangement of atoms or molecules much like a large classroom with a regular array of chairs, each of which is occupied by an atom or a molecule. These atoms and molecules are always of the same chemical substance. They have an uncanny knack for locating each other in the chaos of a solution and crystallising, mostly because they fit each other like the pieces of a jigsaw. Anything that is a mismatch gets unceremoniously thrown out, making crystallisation a highly efficient purification process.

Man has made use of this fact since the earliest recorded history: salt crystallised from sea water has always been an indispensable part of our food. The art of crystallisation has over the years evolved into a science capable of producing remarkable results ranging from the hardness of steel to the deliciousness of chocolates. Attempts are currently underway to develop protocols for incorporating different molecules into the same crystal. The idea is perhaps a bit counterintuitive considering what has been said till now, but imagine if the two different medicines prescribed by your doctor could be punched into one single pill! Not only would you have to take them in smaller doses, but also at considerably less expense because of simpler production protocols. This is but one of the facets of the subject of crystal engineering, which can be loosely said to be concerned with the crafting of designer crystals. It sometimes takes strategising at Machiavellian levels, as I found out when I teamed up with one of my colleagues to persuade six different molecules to enter the same crystal.

Molecules are very pragmatic, always making the best of their surroundings to have the lowest possible energy. Naturally, they crystallise with only those molecules that can bind them strongly enough to effect a lowering of energy for both. The present state of the art is the making of binary cocrystals crystals with two different molecules. Cocrystals with even three different components are achievable, albeit with considerable brainstorming, but raising the number of components any higher is impossible. At least it was, until very recently, when my colleague Mithun Paul noticed something strange in the way molecules of tetramethylpyrazine (TMP) were arranged in its cocrystal with 2-chlororesorcinol (CRES). He realised that some TMPs were held more loosely than the others and guessed that they can be replaced with molecules that would be held
tighter, because of the resulting energy advantage to the whole system. The idea worked: progress could be made to a three-component cocrystal, but *it too had a loose molecule!* This meant that one could incorporate a fourth component into a three-component cocrystal with the same logic. The situation closely resembles the one shown below: One of the blue men holding the slack red ropes in Group 1 is replaced by a grey man who brings a stronger black bond into Group 2. This leaves one blue man whose bonds to the rest of the group are not as strong. The yellow man relieves him to form Group 3. The green man watches all the fun from the bleachers. But not for long…

Molecules in a crystal can be tricked into accepting other molecules as one of themselves. The great crystallographer Alexander Kitaigorodskii wrote in 1973 that if the most important bonds in a crystal are left undisturbed, random molecules in it can be replaced by others that look very similar. The internal structure of the crystal remains essentially unchanged. The phenomenon is called doping and the result is a substance called a solid solution, in which the constituents are present in ratios of fractions (e.g., 0.33:0.67) rather than whole numbers (e.g., 1:4) as in the case of chemical compounds. The energy-lowering in solid solutions happens not by forming strong bonds, but rather by an increase in randomness in the crystal. The greater the disorder, the more stable the system is. Objects crumble away, gases leak out of cylinders and spread everywhere disorder is the natural order of things.

This is relatively easy in metallic crystals, which consist entirely of spherical atoms. A metal atom which is slightly bigger can squeeze into the site of a smaller one with a nominal effort, while a smaller atom can easily slip into the site of a larger one. However, one must factor in the asymmetric shapes of molecules when conducting a doping experiment with molecular crystals. Typically, exchangeable molecules should have essentially the same chemical diagrams, differing

*Designer Crystals*
perhaps in only one atom or so. I had had some experience in this from my doctoral research, and visualised the following scenario involving 2-methylresorcinol (MRES), 2-chlororesorcinol (CRES) and 2-bromoresorcinol (BRES):

Suppose a secret meeting is underway in the above-mentioned classroom and the blue, yellow and grey men stand guard at the door with strict instructions to let only green men (CRES) in. The first man gains entry without any trouble, but the second and the third have the bouncers confused. One of them looks exactly like the average green man but seems to be heavier. The bouncers accept that he will squeeze in somehow. The third also looks exactly like a green man but is thinner. The bouncers agree that he can quietly slip in without jostling other people. Little do they know that the second man is really BRES and is heavier because he has a bromine atom (the B of BRES) in place of a chlorine atom (the C of CRES); and that the third man is MRES, who is lighter because he has a methyl group (a carbon with three hydrogens; the M of MRES) where CRES has chlorine. The bromine and the chlorine atoms and the methyl group (B, C and M) have very similar volumes. It is as if MRES and BRES have put on green masks to slip past the bouncers. So, if either MRES or BRES enter separately and blend into the crowd of CRES in the four-component cocrystal, the resulting crystals would have five components. Similarly, if the two of them enter together the number of components would be six.

The initial X-ray photographs of the supposedly five-component cocrystals were somewhat misleading they were rather like the four-component cocrystal containing CRES, meaning that they were NOT five-component cocrystals and the theory that the fifth molecule (MRES) could get into the structure without disturbing it was incorrect. A closer look at the photographs, however, put wide grins on our faces. We had caught the MRES lurking at random positions in the crowd of CRES. The theory of minimal structural disturbance was correct. It worked for the CRES-BRES
and BRES-MRES mixtures as well, producing a total of three different types of five-component cocrystals with essentially the same structures. But what if CRES, BRES and MRES were taken all together? Considering the sheer gain in randomness, a six-component cocrystal was perhaps even more feasible. Indeed, a CRES could sit next to another CRES or a BRES or a MRES in this case, whereas in a five-component cocrystal with say a CRES-MRES mixture, it could sit next to either another CRES or a MRES. It worked. We could isolate a six-component cocrystal in quite large quantities.

One can only wonder at the raw genius of Willard Gibbs, whose 1873 equation for predicting the feasibility of such a process holds true even today. What we had done on our way to the six-component cocrystal was to simply manipulate the two parts of his equation concerning energy and randomness. First, we had lowered the energy by replacing the loose bonds by strong ones and when that resource had been exhausted, we had upped the randomness in the system by bringing in molecules with similar shapes. This simple logic had lowered the overall energy, making the incorporation of half a dozen molecules into the same crystal possible. Seeing the textbook principles work in real life was humbling, and yet a lot of fun.
Salts in solvent are a prerequisite for performing electrochemical experiments as they provide the necessary ionic conductivity to the solvent. However, the solubility of salts often becomes a challenge for applications (such as in batteries) that require very high ionic conductivity. Added to this there are applications such as solar cells, where the presence of solvent can have detrimental effects on the efficiency of the product. A class of liquids called “Ionic Liquids” have shown that one or two solute by itself without any solvent can be a “Solution” for many applications. By designing compounds that are bulky in size and lesser in charge, room temperature ionic liquids can be made out of solid salts even without the use of solvents. However, ionic liquids are often designed and are not readily available and if available they are of high cost. Now to solve the problem a more improved concept called Deep Eutectic Solvents (DES) has been put forth by Abbott et al. By this concept, large hydrogen-bonded complexes of low symmetry are prepared from readily available bulk organic compounds (Fig.1b). For example, a simple thermal mixing of a quaternary ammonium chloride such as choline chloride (MP 300 °C) and urea (MP 133 °C), can form a room temperature ionic liquid. Within a short span of introduction, DES has been used as a medium for various applications such as enzymatic, organic synthesis, metal extraction, electofinishing, solar cells, and energy devices.
Our studies have been focussed on using DES as a medium for preparing electrodeposited nanoparticles for “ready to use” applications. Electrodeposition was carried out using anodic dissolution technique (metal wire is dissolved as ions at anode and are electrodeposited as nanoparticle clusters at the cathode) to ensure well-adherent nanoparticle surfaces that can be used even in applications requiring vigorous conditions of solvent, heat or perturbation. The procedure involved the electrochemical dissolution of a silver wire at a constant low current density in DES. The dissolved metal ions from the Ag wire get simultaneously reduced at the cathodic metal substrate (Pt/Rh wire). These form clusters of nanoparticles stabilised by the Mercaptophenyl boronic acid (MPBA) molecules present in the medium. So what is the significance of DES in electrodeposition? The inherent ionic conductivity of DES avoids the use of supporting electrolyte which are otherwise inevitable in electrodeposition. During electrodeposition in aqueous medium, while hydrogen evolution at the cathode can lead to poor deposition of nanoparticles, the protons formed from water at anode can passivate the anode preventing further dissolution. These problems associated with the hydrogen and oxygen evolution in aqueous medium at the cathode and the anode are not observed in DES. Added to this, DES can dissolve any passivating oxide species due to their complex formation ability.

Since silver nanoparticles are excellent enhancers of very weak Raman signals, we have explored the application of utilising the AgNP modified substrate for SERS (surface enhanced Raman spectroscopy). A huge SERS enhancement of Raman signal of analytes such as Methylene blue and Rhodamine B was observed on the mesoporous silver substrate after removing all the stabilizer molecules from the surface by the method of high temperature calcination. It was estimated that the mesoporous silver film shows an enhancement by a factor of $10^5$ for Methylene Blue which suggests its excellent potential for using in ultra-trace detection of analytes.
DES as an electrolytic medium for the preparation of non-Pt based metal nanoparticle and core-shell alloy nanoparticles was also explored by us. For example, the gold nanoparticles modified graphite substrate prepared in this medium had superior electrocatalytic properties for methanol electrooxidation reaction with lower activation energy making them useful even at ambient temperatures. We have also studied DES medium for the electrochemical synthesis of core–shell nanostructures comprising of Au core and Pd shells and deposition on graphite substrate (Fig. 2). The method used was the first report of a single step preparation and deposition of core–shell nanoparticles on a solid substrate using a standalone medium without the use of supporting electrolyte, stabilizers and reducing agent.

![Figure 2. Schematic representation of anodic dissolution technique for the electrodeposition of Au@Pd nanoparticle in DES medium (b) SEM images of graphite rod modified with Au@Pd NPs](image)

The mesoporous film was examined in detail for its electrocatalytic applications and was found to be a very good catalyst for methanol oxidation and hydrogen evolution reactions. In all the above cases, the nanoparticle modified surfaces were characterized using FESEM, EDAX and electro-analytical techniques.

We have also developed a novel non-polymeric colloid suspension based on hydrogen bonding interactions of tetra butyl ammonium salt and ethylene glycol (Fig. 3). The colloid suspension exhibited certain unique physical properties and was demonstrated as a medium for monitoring enzyme kinetics by electrochemical method. The gel containing a constant amount of enzyme was allowed to react with different concentrations of substrate. The enzyme-substrate reaction resulted in the formation of ions which is monitored as a function of the ionic conductivity of the colloid suspension measured by electrochemical impedance spectroscopy. The rate of the reaction in the colloidal matrix was found to obey Michaelis Menten equation. The electrochemical method employed here with the colloidal medium acts as a simple robust method to follow enzymatic reactions in a soft medium mimicking biological environment.
The sharp reversible sol-gel phase transition of the colloid at 55 °C was utilised as a matrix for dispersing nanomaterials such as CNT, graphene and metal nanoparticles. A few of such dispersions of nanoparticles (CNT, Graphene, Fe$_3$O$_4$ NP, AgNP) in the colloid are shown in the Fig. 3. A vial containing 0.5 mg /ml nanoparticles in sol were initially sonicated at a temperature of about 50-60 °C. As soon as a stable dispersion of nanoparticles was achieved, the nanoparticle matrix was plunged into cold water. The sudden drop in temperature brings about the phase transition of sol gel, thus freezing the well dispersed state of nanoparticles brought about by sonication. The nanoparticle dispersion obtained in the colloid has the potential for use in electrochemical biosensors, electronic and optoelectronic applications.

**Figure 3.** Photographs of the vial containing the colloidal suspension and a teflon coated magnetic pellet at (a) $T > 60 ^\circ C$ and (b) RT
Fish-Parasite Sentinel System-An Emerging Integrated Biomonitoring Tool in the Offing

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Traditionally, parasites have been considered as detrimental to humans and other biological organisms because they cause immense damage to their hosts in which they take refuge. This was the general perception about parasites among the public and medical practitioners up to the last quarter of the 20th century, nevertheless, such perception has changed in recent times due to revelation of their relevance in various ecological processes. The term ‘parasite’ or ‘parasitism’ is in common usage in various fields (like economy and politics) and is generally used satirically to represent the condition of a person or company as ‘a life of large income without work’. In other words, these tiny creatures are considered as idle fellows surviving at the cost of their host. With such narrative about parasite in the third quarter of 20th century, there was hardly any chance for them to be considered for new emerging studies, such as ecology, ecotoxicology and habitat management. The debate about the status of parasite in the ecological web could be interesting if all the parties including parasite, host and nature are asked to comment about the status of parasite.

Keeping in view the curious nature of host-parasite association, one would expect interesting conservation between the parasite (here John) and host (here Jimmy) about the status of neglected but an important creature of biosphere:

John to Jimmy: I’m known to be most cruel and unusual creature of the mother earth; yet few know I’m the most important asset for the biological and ecological system.

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Jimmy to John: Who will trust you? You are the one who is responsible for morbidity and killing of organisms; still, I believe, you are a necessary evil for the biological system. 

The so-called ‘Cheaters, Suckers and Grudgers’ have recently become compliment-givers as world celebrities and leaders are now being credited with the name of newly discovered parasites that shows that biologists have acknowledged the importance of parasites in the web of life. In 2016, Barack Obama, former president of the US, was given a compliment when the turtle parasite, Baraktrema obamai, was named after him, which according to Thomas Platt (an American parasitologist) reflects the positive features of Barak Obama coinciding with the turtle parasite. The bottom line is that these tiny creatures have many beneficial features, which include the assessment of environmental quality, healing of diseases, understanding ecological principles and other miscellaneous roles. 

As parasite is an integral part of disease triangle, it is imperative to unravel the relevance of these amazing creatures in the assessment of environmental health. Parasitism is a common occurrence and the interaction of parasites with the environmental stress is a complex one. Various studies have shown that environmental deterioration affects community structure of parasites. Parasites can be used to assess the environment health due to their important features, which other organisms seldom possess. For example, parasites are cosmopolitan in distribution, are long-lived and able to responds to the environmental alteration through their effect and accumulation properties. There are two ways by which parasites can be used as bioindicators: they can be used as an effect indicator, or they can be used as accumulation indicator. Knowing the importance of parasites and their fish hosts in the ecological milieu, ‘Host-Parasite Indicator System’ was tested across three lentic water bodies (Manasbal Lake, Dal Lake and Anchar Lake) of North West Himalaya showing clear eutrophic/pollution gradient. The overarching aim of the study was to provide empirical evidence in favour of fish parasites along with their fish hosts as ecological indicators in the stressed aquatic ecosystem and to highlight the ecological significance of fish parasites. The important health attributes including infection descriptors and other parameters were taken into consideration to analyze the effectiveness of this integrated sentinel system. Prior to field investigation, working hypothesis was developed to test the effectiveness of ‘Host-Parasite’ system as a biomonitoring tool. It was presumed that parasite diversity and infection pattern of fish helminth parasites will show sharp increase from least eutrophic lake conditions to the eutrophic conditions and furthermore it was predicted that there could be decrease in these parameters when conditions change from eutrophic to hypereutrophic condition. It was further hypothesized that fish collected from hypereutrophic lake will show more deterioration in health parameters than fish collected from least eutrophic lake. 

In the first field experiment component community and infra community of helminth parasites of fish was tested for impact assessment study. The findings from the five year study depict that parasitic worms, especially endoparasites seem to be influenced by heavy nutrient enrichment as more percentage of infection was observed in the highly polluted lake than in least polluted lake. For example, average infection recorded in fish was more than 25% in Anchar lake, while as it was 20% in Dal Lake and less than 15% in Manabal lake. There was also numerical dominance
of parasite worms in the eutrophic lake, although in few species of fish less parasite density was observed. All these results reveal that parasite diversity and infection altered across pollution gradient which confirm our hypothesis. There could be two reasons for these findings: firstly the enhanced eutrophication could increase the density of intermediate host of parasites and secondly increased level of eutrophication may change the feeding behaviour of fish and thus fish becomes safe refuge for these tiny creatures.

In the second field experiment individual parasite species were tested as an effect indicator to assess how these tiny creatures behave under different pollution condition. The results show promising response of individual parasite species, especially Diplozoon kashmirensis and Adenoscolex oreini towards altered water quality. The infection burden on gills of fish was more in hypereutrophic lake than in least eutrophic lake, thus indicating that these miniature creatures enjoy their life in more polluted environmental conditions. The distribution of these smart sentinel ectoparasites also showed marked variation in the infection level on different gill arches that reflected the impact of external environment.

In the third field experiment, both parasite and fish host were used as combined indicator system tested under different environmental conditions to check its feasibility as an integrated bio-monitoring tool. Interestingly the model of using integrated host-parasite sentinel system worked very well as compared to the situation when only tiny parasites were used as an effect indicators. The health indicators of fish also reflected marked variation across the altered water quality, and gonadosomatic index showed significant negative correlation with prevalence. Overall, the findings from this study reveal that infection indices and health attributes in a battery of host species can provide best model for the determination of the status of environmental health of altered aquatic ecosystems.

Based on the above experiments, three scenarios can be expected when using host-parasite as an indicator system: Firstly, if both host and parasite show alteration in density, physiology and biological indices across pollution gradient, then host-parasite system can be considered as an ideal indicator system. Secondly, if only parasite or host show the above alterations, then host-parasite system can be considered as partial indicator system. Finally if host or parasite show changes in some of the above features, then host-parasite system can be considered as an ambiguous indicator system.

The amazing part of this study is that parasites along with their host have ability to act as ecological signatures of environmental health that will further boost to include them in routine environmental impact assessment (EIA) studies. The study further illustrates how these miniature indicators have transformed from unhygienic agents to ecological indicators. Parasites along with their hosts should be considered as sentinels for environmental monitoring provided we have an idea about the life cycle stages, ecology and accumulation capability of a particular parasite species. The environmental parasitology is a novel area, which will unravel the hidden enigmas in future course of time. With this, we are shifting to the ecosystem approach, a synonym for an integrated or holistic approach. This approach of integrating various aspects is essential because it is generally not known which environmental stress responses or combinations of responses might be affected and
therefore suitable for revealing the effect of environmental stress on parasites as well as their hosts. Long-term surveys are needed to elucidate the impacts of deteriorating environmental quality on the community structure of parasites. We also need to improve methodologies, study design, and modelling procedures.

Host-parasite association has always puzzled biologists from time immemorial. With these new findings, this twin association can entice more amazing roles in future that could benefit humans in many ways. The conventional thinking of host-parasite association has now been seen looked in positive perspective, thanks to current approach of research. In coming decades, researchers may unravel new roles of parasites. Parasites like nematodes have been already tested in space. Although there is lot to convince non-parasitologists about the positive roles of parasite, but I feel parasite itself will have to come forward and say,

"Every Parasite is not Ugly and nuisance Creature"
**Pre- and Post-digestion of Microalgae Makes an Efficient Energy Product (Biogas)**

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Imagine the world without petroleum products; it seems like a nightmare where the lives will be stuck in the darkness of depleting natural energy resources and its geographical availability. We are dependent on petroleum (oil-based and gaseous) for jet fuel, light vehicle fuel, heavy duty vehicle fuel, machine engines and for cooking purposes. These applications cover large sector of industries and households making it responsible for country’s economy in a huge way.

A new era of biofuels derived from plants and microalgae has now achieved its milestones when the biofuel powered aircrafts have undergone successful flights in India and abroad. In terms of gaseous fuels, biomass-derived bio-methane or biogas has also been tested as the only fuel source to drive a vehicle in IIT Delhi, India.

Among biological substrates for fuel, microalgae possess a great potential for biofuel generation as it has high oil content and high carbon to nitrogen ratio. It also has potential to grow and treat waste waters and also fixes atmospheric CO$_2$. Hence, looking at these diverse applications, microalgae can be considered to be one of the most purposeful micro-organism for industrial applications.

Apart from being so useful for industrial purposes, the major limitation in using microalgae for biofuel route is separation of biomass from liquid media (dewatering) and poor digestibility of algal cell wall. The potential dewatering techniques have been critically compared by author in the form of a chapter in book entitled ‘Algal Biofuel’ published by Springer International in 2016.

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To solve the above two problems, the authors have developed a novel process, which efficiently solves the discussed issues of microalgal biofuel route. In the study, the algal biomass is harvested (dewatered) as well as digested within the same system or environment by making use of another biological organism i.e. fungus.

In our study, dewatering issue of microalgae was addressed using a fungus from *Aspergillus* family i.e. *Aspergillus fumigatus*, which was grown in the form of mycelial pellets (tiny thread-like balls of fungus). Allmicroalgal cells were allowed to attach on fungal thread-like mycelium within 4 hours under certain condition, which resulted in the formation of an algal-fungal complex (AF complex). This algal-fungal complex was big and heavier enough to settle down quickly without any application of any external force. This process was then optimised for best conditions relating to maximum/complete algal biomass recovery in the form of algal-fungal complex and was published in *Algal Research* journal in 2017.

The digestibility problem of the microalgae was solved by fungus exposure in two different ways. At first, a two-step process was employed, where the fungus *A. fumigatus* was used to produce enzyme crude using sugar bagasse as cellulose substrate under solid state fermentation. The enzyme crude showed a very high cellulase activity (103 FPU/g), which was then subjected to algal biomass to be acted upon by fungal enzyme. The enzyme activity was so high that even five times diluted enzyme crude was able to kill almost 100% of the algal cells when exposed till 24 hours of incubation at a temperature of 38°C. The dead cells and the live cells showing different fluorescence were distinctly counted using contrast colours by an automated fluorescent cell counter. The release of sugar, as the breakdown product of cellulose, was also found to be 92%, inferring a high level cell wall digestion. Although, this process was highly efficient to digest the microalgal biomass, but to make this a single-step process, another approach was adopted.
According to this approach, the algal-fungal complex formed were directly subjected to simultaneous enzyme production and pretreatment of microalgae for its digestion. Since both of these biomass were in a very close proximity, it was quite easy to provide such a condition, which is favourable for fungus to secrete cellulase like enzymes using microalgal cell wall as its cellulose substrate. On the contrary, it became unfavourable to microalgae as the action of fungal enzymes lead to algal cell wall breakage, which is mainly made up of cellulose. According to the viability assay, both the organisms (algae as well as fungus) were completely viable after formation of algal-fungal complex. However, the purpose was to kill or digest microalgal cell by the action of cellulase-like enzymes secreted by live fungal biomass attached to it. Hence, to complete this activity, the algal-fungal complex was incubated at two different temperatures, i.e. 38°C (optimum for cellulase production) and 55°C (optimum for cellulase activity) for 3 days. Such high temperature i.e. 55°C was chosen for two reasons: (i) to provide an additional heat pretreatment to AF complex for better digestibility; (ii) to provide optimum temperature for real time and efficient cellulase activity. As control sets, algae and fungus were also incubated individually under similar condition.

According to the visual observations, the AF complex and algae control at 55°C showed brown colouration of algal biomass instead of green color within 24 hours of incubation. This indicates the onset of algal digestion due to high temperature and cellulase activity. The enzyme activity, at different time interval using Whatmann filter paper as cellulose substrate, was also highest in 55°C incubated AF complex followed by algae alone (55°C), AF complex (38°C) and algae alone (38°C) after 3rd day of incubation. As cellulose is made up of multiple monomer units of glucose, therefore, the digestibility of algal cell wall was also observed in terms of sugar released
after cellulose breakdown. The sugar release in all the experimental sets followed the same trend according to the quantity of enzyme produced after 3 days i.e. more enzyme, more was the sugar release. When these digested AF complex (biomass) were tested for biogas production for 30 days by anaerobic digestion (with co-digestion of cow dung), the AF complex showing highest degree of digestibility (at 55°C) was able to produce 309 ml per g VS fed cumulative biomethane. This amount of biogas produces contributed to 23%, 30% and 35% increased biogas in comparison to AF complex at 38°C, algae alone at 55°C and algae alone at 38°C, respectively. This quantity of biogas produced is much higher in comparison to the biogas produced by the conventional substrate of biogas i.e. cow dung. Hence, the co-digestion of pre-digested algae with cow dung appears to be the most potent biomass for biomethane production as fuel product.

To summarize, the study provides a new ray of hope to the biofuel industries for using microalgae as a new feedstock. The develop process unravel the hurdles related to microalgae, which was hampering its use as a commercial biofuel substrate. The advancements and new modification in the conventional methods for biogas production may lead to a revolution in the energy industry. Hence, further scale-up and its optimisation will bring us near to the implementation of this technology for fuel generation applicable to number of vehicles and for cooking/burning purposes.
Anti-inflammatory and Anti Diabetic Action of Arachidonic Acid and its Metabolite Lipoxin A4

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I completed the following research work under the supervision of Dr U. N. Das. It is great experience and excitement to work in the following area.

Obesity and diabetes mellitus (DM) are assuming epidemic proportions throughout the world. The modern urbanized habitat (including lack of adequate exercise) and high fat diet are the leading causes of obesity and diabetes mellitus. Per World Health Organization (WHO) statistics, 1.9 billion people are overweight and 600 million are obese worldwide. About 422 million people are affected with diabetes mellitus. The pervasiveness of obesity and diabetes was observed more exponentially in middle and low income countries. India is the 3rd most effected country after USA and China in the world. About 30 million adults in India are obese. During the past two decades the average level of obesity has raised to 8% in Organization for Economic Cooperation and Development (OECD) countries. WHO projects that diabetes will be the 7th leading cause of death in 2030. Diabetes mellitus can be manifested in two forms: one is type 1 diabetes mellitus (type 1 DM) where complete loss of insulin from pancreas due to autoimmune destruction or genetic disorders; second is the type 2 diabetes mellitus (type 2 DM) in which despite insulin presence targeted cells are resistance to its action and leads to glucose intolerance. Majority of the diabetic patients belong to the second category type 2 DM due to consumption of high energy diet intake and sedentary behavior.

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The metabolic stress due to high calorie intake induces adipose tissue to secret stressful cytokines or adipokines like TNFα, IL-6 and Lipocalin 2 (LPCLN2). These adipokines target the insulin targeted tissues like liver, muscle and adipose tissue and induces insulin resistance. The adipokines target the genes of the metabolic tissues and enhance the expression of inflammatory causing genes like Nf-kB, iNOS and suppress the anti-inflammatory genes like Nrf2 and anti oxidant enzymes. These adipokines also suppress insulin receptor substances (IRS) activation that is needed for the downstream regulation of Insulin receptor. In both the types of DM Type 1 DM and type 2 DM) inflammation occurs. In type 1 DM, the inflammation is localized close to the pancreatic β-cells whereas in type 2 DM it is low-grade systemic inflammation.

Among them, Arachidonic acid (AA, 20:4 n-6) is crucial to regulate inflammation. Studies showed that the Lipoxygenases (LOX) metabolites of AA are important constituents in resolving chronic inflammation. Lipoxin A4 (LXA4) is an endogenous metabolite of AA by the action of LOX enzyme that has a significant role in resolving inflammation. Since major metabolic disorders are due to low grade chronic systemic inflammation, we hypothesized that AA and LXA4 may have an important role in metabolic disorders such as DM (both T1DM and T2DM).

To verify our hypothesis, we studied the effect of AA and its endogenous metabolite LXA4 on the cytotoxic action of alloxan and streptozotocin (STZ) on rat insulinoma cells (RIN5f) in vitro and in vivo. Both AA and LXA4 were tested for their effects on cell viability by using MTT assay of RIN5f cells at various concentrations of these lipids and for various time periods. Our studies showed that optimal doses of alloxan and STZ to induce ~ 50% reduction in the number of cells surviving are 4mM and 21mM at the end of 1 hour and 24 hours of incubation respectively. Depend on the results obtained further studies were carried out using 4 mM of ALX and 21 mM of STZ and the incubation time of 1 hour and 24 hours respectively. Our studies also showed that 5, 10 and 15 µg/ml of AA are optimal doses at which it is likely to show its effects on RIN5f cells in vitro since at these concentrations AA did not show any cytotoxic action by itself. Both AA and LXA4 pre- and simultaneous-treatment schedules were used while testing for their modulator influence on alloxan and STZ- induced cytotoxicity on RIN5f cells in vitro. Preliminary studies revealed that 50 ng/ml of LXA4 is the optimum dose to test its actions on RIN5f cells in the presence of alloxan and STZ. This dose of LXA4 is arrived at after testing 1, 5, 10 and 50 ng/ml of LXA4 in the initial studies. While testing for the mechanisms of actions of AA against the cytotoxic action of alloxan and STZ on RIN5f cells in vitro, we evaluated the affect of cyclo-oxygenase (COX) and lipoxygenase (LOX) inhibitors: indomethacin and nordihydroguaiaretic acid (NDGA) (both were used at 1mM dose) respectively to know whether any metabolites of AA play a role in the actions of AA in our studies.

Our in vitro studies with RIN5f cells revealed that AA prevents the cytotoxic action of alloxan and STZ on RIN5f cells and these cytoprotective actions of AA are not interfered with by both COX and LOX inhibitors suggesting that PGs, LTs and TXs do not have a role in this process. Since AA forms precursor to LXA4, we next tested possible involvement of LXA4 in the cytoprotective actions of AA against alloxan and STZ on RIN5f cells in vitro. These studies showed that (i) both alloxan and STZ inhibit the production of LXA4 by RIN5f cells; (ii) RIN5f cells were protected
by LXA4 from the cytotoxic action of alloxan and STZ; and (iii) addition of AA in RIN5f cells restored the production of LXA4 to normal which was suppressed by alloxan and STZ. These studies are in support of the hypothesis that (i) both AA and LXA4 have cytoprotective actions against alloxan and STZ-induced apoptosis of RIN5f cells; (ii) there is no significant role for PGs, LTs and TXS in the cytoprotective action of AA; (iii) alloxan and STZ suppress production of LXA4 by RIN5f cells; (iv) AA brings about its cytoprotective action by increasing the formation of LXA4 in RIN5f cells; and (v) LXA4 is the mediator of the cytoprotective action of AA seen against alloxan and STZ on RIN5f cells. In a further extension of these studies, we observed that LXA4 can restore the antioxidant status of RIN5f cells to normal that was suppressed by alloxan and STZ. It was also noted that LXA4 s able to prevent both apoptosis and necrosis of RIN5f cells induced by alloxan and STZ in vitro. Furthermore, expression of p65 Nf-kB, IKB, PDX1 and beta actin genes that were altered by alloxan and STZ in RIN5f cells were restored to near normal by LXA4.

In extension to these in vitro results and to assess whether the cell culture studies can be extrapolated to an in vivo situation, we tested the efficacy of AA and LXA4 on STZ-induced type 1 and type 2 DM in Wistar rats. In the present study, we tested AA (oral and intraperitoneal injection) and LXA4 (intraperitoneal injection) against STZ-induced type 1 and type 2 DM.

In STZ-induced type 1 and type 2 DM animal models both AA and LXA were tested and were injected for 7 days. In this instance, AA was administered both orally and intraperitoneally whereas LXA4 was given for 5 days only by intraperitoneal route. In STZ-induced type 1 DM model study, AA was used for 7 days since AA was being tested by oral route and so we wanted to make sure that adequate amounts of AA would reach the target tissues (pancreas after oral administration) and hence, was given for longer time. On the other hand, LXA4 was injected for 5 days while testing against STZ-induced type 1 and type 2 DM.

All experiments were performed for 30 days and at the end of the experiment, animals were sacrificed and plasma, pancreas, liver, kidney, and adipose tissue were collected for further analysis. Blood glucose, body weight and food consumption were measured during the experimental period.

The results of the animal studies revealed that both AA and LXA4 have potent cytoprotective and anti diabetic actions. STZ induced type 1 DM was prevented by AA and both type 1 and type 2 DM induced by STZ were prevented by LXA4. LXA4 reverted to normal STZ-induced hyperglycemia and maintained insulin homeostasis. In STZ-induced type 2 DM animals, LXA4 administration restored to normal anti-oxidant enzymes, nitric oxide and lipid peroxide levels to near normal and so also the relevant gene and protein expression such as NF-kB and IκB, GLUT-2, Pdx1, Nrf2, GLUT-2, COX2 and iNOS and lipocalin 2.

Based on these studies, we conclude that AA and its endogenous metabolite LXA4 are not only potent cytoprotective molecules but also have anti-diabetic actions.
“All forms of life are blood kin under the skin and in the roots.”
This statement published in *The New York Times* more than a decade ago suggests that blood is essential for all living organisms. Seems surprising. Are they also suggesting that plants too have blood? Do you think that plants have hemoglobin running in their veins? Here, we are not taking into consideration leghemoglobin, which is there in the root nodules of leguminous plants. However, non-symbiotic hemoglobin (nsHb) is, in fact, present both in monocot and dicot plants.

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* Melatonin cares for all — be it human beings or plants*
Research has revealed that nsHb is involved in myriads functions in plants, including abiotic stress tolerance, hypoxia, salt and cold stress and, it acts as an excellent nitric oxide (NO) scavenger.

**Versatile roles of NO in humans and plants**

NO, a well-known gaseous molecule and for whose roles in vasodilation in human beings, Nobel Prize was awarded to scientists in the year 1998, is also biosynthesized in plants. NO is exceptionally important for controlling blood pressure. In plants, NO is not only involved in regulating growth and development of plants under normal growth conditions, it also regulates many plant responses both under abiotic and biotic stress conditions. It regulates diverse functions of proteins through interaction with various metallic constituents of proteins, such as heme-iron, zinc-sulphur, iron-sulphur and copper. Thus, it modifies the protein structure/function. NO can also cause tyrosine nitration of proteins, which is considered as a significant biomarker of nitrosative stress. Tyrosine nitration can, subsequently, lead to activation or inhibition of target proteins. NO either promotes or inhibits the activity of a variety of hemoproteins.

Now we all know that, plants also have hemoglobin and NO like human beings, do they also have ‘brain’ where all responses are controlled by neurotransmitters? Surprisingly, melatonin, initially discovered as a neurotransmitter in humans and animals, is also present in plants. In human beings, it is produced in the pineal gland and regulates daily circadian rhythms like sleep and wakefulness. Interestingly, in plants it is produced in root and shoot tips and it acts as a potential antioxidant which scavenges free radicals or reactive oxygen species (ROS).
Stress impacts plants and humans alike

These are the biomolecules (hemoglobin, NO and melatonin) whose independent actions or cross-talk with each other I have investigated in sunflower seedlings raised under NaCl stress. In India, salinity stress is a major factor that reduces crop productivity. Many states in India, including Andhra Pradesh, Tamil Nadu, Karnataka, Haryana, Punjab, Bihar, Odisha and Madhya Pradesh, have salt-affected agricultural land. Ever-increasing global warming is causing an increase in sea level thereby inundating coastal agricultural land masses. Sunflower is an important oil crop whose productivity is drastically reduced due to salinity stress. The present work aims to understand the physiological and biochemical mechanisms of salt stress tolerance utilizing the actions of NO, hemoglobin and melatonin.

Whenever man is under stress, a number of ROS are released in blood stream. So is also the case with plants. Plants also exhibit enzymatic or non-enzymatic antioxidant machinery to combat against prevailing stress conditions. The well-known enzymes that detoxify plant cells with harmful radicals or ROS are catalase, various peroxidases, superoxide dismutase, glutathione reductase and ascorbate peroxidases. Recently, I investigated a novel antioxidant enzyme-‘heme oxygenase’ (HO) in plants. Its expression and modulation was also studied in seedling cotyledons in response to salt stress. It is interesting to know the functions of HO in human beings. Many of us are aware of the fact that during jaundice, levels of bilirubin increase enormously in our body. In humans, HO is localized in liver and plays an important role in blood recycling. It is also responsible for the death of blood cells as it breaks down the heme produced via disintegration of hemoglobin from blood cells. Thus, it degrades heme molecule present in the blood to release biliverdin, which is subsequently converted into bilirubin. Both biliverdin and bilirubin exhibit antioxidant potential in human beings and also in plants. It would be interesting to know the antioxidant potential of this enzyme during early stages of sunflower seedlings growth under salt stress. Heme oxygenase, being a hemoprotein (heme containing enzyme), its function can efficiently be modulated by NO.
In plants, HO is localized in plastids and is majorly involved in the synthesis of light signaling molecules, that is, chromophore of phytochrome. HO has three isoforms in plants. HO-2 and HO-3 are constitutively expressed. HO-1 is inducible isoform, which is induced by a variety of stress conditions such as, salt, cold, flood, UV-B radiation. Hence it is responsible for protecting plants under stress conditions.

**Differential spatial distribution of heme oxygenase holds the key**

Immunolocalization of HO-1 by confocal laser scanning microscopy (CLSM) revealed very astonishing result as this enzyme was found to be abundantly present in the specialized cells surrounding the secretory canal in seedling cotyledons raised under salt stress conditions. Secretory structures, including secretory canals, constitute an important anatomical feature in many plants.
Therefore, secretory canals are likely to play an important role in signaling of diverse biomolecules and ions in plant cells thereby affecting long-distance sensing of stress from root to shoot. Such a modulation of spatial distribution of heme oxygenase in response to NaCl stress implicates its role in long-distance sensing of salt stress in sunflower seedling cotyledons for the transport of signaling molecules.

Enhanced accumulation of NO was also demonstrated in seedling cotyledons in response to salinity stress. Immunolocalization of tyrosine nitrated proteins in seedling cotyledons by CLSM revealed the abundance of tyrosine nitrated proteins as well in the specialized cells surrounding the SC where high expression of HO-1 was noted. Thus, NO was found to be positively modulating HO-1 activity by way of its interaction(binding with heme group, which serves both as a substrate and as a prosthetic group for HO-1.

**Immunolocalization of tyrosine nitrated proteins.**

**Melatonin cross-talk with ROS and NO**

Melatonin, a well-known neurotransmitter, was analyzed in seedling cotyledons in the absence or presence of NaCl stress. Its enhanced accumulation was observed under salinity stress. It is in congruence with increased HO-1 activity in (+) NaCl condition. It is thus evident that melatonin acts as a long-distance signaling molecule in response to salt stress and changing HO-1 activity.

Under stress conditions, NO burst is observed as a mechanisms to tolerate stress but at higher concentration it can interact with other ROS species and generate reactive nitrogen species like, dinitrogen (NO_2^-), responsible for tyrosine nitration of proteins) and peroxynitrite. The main role attributed to nsHb in plants is its ability to efficiently scavenge excess NO production. In fact, it is a very interesting observation that if we provide hemoglobin exogenously in growth medium, it can scavenge most of the endogenous NO from the tissue system. Also, it can scavenge an important ROS species, that is, hydrogen peroxide. The role of exogenously supplied hemoglobin as a potent
NO scavenger was further strengthened as it was able to significantly enhance the levels of ethylene biosynthesis enzyme-ACC oxidase in its presence. However, in the presence of NO donor the activity of this enzyme is highly reduced. Thus, application of hemoglobin antagonized the action of NO on ethylene biosynthesis enzyme. Discovery and functions of hemoglobin in plants enable us to enter into a new era of research whereby we can make plants healthier and better adapted to stress conditions via enhancing the expression of genes encoding nsHb in plants.

It is thus, evident that, unlike human beings, plants cannot run away from stress conditions but they utilize similar molecular or enzymatic machinery as present in human beings to combat stress and maintain their growth and development. To build a strong foundation, application of knowledge from fundamental plant physiology or biochemical events is thus necessary to understand its application in human welfare.

And the story goes on….
We are made up of billions of cells. These cells need to talk to each other and sense their environment for various cues such as available nutrients, toxins, mechanical pressure, fluctuations in temperature. Different sensing mechanisms operate for each cue, and ensure that cells coordinate their growth and survival functions according to their immediate environment. How a cell senses its environment and utilises the available nutrients is a fascinating area of research. It is important to study nutrient sensing because failure in sensing mechanisms have implications in several disorders. I joined my postdoc laboratory (Dr Sunil Laxman’s group at inStem, Bangalore) with the determination to work on how cells sense nutrients. As the laboratory was new, I had complete freedom to choose any topic: the thought may scare some of you, but it sure is a delight for researchers!

While I was learning the basic tools in the field using baker’s yeast (*Saccharomyces cerevisiae*) as a model organism, I was thinking about interesting topics that I could pursue. A few years ago, two observations were made related to a nutrient called methionine (Met). Met belongs to a class of molecules called amino acids. There are 20 natural amino acids present in all living organisms. These amino acids can be strung together in different sequences to form proteins (poly-amino acid-chains, much like how Lego blocks are strung together to form chains and toys!), and can be used for generating energy or other molecules. More importantly, amino acids can even act as

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signaling molecules as a part of nutrient sensing mechanisms, an angle which we were interested in the laboratory.

The first observation dealt with Met availability and showed that the presence of this molecule determines the output of a particular nutrient sensing pathway. The second observation was related to overall growth wherein it was shown that, under amino acid limitation, Met alone could boost cell growth as good as providing the rest of the amino acids put together. Just as a starting point, I was interested in finding out the mechanism related to the first observation. Although we had good reasons to follow this observation, we were caught up in the detail and were finding it hard to see the big picture.

One fine day, while having a regular discussion, my mentor and I realised that it made more sense to look at the global picture of methionine-mediated cellular growth (the second observation) and investigate what was happening in response to Met, rather than trying to find its role in one particular cellular process. *You cannot see the forest for the trees!* From the nutrient sensing point, it was an outstanding puzzle: it is a well-known fact that cells need all the amino acids for making proteins, other important molecules and in general for growth. *Then, how does a single amino acid (Met) facilitate growth of cells, and that too, during overall amino acid limitation?!* What happens globally? And why only Met? In short, we were interested in knowing how methionine can single handedly alter the fate of a cell.

Now, one could do the global analysis by looking at many outputs such as levels of proteins, metabolite pools (small molecules such as amino acids that are required for growth), expression of genes (the ultimate effectors of nutrient sensing machineries, which determine which proteins and metabolites are produced) or likewise outputs. Just when we were thinking of which global analysis to take forward, results from one of my experiments showed that a protein called Gcn4, increases
specifically in the presence of Met. It is known that Gcn4 is a global regulator and controls expression of genes involved in synthesis of amino acids. This gave us a strong reason to follow the gene expression angle for our global analysis, in the presence and absence of Met. Cells grown in the presence of all other amino acids were also included to find out Met-specific effects and cells devoid of Gcn4 were included to find out Gcn4-dependent processes.

We looked at the expression profile of individual genes across the stated conditions in wild type (a fully functional, natural isolate of yeast) and Gcn4-devoid cells. Our analysis showed many interesting features of Met-mediated cell growth. First, when we compared the expression profile of wild type cells grown a) without amino acids, b) with Met only, and c) with all amino acids except Met, we could clearly see that presence of Met elicits a structured, hierarchical response. We identified three key nodes of cellular processes that were strongly Met-dependent. These nodes culminate to form precursors for biosynthesis of amino acids (other than Met) and nucleotides, another class of molecules required for cell growth. We observed that the expression of genes involved in amino acid and nucleotide biosynthesis was also upregulated in the presence of Met, suggesting that the response is structured and ultimately leads to accumulation of molecules required for overall growth. It was surprising to see that a single amino acid could do so much!

Next, the gene expression profiles between wild type and Gcn4-devoid cells in the stated conditions indicated that Gcn4 plays a crucial role in mediating the Met response. Most of the genes involved in synthesis of amino acids and nucleotides were strongly dependent on Gcn4. We also found that there are some processes (such as protein synthesis) which are only Met-dependent and Gcn4 does not play any role in them. The overall analysis suggested an interesting model where Met, with the help of Gcn4, increases biosynthesis of other amino acids and nucleotides, and thereby induces cellular proliferation!

To test the validity of this model more directly, we performed more experiments using mass spectrometry and other relevant biochemical tools. A thorough analysis revealed that Met availability increases new synthesis (yes, we can distinguish the newly formed metabolites from the old metabolites using isotope-labeling experiments; details in future articles) of amino acids and nucleotides in a Gcn4-dependent manner. The new synthesis of these molecules allows cell growth in the adverse conditions of amino acid limitation. Overall, we find that Met acts as a strong growth cue and Gcn4 acts as a coordinator.

Of course, as applicable for any other study, we need to do more experiments to comprehend the complete system and above analysis lead us to a more interesting set of questions such as: How does Met increase the levels of Gcn4? How do other global regulators “talk” with Gcn4? Also, the core question, i.e. why methionine alone? We have done some experiments that suggest the mechanism by which Met controls Gcn4 levels and are planning more to find the answers to the above questions.
Far in the remote rainforests of the Western Ghats of India, there's a tree with a tongue twisting name: *Humboldtia brunonis*. It is a small tree, about the height of a guava tree, and grows in clumps with its own kind. Known as Hasige maara in Kannada, this plant calls out to ants, enticing them with special food and safe shelter. The attractive food here is nectar droplets on the leaves! Each leaf has about 30-40 nectaries, producing up to 20 microlitres of nectar per leaf, everyday. The readymade ant shelters are also no less fascinating. The plant modifies some of the branch segments into long and swollen hollow structures called domatia (10-12cm long, 1cm wide), each with a small opening at one end that functions as the door. The ants reside here, establish their colonies, and drink the nectar meal. In return they patrol their host plant, which is now their home territory, and bite and chase away trespassing insects, especially caterpillars that come to eat the young leaves and flowers. The relationship seems like an ideal give and take protection in return for food and shelter except that it is not so. Of the 16 ant species found dwelling in the domatia of *H. brunonis*, only one ant species aggressively protects. So are the remaining ants freeloaders? To add to this mystery, many domatia are occupied by a peculiar tree earthworm that has never been found in soil, anywhere. What is its business here? Are all these ants and the earthworm just squatters, or are there new relationships waiting to be discovered here?

When I first heard about this ant-plant system, I immediately knew this was what I wanted to investigate for my PhD. There are many ant-plants in the world, mostly in tropical Southeast Asia, South America and Africa. In India, *H. brunonis* is the only ant-plant that has, so far, been

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discovered and studied. After years of theoretical understanding of ecology, this was my first chance to go out into the wild, and learn it first-hand. Following discussions with my supervisor, I charted out a plan; as field work could be done only during the dry season, October to March every year, and the remaining 6 months would be spent analyzing data. First, I would chart the distribution range of this plant in the Western Ghats. Then, I would find out if the plant provided the same rewards in all the places. I would also find out if that one protective ant species was present in the place where the plant is most vulnerable to herbivory. I also decided to see if nutrients derived from carcass or excreta of domatia-dwelling ants are absorbed by the host plant.

After much travelling and searching, I selected five sites across the range of *H. brunonis*, and 90 trees in each site, to study. A large number of samples and the randomising process made sure that what we observed was not just an individual characteristic, but that of the whole species at that site.

With each field season, the mystery started unfolding. We found that rewards provided by the plants, in the form of abundance of domatia, size and number of nectaries, and amount of nectar were higher in the southern than in northern sites. Further, nectar in the northern sites had mostly cheap sugars while in the southern sites it had expensive amino acids that are particularly preferred by the protective ant. In fact, the amino acid concentration was highest in the southern site most vulnerable to insect herbivory. This implied that the host plant can actually change its nectar composition, and invest in costly attractive nectar only when and where it needed protection!

The next problem was to see whether nutrients derived from domatia-dwellers were absorbed by the plant. In ants, it’s known that the foraging workers take food back to their nest and feed their non-foraging nest-mates, and their excreta were dumped inside the nest. With this in mind, we conducted an experiment where we fed domatia-dwelling foraging worker ants with sugar solutions laced with a nitrogen stable isotope marker. After three weeks of feeding, we collected leaves and branches from various parts of each plant, to trace the course of the isotope if it was absorbed by the plant via domatia. Our results were positive! The nitrogen we fed the ants could be traced all the way to a branch far away from the experimental domatia! Our calculations showed that domatia-dwellers contributed significant amount of nitrogen to the host plant, (9% from the earthworms, and 17% from ants). This is important because rainforest soils are known to be nitrogen poor, and therefore the nitrogen that the plant received its domatia inhabitants would have been very welcome. We discovered a nutrient-based mutualism! Finally, to better understand waste decomposition and absorption in the domatia, I scrutinized the inner wall of domatia chambers under an electron microscope. The inner walls were lined with a mat of a fungus similar to those known to decompose waste into simpler absorbable products. I also observed that the plant cells lining the inner domatia wall has tiny holes through which the nutrients could pass into the plant’s food channel.

To sum up: *H. brunonis* changes its rewards based on its need for protection, and it lures non-protective domatia- inhabitants for nutrient benefits. Nature is a network of interactions. A forest tree appears all tough on its own, but actually depends on its little friends, the ants and earthworms for protection and food. This novel finding contributes to our understanding of interactions in nature.
Role of Zebrafish C-Reactive Protein in infiltration of Macrophages during Bacterial Pathogenesis

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Liver is a major organ that helps in detoxification of foreign bodies, for example, bacterial cells, toxic chemicals and metals. During bacterial infection, macrophage plays an important part in minimising bacterial load from our body by clearing bacterial cells through phagocytosis. Several proteins are involved in inducing phagocytic activities of macrophages, especially C-reactive protein (CRP) plays a great role in this event. One important point is among different tissues, liver normally remains devoid of resident macrophages, therefore, an obvious question is then how does liver gets protected from bacterial infection. If we look into the cellular constituents of liver we would find that majority of them are hepatocytes and rest are blood cells, and satellite cells. In the present investigation, we intended to investigate whether hepatocytes itself is sufficient to minimize bacterial pathogenicity or other cells are involved. This will provide a better understanding about the contribution of hepatocytes and other cells in protecting liver during bacterial infection.

I have performed several experiments to understand the mechanism of reduction in bacterial pathogenicity in liver. In this context, we emphasized the role of macrophages in reducing bacterial load as these cells are directly involved in phagocytosis. Few important questions arise: i) Does liver tissue recruit macrophage during bacterial challenge for their protection? ii) If this is true, then what are the signals that trigger liver cells to recruit macrophage? iii) Which signaling cascades are triggered by both hepatocytes or macrophages and how these signaling molecules are associated in

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reducing bacterial load? With this hypothesis, we obtained certain important findings which are enumerated below.

In zebrafish liver, role of macrophage during bacterial infection is still unknown as macrophage does not reside in the liver. During bacterial pathogenicity, macrophage plays a great role in destruction of bacterial cells by involving several proteins. Numerous proteins induced due to bacterial infection, trigger enormous signaling cascades for the onset of innate and adaptive immune responses. Among these proteins, CRP acts as a major acute phase protein that dramatically increases during bacterial infection to trigger immunological responses in host. In zebrafish liver, what is the role of CRP during bacterial infection? To understand this situation we conducted several experiments and found that zebrafish infected with \textit{L. monocytogenes}, a gram positive bacteria, and \textit{S. typhimurium}, a gram negative bacterium, showed a dose dependent increase of serum CRP as compared to control. The optimum dose at which \textit{L. monocytogenes} and \textit{S. typhimurium} significantly could induce CRP was found to be $10^{10}$ and $10^6$, respectively. These findings clearly indicate that bacterial infection is directly associated with CRP level in infected zebrafish. Apart from these, we also tested CRP level at different time intervals in infected zebrafish and observed that at 24hrs maximum CRP induction. An obvious question here is how is CRP induced with increasing bacterial infection? (A: See change. Is it ok?)

To have an idea on how bacterial infection could cause high CRP level in serum of infected zebrafish, we came to know that CRP is majorly synthesized in liver in mammals however, in fish scant information is available in this direction. The expression of CRP increased in liver though maximum was noted in serum of infected zebrafish. The differential availability of CRP in liver tissue lysate and serum are may be due to the fact that CRP is a secretary protein and once it synthesized in liver, quickly comes into the serum. Since few proteins regulate CRP expression, we found that expression of CRP enhanced because of elevated expression of IL6 and IL1β in liver. Elevated CRP in infected zebrafish is a marker for bacterial pathogenesis and may be associated with toxicity.

The above findings clearly indicate an association between CRP synthesis and the involvement of IL6 and IL1β therein. To have an idea whether elevated CRP in infected zebrafish could cause toxicity, we performed further experiments. We expected that as CRP level elevated within 24hrs there may be a chance of high toxicity in infected zebrafish. To examine this, we measured the MDA level and found a marginal rise in its level against control in gram positive \textit{L. monocytogenes} with in 48hrs. However, MDA level greatly enhanced in \textit{S. typhimurium} infected zebrafish within the same period as observed with \textit{L. monocytogenes} suggesting maximum superoxide production during this period. Since MDA is a direct measure of superoxides, we expected that increasing superoxides triggers synthesis of endogenous anti-oxidants, which will help in neutralising the toxicity. One of the important anti-oxidants is glutathione which remains decreased in \textit{L. monocytogenes} treated zebrafish until day 2 though after that it gradually increased and almost reached to the control at day 4. The reason for initial depletion of GSH may be due to scavenging of enhanced superoxides that is produced within day 2.

One important point is that liver majorly consists of hepatocytes and CRP is synthesized primarily by these cells while CRP induction requires IL6 and IL-1β which are marginally produced
by macrophages. An obvious question here is how CRP could be synthesized in significant amount by hepatocytes, is/are other cell/s involved here? To understand this, we measured availability of macrophage in the zebrafish liver tissue. It should be noted that normally zebrafish liver does not have macrophages and we found that expression of a macrophage marker-F4/80 greatly enhanced in *L. monocytogenes* infected zebrafish liver thus indicating that macrophage might be infiltrated during bacterial infection within 24 hrs. This was further confirmed by immunofluorescence study where we observed few cells apart from hepatocytes were labelled with FITC-labelled macrophage specific marker, F4/80. The results are further validated by FACS analysis where we determined the percent of macrophages in control in infected zebrafish liver. It could be evident from Fig 5 that in control liver percent of F4/80 labelled macrophage is about 12.1% and this elevated in *L. monocytogenes* infected zebrafish liver to 17.3% as shown in quadra dot plot of FACS. Similar profile was noted in histogram where F4/80 positive cells in liver enhanced from control to treated zebrafish from 1 to 2.1%. Therefore, from these results it is clear that macrophage infiltrates in infected zebrafish liver.

Results from these investigations clearly demonstrates that macrophage infiltrates during bacterial infection in zebrafish liver and that possibly triggers induction of CRP. Earlier there was no report on macrophage availability in zebrafish liver; this is the first time we observed that macrophage enters in zebrafish liver. This event is associated with induction of CRP in infected fish, thus there might be a relation between these two events. However, the precise mechanism of this phenomenon is not yet clear and I am continuing my research in this area.
Modified Curcumin (*Haldi*): A hope in Preventing Brain Cell Death in Parkinson’s Disease

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**Behind the screens**

See that man, his hands are shaky. When he walks his legs go in a direction he does not intend to. He sits and freezes, stands and pauses. Confused and troubled by lack of co-ordination and stiffness, he undergoes a medical analysis and is alarmed to be diagnosed with Parkinson’s disease (PD). If you have witnessed someone dear to you with PD, you will be able to relate. Among many noted personalities, the famous American boxer, Mohammad Ali who knocked many in the ring was himself knocked down by this disease to which he succumbed in 2016. These symptoms of a lifelong debilitating disorder are just the tip of an iceberg. Apart from affecting gait, it disturbs sleep, speech and memory too. It’s a paradox that even with ongoing superlative research, there is neither a confirmatory easy diagnosis nor a sure cure of the disease. All the therapies just provide symptomatic relief.

PD is a complex ailment with multiple factors and manifold consequences. Broadly speaking, what we see as a movement disorder is actually a brain degenerative disease in which brain cells of a particular area (*substantia nigra*) responsible for controlling movement start dying. The level of one of the chemicals that transmits signals to the brain (neurotransmitters) called dopamine drops, producing the peculiar symptoms associated with PD.

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Backdrop

Do you know that our body comprises numerous proteins whose functions depend on their structure? Any deviation from the native structure leads to misfolding and aggregation of proteins into soluble and insoluble chunks *(oligomers and fibrils)*. There is a quality control system to take care of this and its failure plays havoc as we see in PD. If you postmortem a PD brain, you will find aggregated lumps of proteins. Ever wondered what the key constituent in all these could be? It is a protein called alpha-synuclein. This is an important protein that plays a vital role in not only our brain but other body organs too. It is found to be misfolded and aggregated in a typical PD brain. Although there are a number of environmental and genetic risk factors involved behind the screens but alpha-synuclein is involved in majority of the cases. Hence “synucleinopathies” is the common name given to all the clinical conditions with alpha-synuclein as a key player. Visualise, and it appears that insoluble fibrils deposited in specific brain cells can create a mechanical stress leading to cell death. For many years scientists also believed that it is only the fibrils that are notorious.

But behold! The concept has undergone a paradigm shift. Now most of the neuroscientists have confirmed that it is actually the soluble aggregates of protein that cause more harm through various other mechanisms!

Despite all the efforts, we still lag behind to find a cure. The question which still remains is how to cure the disease? Should we lose hope? Of course not and that is what my research was all about.

*“There are no such things as incurable; there are only things for which man has not found a cure.”*

– Bernard Baruch

If the disease is looked from a deeper perspective, it appears clearly that resolving protein aggregation would be a better alternative. There is a dearth of valuable molecules that modulate aggregation and the search is still on.

With a determination to seek potential agents that can break the aggregates, I geared up my search for inhibitors which falls into many classes.

- Some inhibitors are proteins that prevent misfolding *(chaperones)*,
- Others are protein-like in nature *(peptidic inhibitors)*.
  
  Both appear very promising, but they come with drawbacks of
  
  - Being costly
  - Getting degraded easily.
- Not being able to cross the protection machinery of brain, the blood-brain barrier (BBB)

There is then another vast group of chemical inhibitors *(small-molecule inhibitors)*. This group suffers from a problem of specificity. By specificity, I mean if you intend to target a particular process, these molecules can affect other processes as well. Nevertheless, their superiority in not getting degraded, crossing the BBB, ease of use and cost-effectiveness makes them enticing. So, a
word of caution is to understand the aggregation process elaborately and monitor the efficacy of
any of these inhibitors very specifically, intensively and extensively.

**Setting the stage**

When I set out to design the strategy, one way was to build new molecules altogether and screen
them. Another attractive option was to improve upon the existing molecules and study their effects
in great detail.

> “The most fruitful basis for the discovery of a new drug is to start with an old drug.”
> —Sir James Black

Every Indian household is familiar with the age-old spice *haldi* (*curcumin*) used extensively in
cooking. This small molecule is a wonder molecule with excellent anti-carcinogenic, anti-microbial
and even anti-aggregation properties exploited against numerous diseases. The best quality about
curcumin is its safety profile. As every good thing comes with a price, curcumin too is marred
with limitations. The greatest drawback with curcumin is its instability accompanied with poor
water solubility and bioavailability. Nevertheless, I could not overlook the benefits of “modified
curcumin”, which possesses improved efficacy over normal curcumin.

The first question asked was, Can we have more stable curcumin derivatives?
We were fortunate to have an organic chemist in the lab who synthesized known stable
derivatives *viz.* curcumin isoxazole and curcumin pyrazole for initial screening.

It will be interesting for you to know the highlights of the work comprehensively.

**The prelude**

**Getting the protein**
For every protein there is a gene which codes for its synthesis, Alpha-synuclein gene (SNCA) was
exploited to synthesize and purify the protein using standardized bacterial machineries which are
routinely used for such purposes.

**Standardising aggregation**
Once I got the purified synuclein, aggregation was studied in different conditions and time periods.
To monitor aggregation, I used a chemical named Thioflavin T (ThT). It has an interesting property
to fluoresce (emit light) on binding with aggregates which was utilized to standardised aggregation.
After several trials, a 30-day window was chosen for further experiments.

**Preliminary Screening**
Next, I performed a preliminary screen as to which is a better inhibitor; curcumin isoxazole or
curcumin pyrazole. Using unmodified curcumin as control, I found curcumin pyrazole to be
superior.
**Moving a step ahead**

Sixteen different pyrazole derivatives were synthesized and screened. Results led to the eureka moment of identification of 3 lead compounds

- compound 3 (curcumin pyrazole),
- compound 6 (N-3-Fluoro phenylpyrazole curcumin) and
- compound 15 (N-3- Nitrophenylpyrazole curcumin).

**Long story cut short**

With the lead compounds in hand, the next obvious step was to delve deeper to understand the usefulness of the compounds. Till you confirm through many ways, no surety is guaranteed. Hence, I performed detailed analyses of these compounds by various known methods to answer some important questions

- What the nature and characteristics are, of aggregates formed in the presence of compounds?
- Do the compounds disrupt already formed aggregates?
- Are the aggregates soluble?
- Are they toxic?

Congo Red is a dye which allows easy visualisation of the presence of fibrils. Samples containing compounds 3, 6 and 15 showed less fibril. These three compounds even reduced the amount of fibrils when added to pre-aggregated proteins.

“Seeing is believing”. Advanced techniques like atomic force and transmission electron microscopy helped to directly observe the aggregates. It was again confirmed that compounds 3, 6 and 15 not only inhibited formation of fibrils but also disrupted pre-existing fibrils.

**The Finale**

All said and done, the biggest question was still left to answer. What is the nature of oligomers formed? Are they toxic and harmful?

For this we used two methods. We cultured brain cells and studied their survival using a chemical called MTT in the presence of aggregates and compounds. We also directly studied the toxicity of oligomers by a known dot blot assay.

Strange and interesting! Compound 6 favoured the formation of toxic end-products rendering it useless as a therapeutic molecule!!

Only compounds 3 and 15 were effective in alleviating toxicity. Compounds 3, 6 and 15 were also assessed for their ability to inhibit the aggregation of another faster aggregating variant of synuclein (A53T mutant). Again, compounds 3 and 15 showed promising results whereas compound 6 generated toxic oligomers.

**Take home message and a word of caution**

See the irony! Compound 6 which seemed therapeutic via conventional techniques did not impart any beneficial effects in reducing toxicity. Hence, any strategy to discover new molecules should use different methods available and assess toxicity carefully.
Interestingly and pleasingly to conclude, we established that compound 3 and its derivate, compound 15 are potent therapeutic small molecules that can be taken a step further. This step hopefully will move ahead as we intend and not as past American President George W Bush, who struggles with a form of Parkinson’s, says "My legs don’t move when my brain tells them to.”
The primary source of water in the country is the summer monsoon rainfall in the months of June to September, as more than 80 per cent of the annual total rainfall is received during this season. In India where majority of the population relies heavily on rains for drinking water, agriculture and raising livestock, accurate prediction of summer monsoon rainfall is extremely important. Predicting monsoon rainfall has a long history and dates back to 1886. Since then monsoon forecasting has come a long way from simply observing the sky and earth. With the increased data from satellite observations, improved understanding of the processes, and enhanced computing resources, science pertaining to monsoon has progressed significantly. However, reliability of rainfall forecast is still not adequate, because of its large variability in space and time and its dependence on India’s diverse geography, which makes its prediction least accurate compared to other weather parameters and is quite challenging till date.

Over a century, physical laws governing aspects of the atmosphere have been expressed and refined through mathematical equations. The art of predicting weather using numerical techniques by taking advantage of today’s modern computational resources is known as Numerical Weather Prediction (NWP) modeling. Simply put numerical model is a representation of a real world system through mathematical equations that can be analyzed using computational methods. These models
come in handy when analytical solutions and experimental verifications to any such problems are not possible. Over time, NWP models have acquired greater skill and are playing an increasingly vital role in weather forecasting. In the last few decades, great progress has been made by the increasing number of NWP model forecasts.

But, these seemingly big numbers lead to confusion for the general public and for the people who are trying to monitor the monsoon. This calls for the need to develop an effective method to generate a single unified and more skillful forecast compared to the individual ones, on which a user can rely on for making decisions. In view of this, a new approach, known as multi-model ensemble (MME) has gained strong interest in the scientific community in the recent years. Consider figure 1, assume each person to be a model, and everyone to have some information about the unknown distribution. Now if all the information is combined, the unknown distribution can be identified with ease. Analogically, different models have different strengths and weaknesses in predicting a weather event. MMEs combine forecasts from different models and provide additional and more reliable information compared to a single model. Different MME approaches have been attempted by the weather forecasters and researchers, namely, poor-man ensemble or simple mean and weighted mean. In poor-man ensemble, mean of multiple forecasts is considered as the final forecast, whereas in weighted mean, based on the previous knowledge of the model forecast skill, weights for each model are computed. Using these weights weighted mean is computed. It has been seen that the weighted mean approach outperforms the simple mean in forecasting rainfall.

Figure 1: Cartoon showing the concept of multi model ensemble approach.
Now, the question is how to improve the forecasting skill further. In the present research work, an advanced MME approach has been developed for enhancing the existing summer monsoon rainfall forecasting skill. In carrying out the study, five models from different forecasting agencies were considered. These models were selected because of their higher skills in capturing the summer monsoon features. For assessing the skill of model forecasts the rain gauge based rainfall data available from India Meteorological Department (IMD) over the Indian landmass has been used. This data set is derived from a daily record from about 7000 rain gauge stations spread across the country incorporating the necessary quality checks. Quality checks simply mean verifying the location information of the gauge station, checking for missing data, etc. In order to forecast the SW monsoon rainfall, the Indian region was divided into small regions called grids (in the present study each grid corresponds to 25km x 25km area). The forecasts were formulated for 24, 48, 72, 96 and 120 hours (1-5 days ahead) over the Indian landmass.

The first step was to bring out the limitations of conventional MME approaches. The conventional approaches either assign same weight to each model or the weights are based on the past performances of the models. The weather is highly dynamic, therefore, calculating weights for each model only once using large set of past data, ignores this dynamic behaviour of weather. Also the models get upgraded from time-to-time, which is again a dynamic process that affects their forecast skill. Such changes are important to be taken into account while computing the weights for each model as the weights are the backbone of the MME approach and is the key point to be improved upon. Next, question was, how many days should be taken for computing weights. Further, the forecasts from even the best model can often go quite wrong due to the chaotic nature of the atmosphere. This trait of varying performance of models is ignored by the existing MME approaches, as they select all the participating models which degrade the overall performance thereby underestimating the performance of the better performing models.

The newly developed approach overcomes these limitations by dynamical selection of models based on their performance in the recent past, therefore, 45 days (chosen from the summer monsoon season, namely, June to September). The minimum forecast error was achieved by using 45 days, which became the basis for the selection of 45 days in order to weight the models. Unlike conventional MME approaches, the dynamical model selection approach makes a choice from the combination of only three better performing models from the five participating models. The selection is based on the higher correlation between the rainfall values forecasted by the models and observed values obtained from the IMD rain gauge rainfall product. Due to the varying skill of each model at different places and forecast hours, the model selection procedure is carried out at each region and for each forecast hour, hence, the three selected models change for every region as well as for each forecast hour.

To verify the method’s accuracy, forecasts were checked against IMD rainfall data from 2008 to 2013. Results show an improvement of around 6-10% for 24-120 hour forecasts using dynamical model selection approach compared to the existing approaches. The point worth noting was that the improvement increased with the forecast lead time. The newly developed method has shown sufficiently promising results for real time dissemination of the forecasts to the user community.
Due to the inherent chaotic nature of the atmosphere, the precise prediction of the accurate amount and position of rainfall still remains a challenge to the scientific community, but this uncertainty in nature is what attracts the scientists and researchers towards this research field. It reminds me of the words from Edward Lorenz, pioneer of the chaos theory that, “If atmospheric processes were constant, or strictly periodic, describing them mathematically would be easy. Weather forecasting would be easy, and meteorology would be boring.”
Adoption of Green Building for Sustainable Growth of Rural India

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Trivia to home town creates an excitement in a person of any age, education and status. It was my summer vacation after completing first year of Master’s in Civil Engineering. The only way to reach my tiny village “Piapali” in Bastardistrict of Chhattisgarh state in central India was by rail with breaks in journey, first to Raipur and further to Jagdalpur. It was a luxury to travel in AC-3 tier compartment due to tickets being sponsored by my grandfather to visit him at Piapali. Sitting in the air-conditioned train thinking about the beauty of nature and village life, it was a pleasant I realised after getting down from the train to face the scorching heat of central India. Since, I had a connecting train from Raipur to Jagdalpur I had no other choice but to sit in the waiting room which felt like a sauna in the middle of May. After 16 hours of tiring journey from Raipur I reached Jagdalpur station and was happy to see my old grandfather received me. We reached our village and excited and happy to meet my grandmother, relatives and cousins. By the time it was 8pm, suddenly the electricity supply was shut down. On enquiring I came to know that our village is facing 16 hours of load-shedding and electricity would resume only after that. I had a sleepless night with a single fan which was running on inverter and the entire family was compelled to sleep in one room which was suffocating due to lack of ventilation in the room. Next morning, I realised that it was difficult to manage regular chores and potable water was sourced from Indravati river near our house. Staying in an urban area with all luxuries of basic necessity like 24X7 water, electricity and

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other utility services, I never thought about the wastage of specifically electricity and water until I experienced it myself and concluded that the balance of utilisation of natural resources defines the sustainability for long-term human existence. The balance between urban and rural areas needs to be addressed for overall progress of any country. This thought gave birth to a need to carry out research and development in sustainability. Thus after returning, I zeroed down on a research topic for my thesis. After going journal papers, research articles, technical magazines, books and through further discussions with my guide, I started my journey on sustainability. Though, there was a lot of research available but there were very few papers on Indian spectrum for green buildings. After researching I got to know that there were two major institutions in India for green building, out of which one was State sponsored and is known as Green Rating for Integrated Habitat Assessment (GRIHA) and Indian Green Building Council (IGBC) which is a privately sponsored authority under the dian Industry (CII). Apart from others like Leadership in Energy and Environment Design (LEED), Excellence in Design for Greater Efficiencies (EDGE) and World Green Building Council (WGBC).

Meanwhile, in the first half of my thesis tenure I went to Vishakhapatnam to get training from IGBC and further appeared for the IGBC accredited professional exam and cleared it in the first attempt with flying colours. My next goal was to take training in GRIHA which I accomplished in Mumbai. After gaining a thorough knowledge of Green buildings I could not find a platform to calculate utility savings or reduced carbon footprints of green building as compared to the base case. Only EDGE had an online platform and was giving results in an output format for submissions to concerned authorities. Since EDGE is developed by International Finance Corporation (IFC) it lacked India specific requirements. Further to a discussion with my guide to make a soft computing technique for IGBC and GRIHA code of practice, I zeroed upon making a soft computing tool in Microsoft Excel for my Master’s thesis for appropriately calculating the credits with respect to the IGBC Abridge reference guide and preparing a case study using the same programme and comparing with an actual green certified building.

The study included the green building concept like sustainable site planning, building design optimization, energy performance optimization, renewable energy utilization, water and waste management, solid waste management, sustainable building material and construction technology besides health, well-being and environmental quality. The benefits of green building have emerged which will prevent pollution, save energy and thereby save natural resources and expenditure during operation which results in approximately 60% reduction in energy consumption. Efficiency in offices and homes increases with natural non-glare light and proper ventilation in the room, which results in reduction of respiratory diseases by 20% and performance of the occupants up to 25%, which finally results in low utility demands in green building.

The environmental benefits include emission reductions, water conservation, strong water management, temperature moderation and waste reduction. The economic benefits include energy and water savings, increase in property value due to lower operating cost and maintenance of building and decreased infrastructure strain, i.e., less demand on local power grid and water supply. The indirect cost benefits include improved attendance, increased productivity, sales improvement
and development of local talent pool. The social benefits include improved health due to better air circulation, proper lighting, lesser temperature variances etc., and attendance due to better environmental conditions, healthier lifestyle and recreation by use of alternatives to personal driving such as bicycling and public transport which also adds to health benefits of occupants.

After completing my Masters thesis in Civil Engineering and ranking 3rd in the University, I was elated and it resulted in building my self-confidence to carry out further research by pursuing a Doctor of Philosophy (Ph.D.) in Civil Engineering. After taking guidance from my Guide, I decided to carry out my study on “Development of web-based decision tool for green building credit rating certification. During the review of literature in soft computing techniques for green building I carried out a critical appraisal of my literature and zeroed upon the gaps in the literature and thus, defined the statement of problem for my study. Further to my above study, I found that in applying for green rating to the authorities, one has to engage various agencies in the field of energy modelling, water conservation, green consultants, project architects, project engineers, who thereby prepare, large and complex documents to comply with the given intents so as to achieve the Star Rating of any green building. I intended to make a tool to meet the demands for quick, simple and free-to-use online web based decision tool to solve the complexities of the hidden methodology of resource efficiencies and cost savings in comparison to the base case without involvement of pocket burning expense by use of third party specialist to prepare and apply for green rating.

My objective of proposed study was to study all versions of GRIHA and IGBC rating system and to find a methodology for appropriate calculations of credit points with respect to requirements as given in abridged reference guide. The above work required me to prepare programming concepts which included a complex conditional statement, looping of the same, implementation of logic flow diagram for problem solving and communications. After studying the above, I realised the need to master programming tools like PHP: Hypertext JQuery, Cascading style sheets (CSS), Hypertext Markup Language (HTML), Dot Net framework (.NET), C Sharp.NET, Dynamic-Link Library (DLL), Microsoft SQL Server and Java Script. On the hardware front, I had to study and find out the methods of storing data inputs through online and preparation of reports in the back-end for further research and development, front end reports for the users. It was decided by me to make a close source online programme which could be used to avoid copying and redistribution of my programme. The above study also required testing and deployment optimization by the way of algorithmic efficiencies, resource allocation, virtualizing, terminal server testing, power management, data centre power optimization technique, operating system support and means of storage and cloud computing.

The expected outcome of my study will be a web-based decision tool for all Green Rating system so as to meet the demands of easy, faster, reliable and affordable tool which shall be used to plan and estimate the design of resource efficiency in order to boost green building growth in emerging markets and backend data for in-house research and development. My dream to balance the gap of consumables like water, electricity and for sustainability in rural shall come true by adaptation of green building certification in urban area which will reduce the demand of water and electricity and which can be directed to the villages of India.
I don’t like this face mask. It looks very ugly on me”, rebelled Vedant, a selfie-conscious teen, while having a family evening stroll in the smoggy lawns of IIT Delhi.

“Papa, why everyone walks-with-these-masks”, exclaimed Aarav in rhyming style, while jumping in the bandwagon of curiosity with his elder brother.

“Look, my boy”, I started to explain, but was cut short immediately by The lady of the house, “No technical jargon, please”, pleaded the student of literature.

“OK”, I promised in order to earn a green nod from my lady. “So, these masks save us from the pollutants present in the air. Vehicles around us exhale many dangerous gases from their tails”, I said.

“Oh, like dragons fire from their mouths”, wondered the movie buff Aarav.

“Yes, but that will be more fitting for chimneys of factories”, I responded.

“Can’t we fix these polluting tails and appear again like humans on our evening walks?”, was the most difficult question of the day asked by a visibly upset Vedant.

He awakened the researcher inside me and I responded enthusiastically, “Yes, people are trying and I am also playing a part in the solution. My research is focussed on developing materials for alternate power sources that are non-polluting and efficient.” I guess, the discussion made their mom conscious and turning around she signalled for concluding the walk and the talk, both. Obviously, we obliged with silent gestures of continuing later.

On the way back home, I remembered many intense discussions held in our research

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scholars’ room on the delicate situation of our environment. Overdependence of human race on the fossil resources for the survival and the unsustainable growth has nearly depleted the rich coffers of earth, which took millions of years to deposit, within a century. Moreover, our hunger for energy-intensive essentials and comforts of life are severely polluting the air, water and land systems. Till date, the extraction of energy from these non-renewable fossil resources has been very inefficient, like in thermal power plants (roughly 30%) and automobile engines (20-30%). Nuclear and hydro power sources have their own complications, viz, safety concerns and disastrous ecological footprints. Undoubtedly, we need cleaner and efficient sources of power to extend our survival on earth. Solar cells seem to be rising on global scale but they too struggle with their efficiency issues.

Fuel cells and specifically, Solid Oxide Fuel Cells (SOFCs) are among the most promising candidates, which produce power very efficiently (approx 80%) and more importantly, they release only pure water vapours from their tails (exhaust), when run on hydrogen and oxygen. They have been successfully tested on all conventional fuels including gasoline, LPG, coal and biogas and have the added advantage of efficient extraction of power from these fuels as compared to conventional routes.

“So, what you develop in your lab?”, thus started the questions of big boy, as we entered in our lobby.

“OK, just settle down and listen”, I started to explain the partial intricacy of my graduation journey to our school boys. “You know it well, how much we are dependent on electricity in our daily lives but do you know how much power is lost midway before it reaches our home? It is more than one-third. Even the vehicles around us burn their fuel very inefficiently and worse, we also get life-threatening pollutants like NOx, SOx and particulates from them.

Now, just imagine a power-producing device that has no moving parts, no irritating noises and is thin as a paper of sheet. Interestingly, this compact device have a very clean tail (say exhaust) giving out pure water vapours. And it is not even like your gadget’s battery that drains every now and then. As long as you supply it the fuels (say gases), you can generate clean electric power silently. A small suitcase-size unit of it can power our entire house, non-stop. It is called solid oxide fuel cell or SOFC, in short”

“Oh, is it so?”, asked the surprise in his eyes. Vedant continued, “So, is that what you make in your lab?”.

“Yes, we do that but partially. I mean, we develop and test the performance of some components of these solid oxide fuel cells”, I responded.

My response made him wonder, “Do you mean that this paper-size fuel cell has many components, really?”.

“Of course, a single SOFC has a solid electrolyte sandwiched between two electrodes”, I told.

“Sandwich! Oh yeah...hhh, my favourite”, shouted the younger one, making us laugh with his unwavering attention to catch possibly the only meaningful word that made sense to him.

“Look, this is a rough sketch of SOFC”, I drew on a paper, as shown above.
“To get some useful chunk of power, we need many cells because a single cell of one square centimetre area can generate only around 1 watt power. So, another component known as interconnect comes to our aid and depending on the requirement, we join multiple cells using these interconnects. Though, the electrolyte and electrodes of a SOFC are made up of ceramic materials (as they have to transport ions across them), the interconnects can be made using metals also, while operating at lower temperatures.”

“What do you mean by lower temperatures?”, interrupted Vedant.

“Oh, I forgot to tell you that latest generation of SOFCs operate between 600-800°C. Wait wait…, I got your ‘why’ signal. It is because the chemical reaction, rather the electro-chemical reaction (as it involves electrons), needs that much temperature to take place. Actually, for this reaction, the ions need to be pushed across the reluctant solid electrolyte and thus, that much thermal push is necessary to overcome the ionic distaste of electrolyte.

Thus, single unit of SOFC is a layered structure consisting an interconnect, anode, electrolyte and cathode, as you can see in the drawing. Combination of many such cells is known as the Cell Stack. Now, let me explain about my contribution in this context”, I set the pace.

“But papa, do we need some special fuel to run this device”, was the confusion of Vedant.

Also, I noticed that the younger one was already zooming in his dreams, so I tranquillised him with little heavier dose, “In ideal case, hydrogen gas on anode and oxygen gas on cathode will yield the maximum power output and pure water vapours from exhaust. But for practical purpose, air can be used at cathode side and many common fuels like biogas, syngas and gasoline can be efficiently utilised on anode side. Extra heat can also be put to use, if the situations demand”.

So, as I mentioned earlier, metals can also be used as interconnects. But, they face many
restrictions in their selection. In addition to their good electrical conductivity, they must have matching thermal properties with other ceramic components and must be stable in both hydrogen and oxygen environments in such hot condition. My work is related to improve the properties of such metallic interconnects, so that the life and performance of SOFCs stack can be enhanced.”

“Hmmm…”, he nodded slowly.

“We fabricate specific grade stainless steel alloys and study their degradation behavior under operating conditions of SOFCs. We have developed new and innovative routes to fabricate such alloys. Also, in our lab we test the interaction of these interconnects with cathode materials at high temperatures to look for their compatibility. And I can say that till now the results have been promising at lab scale”, I finished so and it was taken as my concluding gesture.

“Yes, I think that much is enough for today. Though, I can’t claim to understand everything you said but at least your ‘tales of fixing the tails’ seem interesting and are definitely part of the solution. I will read more about solid oxide fuel cells and get back to you with more doubts”, he hummed slowly and slipped into his bed swiftly.

“You people are still talking. Look at the clock! Switch off guys”, commanded the slumberous voice. Lights went off immediately.
The research story jotted below is a narration of a laboratory attempt to eradicate predicament of a fish population utilising the other entities in its own inhabiting environment. The work aims towards a transformation from harmful synthetic aqua-framing to sustained organic aqua-farming with an effort to reduce the discharge of toxic chemicals into the environment.

Aquaculture is one of the foremost and broadest economic sectors of India, contributing 1.1% to the total GDP and 10% to the total exports of the country which accounts for 6.3% of the global fish production. Wetlands are distinctive and productive aquaculture ecosystems which are inundated by water permanently or seasonally. There are usually multiple numbers of flood plain wetlands in the lower delta of river Ganga, structured with hydric soil and harbouring unique flora and fauna. Parallely, these water bodies also bears ample responsibility for adverse environmental cause and impact linearity. Demands for high yield impels fisherman to use extensive synthetic chemicals which not only causes numerous pathogenic outbreak in wetland fisheries but also exerts detrimental health concern on producers as well consumers.

Holding this preview, the therapeutic traits of a well known wetland macrophyte, *Ipomoea aquatic* Forssk. (Hindi: कलमीसाग) was evaluated towards fin and tail rot disease of a cat fish, *Pangasiushypophthalmus*, commonly known as Pangus fish (Hindi: पंगासमछली).
The lyophilized and powdered leaf of *I.aquatica* was defatted and subjected to partition chromatography using organic solvents from low to high polarity. Finally the aqueous extract was obtained from the Methanol residue isolated from Chloroform : Water:: 4:1. The fractions were eluted through silica column and crystallized which was further flushed through Petroleum Ether : Chloroform 1:1.

The fish was obtained from Akaipur wetland, West Bengal. While still on stocking tank for acclimatization, the Pangus fish shoal was seen infected with fin and tail rot (पंख और पूंछ गलन). Though we had a preparation for fish challenge with different concentration of bacteria to optimise the LD50 but there could be no better experimental resource than the infected fish which carried the infection right from its natural habitat. One of the most commonly seen disease symptoms rendering to high mortality in Indian fisheries is witnessed due to fin and tail rot which is largely caused by Aeromonas species viz; *A. hydrophila*, *A. veronii*, *A. popoffi* and sometimes by *Edwardsiella tarda* where again *A. hydrophila* mostly causes secondary infection by gas formation. These are gram-negative and mostly water-borne bacteria. In-order to confirm the bacterial strain, the infected parts were wiped with alcohol and tethered to streak on Muller Hilton Agar (MHA) plates followed by 16S rRNA sequencing which confirmed it to be *A. veronii*.

Before going into In-Vivo assay, disc diffusion assay was performed on MHA plates where a zone of inhibition of 14 mm was obtained ($T_1$).

The crystals obtained from Ipomoea leaves were hygroscopic in nature which aided to blending with commercial fish feed using egg white as binder and fed twice a day for seven days. A control group of infected fish was maintained which was fed with normal feed with egg white. Initially the results were very much promising but in later days it did not show any curative effects and the overall experiment to use *I.aquatica* leaves as a therapeutic source was not satisfactory or rather unsuccessful. Literature survey had plentiful studies on the prophylaxis trait of Ipomoea against cancer and some other diseases. Hence a remake of the previous experiment was deliberated in the simplest way possible to check its prophylaxis property instead of therapeutics, against fish disease. Fresh fish were segregated into two sets, one fed with the Plant sample + feed + egg white and the other group fed with normal feed + egg white each for 14 days and then both the groups challenged intraperitoneal (IP) with the previously isolated and freshly sub - cultured bacteria (0.5 McFarland; 10µl/gm body weight) using insulin injection. The results were inferred with fresh uninfected fish.

Technically better results were observed than the previous trial and the clinical symptoms for the disease appeared after almost 17 days for the first group fed with plant sample as compared to 100% mortality 54hrs for the second group. To understand the differences better, the liver and kidney histopathology of the normal, infected fish fed with feed + Plant sample and infected fish fed with normal feed was compared in Haematoxylin eosin stain after 54 hrs.

The liver histopathology (Figure: 1) reveals the normal liver section with intact portal triad, distinct bile duct and proportionate hepatocyte and pancerocyte (A); the infected fish fed with plant material had almost the same histopathology like the normal with only exception of cytoplasmic
vacuoles (B); the infected fish with normal feed showed disintegrated portal triad, disintegrated hepatocyte and (C) dissociation of the hepatocyte & pancerocyte.

The kidney histopathology (Figure: 2) reveals the normal kidney section with intact Bowman’s capsule with Glomerulus with intact proximal tubules (A); the infected fish fed with plant material also was seen with prominent Bowman’s capsule but some tubules were seen dilated (B); the infected fish with normal feed (C) showed disintegrated Bowman’s capsule and the sloughing of the epithelial lining of the proximal and distal tubules.

The economical affairs of these researches are fairly cheap and within the periphery of the fish farmers which can serve as a convenient solution to problems faced by them or at least lend them some time to treat the diseased fishes by delaying natural mortality. We have also taken up three more floodplain wetland macrophytes in this aspect and expecting to find further worth mentioning results. Way forward to participatory rural appraisal towards efficacy of aquatic macrophytesin fish health.

The research is financed by Women Scientist Scheme (DST WOS-A), Department of Science & Technology, Govt. Of India and the research team consists of myself (Nabanita Chakraborty, DST WOS-A & PhD Scholar, ICAR-CIFRI, Barrackpore), Dr. Archan Kanti Das (Principal Scientist, ICAR – CIFRI, Barrackpore), Dr. Basudev Mandal (Assistant Professor, Vidyasagar University, WB), Dr. Ranjan Kumar Manna (Principal Scientist, ICAR – CIFRI, Barrackpore) and Dr. Basanta Kumar Das (Principal Scientist & Director, ICAR – CIFRI, Barrackpore).

Population and Ecology Symbiosis – Wetland, Macrophyte and Fish
Necessity of Gas Sensing In Daily Life: Graphene/Metal Oxide Nanocomposites for Carbon Monoxide Sensing

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With the expansion of scientific and technological boundaries, we are living in an environment where plenty of hazardous and flammable gases are being supplied through various pipelines / passages as part of various industrial and household applications. Our environment is changing daily and it needs to be monitored closely. Here are a few case studies which the need to monitor the environment. The Bhopal gas tragedy (1984) which occurred at Union Carbide India Limited (UCIL), in Bhopal, Madhya Pradesh, was an eye-opening incident. The methyl isocyanate (MIC) leakage had caused 3,787 deaths and 5, 58,125 injuries. The MIC is a highly toxic gas which is extremely hazardous to human health. This incident continues to haunt the coming generations as many are suffering from the side effects and are born with disabilities. The Chasnala mining disaster (1975, Dhanbad) was the worst of its kinds in the history of Indian mining. The explosion happened due to a spark hit on a methane gas pocket. This incident had taken the lives of 372 miners, who were buried alive inside the cave. In May 2017, the poisonous gas named Chloro (methyl) diphenylsilane leaked in a container depot at Tughlaqabad and 475 students along with nine teachers had to be hospitalized from two nearby schools. The inhalation of Chloro (methyl) diphenylsilane causes eye and throat irritation and acute dizziness. C gas leakage in a water treatment plant in Karnataka (May 2018) led to the hospitalization of 20 workers. A similar incident occurred in Vadodara district, Gujarat, where chlorine leakage from a cylinder affected 25 employees with severe eyes and throat irritation. In March 2017, in a horrific accident,

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ammonia leaked from a chamber of a cold storage facility in Shivrajpur, Kanpur. The roof of the building collapsed trapping around 24 people. Also ammonia is a highly corrosive and hazardous gas. The carbon monoxide (CO) leakage in Bhilai steel plant (Raipur, Chhattisgarh) was another fatal accident. Around 6 people were dead including 2 officials and nearly 40 people got were affected. In a similar way, CO gas leaked in a Brazilian-owned steel plant in Andhra Pradesh on July 12, 2018, while employees were busy with maintenance work. The incident led to 6 deaths due to CO inhalation. CO leakage cannot be detected as it is a colourless and odourless gas. Inhalation of CO causes dizziness. Excess inhalation leads to brain damage and death. Apart from this, presence of several other toxic gases in our surroundings cannot be detected by human sensory organs. Moreover, there must be so many more accidents that go and are buried in history.

In order to detect them, there should be something which can smell/detect these gases easily and alert people. If the hazardous, toxic or flammable gases are detected early, it can save lives and government’s money. The question is how do we detect the gases in advance? Indeed, it is possible with the support of “electronic nose” which is technically called a “chemiresistive gas sensor”.

Electronic nose/Chemiresistive gas sensor device contains a material which shows differences in their electrical conductivity upon change in surrounding ambient. When the surrounding react with this material, it alters the electronic states of the material through which the conductivity change occurs. While the electrical conductivity of this material is being measured on continuous basis. This change in conductivity will be used as the signal to alarm by connecting to any siren. The reaction capability of material depends on the material’s nature and corresponding gaseous environment it is reacting with. Generally, metal oxides are well explored materials for gas sensing. However, the poor conductivity properties of materials can be overcome with the addition of some other highly conductive material. Our group is working on the development of sensing materials which provides better response against various hazardous, flammable and organic vapours.
Our main theme of production is making composites of various metal oxide nanostructures with graphene. Firstly, what is graphene? In simple terms, the graphene is a layered material with single atomic thickness derived from graphite. Possessing higher electrical conductivity with larger available surface area is one of its unique features. This supports the metal oxide and helps in providing better sensing response. Recently, we have synthesized a composite material with titanium oxide (TiO2) and graphene for CO sensing. We have followed a waste management approach to synthesize graphene used in this process by extracting graphite electrodes from waste Zn-C batteries.

The graphene synthesis requires graphite as a preform material. Dry cell batteries are primary kind of non-rechargeable which are being used for various remote controls, electronic devices and household applications. Yearly, million tons of these batteries are being dumped after their usage. The inert graphite rod placed in the center of these dry cells can be used for the synthesis of graphene. It serves three purposes at the same time. One is waste management, second is graphene production and the last one, it reduces resources and efforts utilized in graphene production industries. The quality of graphene produced using comparative with other existing routes. Also, we have filed a patent on this work (Application No: 201821006507 A).

The graphene synthesized from the above mentioned process was used in making composite with TiO2 nanoparticles. The material was tested against the CO of 100 ppm and 200 ppm concentrations in a closed chamber. When the CO comes in contact with TiO2, it donates electrons by adsorbing on the O-lattice site. Due to this increase in electron carrier density, the material shows increase in conductivity. Here, graphene helps in this change in conductivity to measure at room temperature. The composite material had shown significant response to the both concentrations. The work has been published, titled, “In-situ TiO2–rGO nanocomposites for CO gas sensing,” in Bulletin of Material Science (Bull. Mater. Sci. (2018) 41:115). In addition, we are also trying to develop various kinds of such materials to test against different gases.

Finally, the gas sensors (electronic noses) made of appropriate materials could be used in high density population areas to prevent accidents occurring due to gas leakages. Once the sensor detects the gas in the environment, corresponding disaster management department can take the necessary actions in a quick manner to save more lives.
I constantly toy with the possibility that I am an obsessive germophobe; I wash my hands innumerable times a day, at times causing inconvenience to people around me. Fear of infection is a real concern, and to some extent we all are and should concerned about tiny (micro) organisms that can cause infections. Bacteria, for example, are tiny organisms that can cause a variety of diseases such as cholera, pulmonary tuberculosis, leprosy and many more. Though not all bacteria are bad. Gut bacteria, for example, are good guys who help us digest our food. However, the villainous ones, called pathogenic bacteria, can wreak havoc inside our bodies.

Before we take external medical help, our cells themselves have internal defense mechanism to fight these micro-invaders. Our bodies do this with the help of cells known as phagocytes. Phagocytes engulf the bacterium to form objects called phagosomes. Phagosome, with its captive bacterium, then travels around the cell to find another kind of objects called lysosomes. Lysosomes then join the phagosomes and take it on themselves to destroy the pathogens before they can cause trouble to us. Unless the bacteria itself evolves to avoid destruction (which happens quite frequently), the defense processes happen continuously and efficiently inside our cells. But phagosomes and lysosomes are too small compared to the size of the cell. Then how does a phagosome locate the lysosome to complete the defense action? Turns out there are spatial roads inside cells on which phagosomes are transported by certain protein vehicles, and like in a fantasy movie, these roads and vehicles help the phagosomes to find the lysosomes. But this isn’t a fantasy. Biologists have observed the behaviour of these roads

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under microscopes; these roads are called “microtubules” and they are no ordinary roads. They have a fascinating life of their own. It is their life that I am trying to understand through my research and it is their story that I am going to share.

Microtubules are shaped like cylinders, and the building blocks which form them are tiny proteins called tubulins, which stack themselves to form these tubes. Microtubules are truly multifaceted. There are myriads of proteins, carrying various cargo, which walk on microtubules to their own destinations. To enable this transport, microtubules have to remain stable and intact. However, at other times microtubules have to build and collapse their cylindrical structures too rapidly and frequently. This necessity arises before cell division, when the dividing cell has to bequeath its hereditary materials equally to the two daughter cells. They also need to rearrange their structures appropriately to enable the cells to move. Sperm cells, for example, use structures formed from microtubules in order to move inside the female reproductive tract. The research work that I am involved in is an attempt to understand how microtubules, and the tiny tubulins which make them, keep up with this demand to constantly rearrange themselves. More specifically, we try to understand the probable reasons for the sudden collapse of these tubes and the recovery afterwards.

There is more than one way to understand this problem. There is experimental work, which uses actual samples of these proteins and makes measurements from them using suitable techniques. Then there are theoretical techniques, which consider these chemicals as more abstract objects, write equations using them, and then solve them, often with the help of computer simulations. The two approaches can often result in supportive or complementary results, that is good as it provides stronger evidence and improves our understanding of the problem. My work is of the latter kind; we try to understand the behaviour of microtubules by simulating their behaviour using computer programs. In order to do this we simplify the structure of microtubules by assuming a 1-dimensional stack of tubulins in lieu of a 3-dimensional cylinder. This simplification is a reasonable one vis-à-vis the purpose of our study, which will be made clear a little later.

It is known from experiments that tubulin proteins have a dual-face; they can exist in a form attached to a GTP molecule or in an alternate form attached to a GDP molecule. GTP is one of the “energy molecules” of the cell; it can undergo chemical changes to become a GDP molecule while releasing energy as the cell requires. Microtubule cylinders which consist of more number of GTP-attached tubulins (at least at their ends) are longer and more intact than those with more GDP-attached tubulins. In our simulations, we consider the possibility that this existence of an alter-ego makes a difference in the likeliness of tubulin to attach at the end of a microtubule. We ask the question, what might happen if a free GTP-attached tubulin, that comes near the end of a microtubule, is more likely to join the tube if it sees one of its own kind at the end rather than a GDP-attached tubulin. Our results tell us that the consideration of this individual preference of tubulin is sufficient to capture the incessant collapse-recovery behaviour of microtubules. We can also measure how frequently microtubules shift from the intact form to collapsing form. These results compare well with previous measurements from experiments, so our 3-dimension to 1-dimension simplification has not caused us much trouble so far.
The formation or collapse of microtubules depends on the amount of GTP-attached tubulin proteins present in the cells. We can denote this quantity by the term “concentration” of free tubulin. If this concentration is very high, proteins readily assemble into long microtubules. If the concentration is too low, tubulins in the microtubule will detach to become free souls before new tubulin have the time to attach. This kind of behaviour of a group of individual objects is aptly named as “collective behaviour”. It is not just tiny proteins which exhibit collective behaviour. If you are the sort of person who likes to goggle at the sky during sunset, you would have noticed the orderly patterns formed by flocks of birds flying by. Closer home, you may have noticed the regimented army of ants going about their usual business every day. These are all examples of collective behaviour. It essentially boils down to this: it does not matter what a single individual does at a particular time, but the group of individuals on an average behaves in a certain way depending on a variety of conditions. In the world of tubulin, this behaviour manifests in the form of growing microtubules at high concentrations and collapsing microtubules at low concentrations.

There are many benefits in knowing how rapidly this collective behaviour changes with the amount of tubulin. For example, it tells us what is the amount of tubulin required to salvage collapsing microtubules. Results from our simulations tell us that this change of collective growth to collective collapse is extremely rapid, i.e., it takes only a slight change in the amount of tubulin present. We also learn that the individual preference of tubulin that we have earlier talked about is crucial for this rapidity. Between the tubes that grow and the tubes that collapse, there is a small range of tubulin concentration where all hell breaks loose. In this small window of concentration, every individual microtubule can itself constantly rearrange its structure. This knowledge is crucial as this dynamic state of microtubules is essential for cell division. We know that cancer cells undergo unbridled proliferation. This proliferation happens through cell division. Hence, many anti-cancer drugs try to target microtubules in order to suppress cell division. So if we can understand what the conditions conducive to cell division, experiments can be designed to drive microtubules out of those conditions to suppress cell division, and, thereby, act in our favour against diseases like cancer.
There are many ways in which our computational study can be improved by adding additional details about microtubules. The ultimate goal of all research work in this area, including ours, is to understand what factors enable microtubules to perform the myriad duties they occupy themselves with or the ways in which they can be to treat diseases such as cancer.
India experienced its first Hepatitis E viral outbreak in 1955-56 (Delhi) where 29000 cases and later during 1978-83 in Kashmir valley where ~52000 jaundice cases with 1700 deaths were reported. Recently in 2016, Shimla witnessed ~15000 cases of acute jaundice due to Hepatitis E virus (HEV) which took life of 21 residents. Such a huge magnitude of HEV infection was due to lack of specific antiviral drug and FDA approved vaccine which need to be addressed and solved as a researcher.

As a PhD student, working on Hepatitis E Virus, in the Department of Virology at the premier Medical Institute; Postgraduate Institute of Medical Education and Research (PGIMER), Chandigarh under the renowned clinical virologist Prof.(Dr) R K Ratho, I actually witnessed the pain, stress and sufferings of patients and their expectations from the medical surgeons and scientists. My science journey daily started with a phone call to the Senior Residents of Liver ICU and Septic Labour Room (SLR):

Me: Hello,
Resident: Hello, Liver ICU/ SLR.
Me: Good morning Sir/Mam, this is Vikram from Virology department. Is there any HEV IgM/RNA positive patient admitted there?
Resident: Yes Sir, One patient X on Bed No. #. He is the liver transplant patient and now showing acute rejection (liver failure) due to HEV.
Me: Ok fine, Thank You, I will be there!

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Unfortunately, this was my daily scenario for collecting blood samples from infected patients those are on central line for monitoring Heart Rate, Blood Pressure, Sodium and Dextrose levels. I always resist myself to collect blood from such patients who are in severe conditions and about to die. I was heavily stressed with the expectations of the patients for their cure, disease management and recovery.

Occasionally, I received calls from Liver ICU
Resident: Hi, This is Dr# from Liver ICU.
Me: Good morning, Sir.
Resident: The patient from whom you collected blood yesterday, passed away last night.
What about the other reports sir?
Me:................

I experienced such painful and emotional incidents during my last 4 years as research student, that I always thought, why can’t we simulate clinical conditions and do research for the betterment of the patients. Why always, I need to carry out research on every patients and treat them as experimental animal for our own interest. We are in the era of artificial intelligence and data science, with tonnes of scientific (genomic and proteomics) data in the form of sequences, clinical case reports, articles, etc. published and freely available to everyone. Why there is publish and perish attitude, where is the translational output? Swirling in these thoughts, I attempted to implement Structural Bioinformatics (Computational approach) to study HEV structure for better understanding of disease pathogenesis. This attempt helped me to get CSIR travel grant to attend 5 days training in European Bioinformatics Institute, Cambridge in United Kingdom (3rd- 7th Sept, 2018), where I equipped myself with all the possible algorithms, soft wares, servers, programmes, tools and implemented to predict “Structure of Hepatitis E virus X domain to limit viral infection” which might be useful to design the inhibitors. The research activity as follow:

The macro domain (X) is found to be ubiquitously present from Bacteria to humans and in many positive-strand RNA viruses like Rubella, Sindbis and SARS CoV. So far, HEV ORF1 X domain is known to interact with cellular ADP-ribose protein (involved in host pathogenesis). However, the detailed physiochemical characterization and putative refined structure of HEV X-domain with ligand binding active sites is not reported yet. So we proposed in-silico 3-D structure and functional characterization of HEV X-domain which will significantly improve our understanding of HEV pathogenesis and replication.

HEV X-domain sequence was retrieved from NCBI and characterized by ExPASY server. Crystallization probability was predicted by XtalPred, solvent accessibility by Raptor-X and disulphide linkages was predicted by DiANNA and DISULFIND server. Secondary structure was predicted by PredictProtein, SOPMA, PROFsec and Raptor-X Property server. 3-D structure was predicted by Phyre2, SwissModel, ITASSER and Raptor-X and refined by ModRefiner server. Refined structure was validated by SAVES, RAMPAGE, QMEAN, Verify3D and ERRAT server. Finally the model was visualized in PyMol and the active binding site and ligands were predicted using RaptorX Binding tool and 3D ligandSite server.

The predicted HEV X domain model was found to be more stable (S^2> 0.8), ordered and
compact. HEV X-domain represented high crystallization probability (score 1), two disulfide bond linkages \((Cys16-Cys145\) and \(Cys34-Cys91\)), higher percentage of alpha helical (34%) and extended strand providing thermodynamically stable nature. RaptorX predicted 3D structure and identified HEV X-domain as putative phosphatase (resemblance with 1spvA). Refined structure with 98.1% residues in favoured region (Ramachandran plot), verified with Verify3D (85.44% residues 3D/1D score ≥ 0.2) server was acceptable predicted HEV X-domain. Multiplicity of 51 represented a deep binding pocket with 19 binding residues for three different ligands viz. MES, APR and AR6.

Physiochemical properties suggested that the model is stable and in ordered form and has higher probability for crystallization which could be tried experimentally. Three ligands are predicted to bind with active binding site of HEV X-domain might prove to be a potential inhibitor to limit the HEV pathogenesis.

We communicated a Letter to Editor reporting Chronic HEV genotype-1 case in Journal of Hepatology (Deceased patient X). Although this was just the prediction and needs to be validated in the wet lab. An abstract of this work was submitted for International Conference INTERVIROCON to be held on 12th–14th November 2018 and full length article is in process for communicating in International Journal of Biological Macromolecules.

The main source of inspiration for this work is my Guide Prof. R K Ratho, Dr Amin Sagar and EMBL-EBI mentors. I was fortunate to meet and talk with great scientist Prof. Dame Janet Thornton during UK training and her amazing words that “Everything, even Brain is multidimensional and we should think 3-D dimensional to understand the protein structures” continuously inspiring me to unlock the secrets behind the structures of viral proteins.
Moss: Little Things Which Can Fill the Huge Glitch in Agriculture

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The problem of drought, famine and farmer suicides:

It’s a known fact that India is a largely agricultural country with a wide variety of crops grown not only for domestic use but also for export. It is also a fact that farming in India is mostly unorganized and dependent on natural weather cycles rather than usage of modern technologies. Farmers depend heavily on the rain gods and unpredictable weather cycles often cause largescale crop failures due to drought leading to bouts of famine. Add to this, other stress factors such as pests and crop diseases puts tremendous pressure on farmers and their families. In the recent past, this has also led to extreme measures among farmers including suicides and the situation does not seem to be improving.

India is the second largest producer of cereal grains in the world with a recorded production of 259.32 million tons in 2011-12 and it is roughly hypothesized that consumption will increase to 377 million tons by 2050. Besides feeding its own citizens, India is an exporter of cereals for many countries such as Iran, Saudi Arabia, Bangladesh, etc. The gap in supply and demand is likely to affect the economy of the country as well as the living condition of its citizens with an added speculation of a fall in agricultural production due to drought and pests. There is a dire need to identify new traits for developing resistant varieties and introduction of these for commercialization.

Agriculture in India is flawed as it involves the cultivation of varieties of wheat, rice and pulses (cereal crops) which are mostly susceptible to the adverse biotic and abiotic conditions of

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the environment while the tolerant varieties of crops remain neglected in the wild. Genetically modified crops (GMOs), with integrated traits of resistance, do not find government approval for commercial cultivation except for field trials, due to health concerns of citizens. After Bt Cotton there has not been a release of any new GM crop, all of which remain in the developmental stages. GMO versions of mustard named as Dhara Mustard Hybrid 11 (DMH-11) is the next enlisted to be released and has found clearance from GEAC (Genetic Engineering Approval Committee). In comparison to this data, there are already 10 GMO crops cultivated in U.S. including apple, canola, potato, soybean, sugarbeet, alfalfa, papaya, corn, cotton and squash. Standard American Diet (SDA) includes a high percentage of potato and corn which they seem to have already secured against stress conditions. India should not fall behind specially in terms of agriculture.

**Moss to the rescue – A probable solution:**

There are approximately 126 research institutes involved in the field of Biological and Agricultural Sciences (DST, Govt. of India) in India with numerous laboratories continuously identifying genes which confer tolerance traits.

Our laboratory at the University of Calcutta has been involved with the identification and analysis of dehydrins (drought responsive proteins) for its potential in drought tolerance. We chose *Physcomitrella patens*, a moss, for our molecular analysis as it would mark the evolutionary pattern from lower to higher group of organisms for the protein group under study. *Physcomitrella* is a well-known dehydration tolerant plant and its analysis has been restricted to only a small group of researchers in crop improvement. Dehydrins have been widely analyzed since its first report in
1996 (Close et al.), and it is fairly distributed from moss to angiosperms. Yet, its precise mechanism of action in drought tolerance remains to be unravelled.

**The research:**

With the research in our lab from (2012-2018), we were able to simulate the conditions of growth for *Physcomitrella* in a growth chamber and propagate it by tissue culture. We tried to derive a comparative analysis of three dehydrins (DHNs) reported from the moss namely DHNA, DHN B and DHN C. DHN A has been reported to provide enhanced tolerance to osmotic stress. All the dehydrins were cloned, sequenced and their proteins confirmed on SDS-PAGE protein gel. The proteins isolated were characterized for enzyme protection. Kinetic analysis with lactate dehydrogenase showed the effectiveness of DHN A in retaining enzyme function under extremes of temperature conditions.

In order to define its mechanism of action, post translational modifications of the proteins were studied in detail. DHN A was found to undergo phosphorylation and a shift in protein gel assay due to change in molecular weight. The phosphorylation event was confirmed with phospho-specific staining with ProQ Diamond. This phosphorylation may be an important trigger for its enhanced activity under stress.

Besides, it is well reported that dehydrins have three conserved segments K, S and Y. With our analysis, we could identify another highly conserved segment in DHN A which was present in conjunction with Y segment in definite repeats throughout the protein. Biochemical analysis of the segments showed that they could form amphipathic alpha helices. Several deletion mutants of the protein with different permutations and combinations were generated to identify the function of each segment and the reason why so many repeats of a segment were present. Further, amino acids of the repeats were shuffled to make a mutant protein with the same amino acid composition but a shuffled position to break the structure of the protein. Such, in depth molecular analysis coupled with biophysical analysis was undertaken to provide an insight into the exact mechanism of its action of the protein so that it could be extracted for its use in bioengineering and manipulation of crop plants in a similar way.

**Killing two problems with one Dehydrin an unexpected positive side effect:**

The drought tolerant property of the DHN A was assessed by overexpression of the protein in tobacco. Identifying a protein from moss and its over-expression and stress tolerance in dicot showed its potential for field trials in crop plants in the future. Tobacco transgenics of the deletion mutants were also generated to define their role in stress. It was not in our agenda but as a byproduct of our experiments, we also identified DHN C to have antibacterial properties. It was effective against *Bacillus subtilis*, a common laboratory bacterial strain and *Rhodococcus fascians*, another bacterial strain. Spectrophotometric and SEM analysis revealed that the protein may be able to cause plasmolysis of the bacterial cells and target its membrane for disruption. This is the first
report of an antibacterial dehydrin from moss and only one or two dehydrins have been reported earlier from rice and wheat to have antibacterial properties.

**Publications so far:**

A part of these findings has been reported in Springer Journal *Planta* and continued experiments have been ongoing for further molecular studies.

**Conclusion:**

A comprehensive knowledge of the action of dehydrins would be beneficial in making it to the top of the list as a putative gene for biotechnological manipulation of crop plants. Efforts to develop tailored protein with different segments of the dehydrin and obtain a super-protein with all the resistance powers in a single molecule may be successful. This, when introduced into crop plants, would give rise to crops with superpowers of stress resilience.

Answers to sustenance of mankind can only be found when we travel the untrodden depths of wilderness and scientific achievements made by unearthing the solutions that are embedded in the expanse of nature.
Ever thought of lighting a bulb without paying electricity bill!!! Though it seems to be a dream, it can come true if we utilize renewable sources of energy that nature has blessed us with. With the increasing demand for energy and declining non-renewable sources, the cost of energy production is increasing day by day. Moreover, the carbon emission due to combustion of fossil fuels contribute to global warming which results in the increase of earth’s temperature. This calls for the need for alternative energy resources and sun being one of the ultimate sources of energy on earth, it provides a ray of hope. The solar energy is seen as one of the most important sources for clean and renewable energy to avoid the energy crisis. Since the sunlight falling on earth is a blessing to us and do not require any payment, solar energy requires only initial installation cost.

The key element in obtaining energy from the sun is a solar cell. Solar cells convert energy obtained from the sun into electrical energy. The performance of solar cells is measured by using efficiency as one of the parameters. The efficiency of a solar cell is defined as the ratio of electrical power to the optical power, generated by light falling on it. The favourable properties of silicon, like robustness, reliability and ease of availability among others, makes it a dominating material in the market of solar cells. Conventional silicon solar cells are based on junction formation technology that requires high-temperature processing. The high-temperature processing increases the cost of the solar cell, called “thermal budget”, and also reduces its efficiency by degrading the silicon material. This depreciates the advantage of using solar energy by increasing the initial installation cost.

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cost. Therefore, a low-cost solution for the development of solar cells is the need of the hour.

Our research focuses on the development of solar cells that do not require high thermal budget and result in improved efficiency. We started looking for an alternative design for solar cells that could solve our purpose and help us in contributing to society. Junction-less solar cells that utilize thin layers for separating charge carriers and, hence, produce electric energy seemed to be a good substitute. Now the next challenge was to find the materials that can act as charge separating layers with silicon in these Carrier Selective Contact (CSC) solar cells. After exploring various options, we found titanium dioxide combined with molybdenum oxide or nickel oxide layers, popularly known as Transition Metal Oxides (TMOs), on either side of silicon as possible suitable options. The validation of the idea was required. In order to understand the performance of CSC solar cells, we first chose to model these cells using software to minimize the wastage of hardware resources. The modelling of the working of CSC solar cells showed that under ideal conditions, these cells have the potential to reach efficiency higher than the reported efficiencies till now in silicon solar cells.

The literature helped us to understand that the practical realization of CSC solar cells with TMO layers over silicon result in highly non-ideal surface and, hence, poor performance. In order to overcome the issue of the non-ideal surface of silicon and TMO, we incorporated a passivation layer using amorphous silicon (a-Si) to achieve better surface quality. We went ahead to understand the surface quality using a-Si by practically depositing the TMO layers and incorporating a-Si layer in between silicon and TMO surface. When we did the minority carrier lifetime measurement to understand the quality of the surface, we found that surface quality had improved more than 30 times by inserting the a-Si layer. This verified that we are on the right path and increased our curiosity level even more to see these solar cells working in real life.

But still, the satisfaction level was missing because there were still absorption losses in the thin layers that were obstructing the conversion of optical energy to electrical energy and, hence, hampering the performance of CSC solar cell. To eliminate these absorption losses, we came up with the idea to use these thin layers at the rear of the solar cells. This type of solar cell is proposed to absorb most of the light and convert it into electrical energy. Since this was a novel idea, we termed this type of design as Carrier Selective Back Contact (CSBC) solar cells. Modelling of CSBC solar cells showed that they can achieve efficiency close to maximum achievable efficiency in silicon solar cells.

The promising results for CSC and CSBC solar cells boosted our confidence and we went ahead to understand the physics underlying the working of CSC and CSBC solar cells. Best way to explain the working of these solar cells is through the development of mathematical equations. Hence, we first developed mathematical equations for these solar cells and then decided the parameters to be obtained practically.

**A screenshot of a solar cell**

Now the next challenge started, getting each layer optimized to get the desired results. We started
with the development of TMO layers and adjusted the deposition conditions to achieve favourable properties for the transport of charge carriers and, hence, improve efficiency. The development of the a-Si layer for surface passivation was successfully integrated into the device design. After a combination of these layers was successfully implemented, we conducted contacts to flow the electric current into the external circuit. In other words, the generated charge should be collected across the load for its utilization.

We are currently working on the development of indium tin oxide (ITO) and silver stack above molybdenum oxide for extraction of charge. This way we would be able to realize the CSC solar cells in the real world. For the realization of CSBC solar cells, we need further optimizations at the rear contacts for better efficiency. Through this work, we hope to contribute to the ambitious project of the Indian government titled Jawaharlal Nehru National Solar Mission (JNNSM) that aims to achieve a target of 100 GW solar energy production in India up to 2022.

The research team constitutes Astha Tyagi (IIT Bombay), Prof. Kunal Ghosh (IIT Mandi), Prof. Anil Kottantharayil (IIT Bombay), and Prof. Saurabh Lodha (IIT Bombay). We have published a research paper titled “Performance Evaluation of Passivated Silicon Carrier Selective Contact Solar Cell”, in IEEE Transactions on Electron Devices (IEEE TED) in January 2018 issue (Vol 65, 1) and the work has also been presented in IEEE Photovoltaic Specialists Conference (IEEE PVSC) 2017 under title “Carrier Selective Back Contact (CSBC) Solar Cell using Transition Metal Oxides”. The novel structure of CSBC has also been filed for Indian patent titled “Solar cell and structure thereof” under application number 201721004570 on February 2018.
People say that there are at least 7 people on earth who are identical to each other. But what if two of them are invited to the same party and decide to fool their spouses. The partners get confused as they look the same, wear the same dress and have the same mannerisms. A difficult situation! Isn’t it? Now, if the partners are smart enough, they can check for some minute features which differentiate the two. If that also doesn’t work, the only solution is to do fingerprint or DNA test. Just like the quantum numbers of electrons in an atom, every person in this world has a unique fingerprint and DNA.

Now think about such a situation in the particle physics world. Just like these two identical people being invited to the same party, two fundamentally different particles falling on the same detector can produce the same kind of signals. For instance, consider an electron and a proton. An electron gives rise to an ‘electromagnetic shower’ in the detector whereas a proton, which belongs to the group of fundamental particles called ‘hadron’ gives rise to a ‘hadronic shower’. A shower is a cascade of secondary particles produced as a result of the interaction of a primary particle or incident particle with matter. In our case, both the showers look almost the same in their recorded digitised signal. Now, the experimenter here has to play the difficult role of the partner to identify the particles in spite of their identical nature. The first task is to find the fingerprint or DNA like features which distinguish one from the other and then use that feature to identify the source of the shower. A lot rests on the shoulders of the spouse as for only if she/he can correctly identify the

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sources and separate them can the data be used without doubt for further physics analysis. This is what I am trying to address in my PhD thesis. My work is on separating the showers produced by an electron and a hadron in a particle detector and use that information to improve the capability of detector and further physics studies using it. We are addressing the problem such that it can be applied to any detector with similar signals.

If we just delve a bit beneath the surface, we find that our experimenter bears the staggering task of separating out the showers, which unlike human, have no such unique fingerprints. All one has are digitised hits of the position and the time information of the passage of thousands of particles through the detector at a time for him to sort through. Well, fortunately all is not lost, and to her aide comes the application of advancement in technology in pure science. Machine learning algorithms, which have changed the face of the modern world, from self-driving cars to making financial decisions for big businesses to enabling the cameras to take better selfies, comes to her rescue. Machine learning, as the word implies, involves teaching a machine to perform some tasks from its ‘experience’ of previous exposures to similar problems. In our case, we teach the algorithm, how these two showers will behave in a detector using simulated results. Once they are trained with it, they can identify the source of the shower from any noisy set of data with considerable certainty. Just like once we know a person very well, we can identify him from any crowded place, these algorithms, especially the neural networks used in them, are inspired from how the human brain works.

Towards this endeavour, we simulate the detector using a software package GEANT4. The patterns of the electromagnetic and hadronic shower in the detector are obtained separately by making them fall on the detector in the simulation. Also, the hit information corresponding to each case is obtained. But, this raw information cannot be fed into the machine learning algorithms as such. As we have stated earlier, we need to get that DNA-like character or feature which can distinguish between the two showers under consideration. We extract these features after a number of trials and errors and feed them into the machine learning algorithm. The task of the algorithm now is to understand the feature corresponding to each class well and tune it for maximum efficiency. For us, efficiency is the ability to identify an electron signal correctly as an electron. Once the algorithm is ready after the training, the simulated data corresponding to realistic events in the detector where all these interactions happen at the same time will be passed through the algorithm. By then, the algorithm becomes able to separate the events based on the training it had received already, which in effect, now makes the detector even capable of giving information regarding electrons and hadrons.

But, we have told only a part of the story. Our original motive is not just to separate out the electron shower and hadron shower but to obtain the information regarding a mysterious and omnipresent particle called the neutrinos. It is natural to ask how neutrinos came into picture here all of a sudden? Well, for that we need to go back to our past. Trillions and trillions of neutrinos pass through human body every second without us having a clue to such a thing. It’s because they are very weakly interacting with matter which also makes it extremely difficult to detect them. But, it is already known that when they interact, their interaction can be classified into two types...
current interactions and neutral current interactions. In charged current interaction, these neutrinos produce electrons and hadrons at the output. While in neutral current interactions, they produce only hadrons. Detecting the products is the only way to predict about these interactions. Here, in our case, detecting electrons and hadrons will give us the information we were seeking, enabling us to address some open problems related to a particular fundamental particle the electron neutrinos and as such deepen our understanding of particle physics and also the universe as a whole. And that is why we are eager to address the difficult task of separating out the shower or cascade produced by electrons and hadrons in the detector.

I agree, it may seem a lot to wrap one’s head around but that’s what also makes it exciting. I hope I was able to give you a glimpse into it.

Physics is a discipline that comes with philosophy. Every new discovery leading to the enhancement of human knowledge will answer some fundamental existential questions like how did the universe come into existence? What happened in the initial stages? And how did everything evolve? Ultimately, we, the humans, seek these answers and, with time, also get better at finding them. Sounds familiar?
Naturally Inspired: Understanding How Pomegranate Prevents Pancreatic Disorders

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Theme:

This article talks about the potential of pomegranate in reducing the risk and symptoms of pancreatic disorders. A variety of stress points present in our environment and lifestyle inflict damage to the pancreas, an organ that plays a central role in digestion and maintenance of blood sugar levels. In many patients, by the time this damage is diagnosed, the disease is too far progressed. Our study shows that incorporation of pomegranate supplement in our diet can protect from such consequences and decrease the risk and complications of diseases like diabetes and pancreatitis.

About problems and remedies:

While growing up, my grandmother had a “nuskha” for every disease. She would give us a home brewed “kadha” when we were down with a cold, a ginger-honey paste was made for cough, and bitter gourd juice was made when my father was diagnosed with diabetes mellitus. When I started my journey of scientific inquiry, these little tricks and concoctions stayed with me. As I read about the complexity of diseases, I was surprised how these simple age-old remedies still work given our current lifestyle. Today, we are rediscovering traditional medicine. If you take a walk down the aisle of any supermarket you would see a plethora of natural extracts being sold for different purposes. The question is whether these are effective enough, whether Nature really has the answers to our current-day problems.

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We are exposing our bodies to a variety of stresses every day. Excessive sugar intake, reduced physical exercise, increased consumption of processed and preserved food, consumption of adulterated food, alcohol abuse, cigarette smoking and many more such practices have become an integral part of our day-to-day life. All these factors cause oxidative stress and inflammation in our system. One of the direst outcome is pancreatic damage and eventually pancreatitis which is characterized by abdominal pain, indigestion and diabetes. Our group has been striving to understand how oxidative stress and inflammation orchestrate the progression of pancreatic disorders, and whether the consumption of a pomegranate extract can help reduce this damage.

The reason for choosing pomegranate supplementation is that pomegranate is packed with a booster of antioxidants and according to a study conducted by Seeram et al. in 2008, pomegranate juice has up to 20% more antioxidant potential than commonly consumed beverages like green tea, grape juice, etc.

**Piecing out the puzzle:**

To achieve our objectives, we created animal disease models by treating mice with a bacterial endotoxin that causes inflammation. This model allowed us to study the natural physiology of the disease. We also had a separate group of animals who were being given pomegranate extract supplement and were exposed to the inflammation trigger.

We studied various parameters to assess if there was damage inflicted to the pancreas. Pancreas is an organ that manufactures and secretes digestive enzymes which help to breakdown food into simpler components. It also secretes insulin, a key hormone regulating the glucose balance in our bodies. When pancreatitis sets it in, the digestive juices made by the pancreas starts to digest the organ itself. The amount of the digestive enzymes like amylase increase in peripheral blood.
Also, there is a decrease in insulin production which leads to increased blood sugar. We observed that in diseased mice the levels of amylase were high and insulin production was impaired. Upon pomegranate supplementation, the blood insulin goes up and amylase comes back to near-normal levels. We also assayed the levels of common enzymes that are routinely used as diagnostic markers for toxicity, like alkaline phosphatase, lactate dehydrogenase, etc. We saw that diseased individuals had higher than normal levels of these enzymes in blood indicating breakdown of body’s metabolic machinery. Pomegranate intake was able to reduce the expression of these enzymes indicating improved metabolic health.

We now needed to understand the role of oxidative stress in all of this because we were proposing the use of pomegranate based on its anti-oxidant potency. Oxidative stress, basically, is an imbalance between the generation of reactive oxygen species and a biological system’s capacity to get rid of these reactive species and repair the damage they cause. The process of generation of these reactive oxygen species, or ROS as we call them is inevitable to our life process. When we breathe, we take in oxygen which is used to burn the food that we eat in order to generate energy. In addition when we are infected, our immune system uses oxidative burst, much like a mini bomb going off, in order to kill the infecting agent. Both these processes, generate ROS. A biological system is well-equipped with detoxification machinery which helps get rid of this ROS generated as a result of basic metabolic activities. However, when we are constantly faced with excessive stressors mentioned earlier, our body is no longer able to clear ROS. This excessive ROS causes oxidative stress and left unchecked results in organ damage.

In our study we analyzed key molecules which form the body’s defense line-up against oxidative stress. We saw that in the diseased animals, there was extensive ROS in the pancreatic tissues. This was
coupled with a failure of the defense enzymes like Superoxide Dismutase (SOD), Catalase (CAT), etc.

In subjects that had received pomegranate supplementation the ROS generation was substantially less and the levels of defense enzymes were much higher. This led to the understanding that the components of the pomegranate fruit act like a sponge in soaking up excessive ROS in a system, thereby helping our body fight against the damages that it would otherwise cause.

We also looked at a process called apoptosis, which results in the death of cells in a tissue. This is a process by which unhealthy cells commit suicide in order to maintain physiological homeostasis. According to our data, oxidative stress increases cellular death and, therefore, causes organ damage. Incorporation of pomegranate extract in the diet mitigates this stress and prevents cells from dying out, thus offering relief from pancreatic damage.

Taken together our data indicates that inflammation and oxidative stress affects our metabolism adversely. These induce death of the pancreatic cells and causes pancreatic damage. When our body is unable to fight back the stress, the functions of the pancreas start getting affected. This results in abnormal secretion of digestive enzymes and symptoms of diabetes. Dietary supplementation of pomegranate offers a defense back-up to our intrinsic machinery.

Pomegranate is rich in anti-oxidants, compounds that soak up the extra ROS generated during the inflammatory process. This boosts our metabolism and helps prevent pancreatic disorders.

Diseases like chronic pancreatitis don’t happen overnight. Recurrent stressors which are part of our lifestyle keep inflicting regular damage and eventually result in disease symptoms of pancreatitis and other pancreatic diseases. By the time an individual starts feeling the effects and displaying symptoms of pancreatic damage, the disease is already progressed and the damage done. A report published in 1997 stated that there were up to 200 cases per 100000 population of
chronic pancreatitis in South India alone and the epidemiological trend had shown an upward slope. The incidence of diabetes needs no mention. Our study offers a simple and scientifically tested remedy to this problem. The incorporation of pomegranate supplement in our diet will help prevent such grave consequences.

Pancreatitis and other diseases stemming from pancreatic break-down are poorly understood. The clinical management of such diseases remain evasive and difficult. There is imminent need to further understand the pathology and epidemiology of such diseases. The study that I am pursuing deals with understanding processes that involve and affect our life and well-being. Even the first antibiotic, Penicillin, was a product inspired from natural sources. Grave diseases like Cancer start off as a localized inflammatory process. The simple practice of incorporating pomegranate in our routine diet will help our body fight inflammation and oxidative stress, reducing our disease burden.
Some Tensions are Good for Life

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This science article is based on my first author paper titled ‘Mechanochemical feedback control of dynamin independent endocytosis modulates membrane tension in adherent cells’ accepted in ‘Nature Communications’ journal.

Like every animal has its characteristic size and shape, each cell type in our body has a size and shape. Neuron (nerve cell) is very different from muscle cells that are dramatically different from the cells in the bone. All these cells look different, perform diverse activities, share things with each other and multiply, albeit somehow maintaining their individual size and form. The plasma membrane of a cell defines the boundary of a cell and thus its size. However, it is not a static wall. The membrane is under constant flux every moment because a cell talks to its surroundings via this membrane. Cells uptake enutrients and other material from surrounding via endocytosis by bending the membrane inward and forming a vesicle containing these (Endon- within, kytos- cell: uptake of material by a cell from the environment by invagination of its plasma membrane). Exocytosis, on the other hand, helps add material to the surface through vesicles. However, taking material in each time also removes a bit of plasma membrane from surface. Imagine each time you enter a room, you take in the door and a portion of the wall with you. If membrane is not carefully put back each time through exocytosis, the cell would shrink or enlarge. To make it even more

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complex, cell makes multiple doors every moment to take in or remove stuff from the cell. So how does the cell maintain the endo-exocytic flux to help it maintain a size?

“Don't underestimate The Force”
- Darth Vader. (Star Wars)

We find that like ‘Jedis’, cells also maintain the balance in their lives and processes by utilizing the Force. Force, in this cellular context is called the membrane tension. I found that endo-exocytic processes are intimately connected to membrane tension. Though there are myriad of endocytic pathways operating in parallel at a micron scale, only one of them is able to quickly sense and respond to changes in force i.e. membrane tension. This pathway is called CLIC/GEEC pathway. Increasing membrane tension decreases this endocytic pathway while decreasing membrane tension increases the endocytosis. I find that the CLIC/GEEC pathway can sense and respond to forces. This pathway, if you will, is the ‘Yoda’ among the many endocytic mechanisms.

How did we change tension of a cell? For this we collaborated with physicists in Barcelona, Spain who were interested in understanding how forces influence life. A cell stretcher was made using a silicon based membrane much similar to a contact lens but with a diameter of 6 inches. Cells are attached to the membrane and stretching them causes cells to stretch and thus change the membrane tension. This silicon membrane is divided into two concentric circles and cells are added to the inner circle. To stretch it, we apply precisely calibrated vacuum to the outer concentric circle, sucking the membrane in and thus causing the membrane in the inner circle to stretch. To look at endocytosis, we add fluorescent material from outside (that is not permeable through plasma membrane) and ask how much the cell takes in for a given amount of time. We image the fluorescent material in a cell to study endocytosis with changes in tension of a cell.

We then used a special microscope called ‘optical tweezer’ which as the name suggest acts as a light based tweezer. Using a focused laser, you can hold objects (in our case, a micron size transparent bead) with high precision. We used this tweezer to carry out a tug-of-war between the cell membrane and the bead. We held a bead in this tweezer and pull a thin membrane from the cell. If cell applies higher force, it will pull the bead closer to it while if the force is less, the bead would move less. Using this we asked what happens to the forces applied by the membrane tethers (called here as ‘tether forces’). We use this tether forces as proxy for membrane tension. We find that this CLIC/GEEC pathway is essential for the maintenance of the membrane tension. Removal of plasma membrane on increasing the pathway increases the membrane tension and inhibiting the pathway, decreases the tension. Thus, addition and removal of membrane directly influences the tension of membrane.

So, every time a door and wall is removed when you enter a room (endocytosis) there is a change in the physical property of the rest of the wall (membrane tension) that indicates how much is removed. This provides a clever way for the cell to maintain homeostasis. So, each time membrane is removed by endocytosis, membrane tension increases and if a cell could sense and
respond to this change in tension by adding membrane, it could maintain the homeostasis of membrane turnover.

So how would a cell sense the change in force and control an endocytic pathway? In other words, how does the cell convert physical information to a bio-chemical one to control a biological process? By using mutant cell lines, we found that a molecule called vinculin is responsible for this. Vinculin remains closed under low forces while on higher forces, it changes its conformation and opens up like a hair pin that is being pried open under force. Vinculin in its open state then inhibits a key upstream regulator of CLIC/GEEC pathway, thereby regulating endocytosis in response to the membrane tension.

Thus, like a perfect air conditioner maintaining the room temperature by sensing increase or decrease in temperature and responding to it, each cell senses the force and regulates the CLIC/GEEC pathway to maintain membrane homeostasis. If the force goes higher, the CLIC/GEEC pathway is shut down helping the membrane relax while if tension goes lower, endocytosis increases and extra membrane is taken in. Cell does this by employing vinculin that can open up and close in response to tension. Thus each and every moment the cell is constantly measuring and responding to tension through this pathway to maintain membrane homeostasis without which a cell, and thus life, won't exist. CLIC/GEEC endocytosis is also hijacked by viruses to enter cells. This pathway is also important for cell migration which is employed by cancer cells undergoing metastasis to spread to different organs. This study shows the importance of understanding forces in regulating these processes and thus would be important for fighting them effectively. For these cells, Do or Do Not, there is no try!
Improving the Immune Health of the Muga Silkworm: In A Natural Way
The Probiotic Way

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Muga silk fabric has been an indispensable part of Assamese culture from time immemorial and is considered as the guardian of Assamese ethnic weaver's pride. Muga silk has witnessed the affection of 600-year sovereign Ahom kingdom. Due to its unique golden yellow luster, durability and toughness (toughest among all commercial silks), Muga silk has gained popularity throughout the world. This variety of silk moth is endemic to the Brahmaputra valley of Assam and the adjoining hilly area of Northeast India and was assigned geographical indication (GI) tag in 2007.

Muga silkworm (Antheraea assamensis) broods 5-6 times a year. It feeds on a range of host plants. Among the food plants, Som and Solao (as called in Assamese; Perseabomyxina Kost. and Litseamonopetala Roxb. as per scientific naming) are the primary host plants. When these are unavailable, muga silkworm can also feed on secondary food plants Dighloti (Litseasalicifolia Roxb.) and Mejankori (Litseacubaba Lour.). The avenue is highly employment oriented and requires low capital-input. One of the striking features of Muga silkworm is its outdoor mode of rearing unlike other silk moth varieties (namely, Mulberry and Eri). This is also the reason for it being highly disease prone. Shifts in the agro-climatic conditions and pollution easily affect muga cultivation. As an intrinsic feature, mugasilkworm is less resistant to infection (linked to its genetic make-up and difference in physiology). Even after observing the standard package and practices, muga silk moths easily get diseased in the field.

Much of the yield loss is caused by bacterial and viral infection (more specifically called ‘Flacherie’ and ‘Viriosis’, respectively). The severity of these diseases is such that, in a group of

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100 moths, under the typical condition, 70 moths get infected by Flacherie (called the ‘percentage disease prevalence’ a measure of ‘how-bad’ is the disease). There are also other comparatively less severe forms of Muga silk disease, namely, ‘Grasserie’, ‘Muscardine’. Each of these diseases is not caused by a specific microorganism, but by a combination of them. With gradual changes in agricultural practices (use of pesticides, felling of forest areas), shifting of agro-climatic conditions, increase in ambient mean temperature, there has been increasing cases of crop failures. Such a situation is very discouraging for the farmers with limited means.

It has long been suggested that healthy and clean leaf diet is a sustainable way to protect the silk moths. However, in out-door rearing sericulture practices, such condition cannot be maintained. From the studies into silkworm gut, it has been observed that the intestinal linings of silkworm support a diverse group of micro-flora. These bacteria perform a range of activities, namely, food digestion, assistance to pheromone production, the supply of essential nutrients, prevention of pathogen colonization and detoxification of harmful chemicals. The necessity of healthy gut-flora (the good bacteria) has already been established in mammals. Thus we hypothesized that maintaining a healthy gut might help increase silk productivity.

With this in mind, I started my research on studying the population of bacteria in healthy silkworms. The idea was to assess bacterial population present in the gut of healthy Muga silkworms. After studying the activity of the beneficial bacteria, they were to mix with suitable carriersolutions to be sprayed onto host plants. These bacteria, when eaten by the worms while feeding on the host-plant, would harbour in the gut of silk moths, thus will protect them from bad-bacteria.

Healthy silkworms were collected from different areas of Muga growing regions (also neighbouring states of Assam). The idea was to get a wider view of the bacteria harbouring in the gut of healthy Mugasilkworm. Upon vigorous screening, we observed that bacterial population belonging to a particular species (Bacillus species) were common in all the healthy silkworm gut. We then studied each of the bacteria in detail to havemore insight into their contribution towards the well-being of the healthy silk moth. It was found that the bacteria produced several enzymes that are useful for digesting host plant-leaf the worms feed upon (enzymes Cellulase, Lipase Pectinase). The good-bacteria that we isolated also prevented some bad-bacteria (pathogens of Mugasilkworm) from growing (called antibiosis). This property was due to secretion of some chemicals (antibiotics) that kill the disease-causing bacteria. Thus, we alsounderstood that some bacteria present in the gut of healthy silk moth help in digesting different components of food (carbohydrate, lipid, etc.) while some prevent harmful bacteria from getting access to the gut-linings.

The next goal of our study was to make use of these good-bacteria to enhance Muga silk production. For this, the preliminary requirement was to make sure the beneficial bacteria did not inhibit one another (antibiosis). Only after ascertaining compatibility among the good-bacteria, they were incorporated in the formulation. We made liquid formulations of these bacteria with certain additives and sprayed onto the host plants periodically. The idea was to observe different vital parameters (Larvae weight, cocoon weight, cell weight, Silk ratio percentage and effective rate of rearing) of the silkworms fed on normal leaf diet and those reared on leaf sprayed with good-
bacteria formulation (pro-biotic formulation). Our study signifies that there was an enhancement in the vital parameters in silkworms reared on probiotic containing diet.

The concept of probiotic incorporation in the diet of silkworm has long been studied; yet, these have not been recommended for standard package and practices for the farmers. For Muga silkworm, application of microbial consortia for enhancing productivity has not yet been reported. We have worked out some of the possible combinations of good-bacterial consortia that can help Muga silkworm to maintain a healthy gut lining. This will help silkworm survive the quantum of pathogenic attacks in the field. Our work for enhancing Muga productivity (using combination of bacteria, superior carrier agent that enhance the formulation shelf-life) will encourage more farmers to adopt sericulture and help sericulturists of the region to meet the global demand and reach the world community.
Kidney Stone Disease, also called renal calculi, is a common, painful disease which results from the combination of numerous risk factors such as age, gender, lifestyle and family history. The prevalence of kidney stones varies greatly between geographic locations. In India, 12% of the population are affected with this disease with incidences of patients generally low in the south while high in the northwest regions. The scary thing about kidney stone disease is that even after availing proper treatment, there is 35 – 50% chance for recurrence of stone. Of the various types of stones, calcium oxalate (CaOx) stones occur in the major population of patients. Other types of stones include uric acid, cystine and struvite stones. Since, CaOx stones account for majority of the population, Prof. G. S. Selvam dedicated his entire research career to find possible therapeutic strategies. Knowing that CaOx stones occur at such high frequencies, one may wonder if he/she may develop a stone sooner or later in life. The major risk factor for development of CaOx stone is the increased levels of urinary oxalate excretion. So when does one excrete more oxalate? The answer is straightforward. One who consumes more amount of oxalate will excrete more oxalate. This leads to another question. Which food commodity exhibits high content of oxalate? Foods such as dark chocolates, beverages, nuts, beetroot and green leafy vegetables contain substantially higher levels of oxalate. Besides consumption of such food group, increased levels of urinary oxalate can result due to genetic factors too. Fortunately, the incidences of genetically influenced kidney

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stone formation are sparse. Hence, I too have started my research career wanting to explore various aspects of food influenced CaOx stone formation.

Although the consumption of oxalate rich food caused a significant increase in urinary oxalate excretion, the underlining factor for CaOx stone formation is uncertain. Hence, to understand the origination and development of the disease, the scientific community requires an experimental model. Animals such as mice, rats, rabbits, swine and monkeys are routinely used to study various diseases. Currently, numerous animal models are available to study CaOx stone disease. Unfortunately, stone development in these prevailing experimental models does not occur as a result of ingestion of natural food commodities. Therefore, studying various aspects of food influenced by CaOx stone formation using existing models may not help us complete the puzzle. In an effort to tackle this simple but important problem, I sampled the level of oxalate in various food commodities. On estimating, I identified that spinach, a green leafy vegetable commonly consumed by all exhibited the highest oxalate content. Therefore, I extracted the oxalate present in this vegetable and fed it to laboratory rats in addition to their regular food. Besides this group of rats, I fed another set of rats with the similar amount of chemically synthesized oxalate (a previously established model for inducing CaOx stones). At the end of the experimental period, the animals were euthanized and kidneys were assessed for stones and damage. Interestingly, both rat groups developed CaOx stones but rats that were fed with the commercially synthesized oxalate exhibited severe kidney damage with high number of stones. The increased number of stones can be attributed to the fact that injured tissue favoured stone formation. On the other hand, the oxalate from the spinach extract invoked mild but significant responses. The abrasive nature of the synthetic oxalate was missing in the spinach extract; suggestive of oxalate from natural sources could induce stones with minimal kidney injury. The findings were published in a peer-reviewed international journal (ToxicolMech Methods. 2018 Mar; 28(3):195-204).

Now that the mode for CaOx stone formation was established, another question came to my mind. What is the mechanism for stone formation? The question is valid since the sequence of events that leads to the formation of kidney stone disease remains unclear. Every scientist had proposed a pathway to illustrate stone formation. However, the one thing that was agreeable among all the research groups was the fact that interaction of renal cells with oxalate ions act as precursor for renal epithelial cell injury, crystallization, crystal retention and development of stone. This unpleasant contact between kidney cells and oxalate ions results in free radical generation. Free radicals are dangerous molecules that inflict injury to various cells and tissues. This aspect was extensively studied for decades. Hence, the biological question raised here was, “Besides free radical generation, are there any other factors responsible for CaOx stone formation”.

We have all learnt in school that endoplasmic reticulum (ER) is a cell organelle that plays a significant role in protein synthesis, folding, assembly, transportation and maintaining calcium ion homeostasis. When the cell is under threat due to toxins, or viral and bacterial particle invasion, or even aging this organelle is pushed to work harder. Since the organelle is unable to achieve the target set by the cell, the organelle and the cell harbouring this organelle are ‘under stress’. Many a time this stress can cause the cell to die. If the level of stress is below the threshold limit, the ER
invokes an adaptive response and thereby the cell survives. Therefore, I wanted to observe how the ER responds to oxalate toxicity.

Computer stimulations were performed to see if the protein responsible for adaptive response interacted with either oxalate or CaOx crystals. The answer was yes. Oxalate ions and CaOx crystals were strangely attracted to this protein, GRP78. This illicit attraction could spell disaster for the cell to survive. The binding of oxalate ions and CaOx crystals to this protein could hinder or alter its functional ability. Since preliminary results were encouraging, the same was studied using kidney cell lines and rat model. The results obtained implied that oxalate toxicity did incite ‘stress’ on ER (J PhysiolBiochem. 2017 Nov;73(4):561-573). Although the stress incurred on the ER was significant, the implications of this stress on cell death was minimal. This exercise taught me that in case of oxalate toxicity, free radical generation controlled the life and death of the cell and ER stress played second fiddle. However, the identification of ER stress as a factor in CaOx stone disease has provided the scientific community with a new therapeutic target.

Now that free radical generation was identified as the chief cause for kidney stone disease, I desired to develop a new therapeutic strategy to tackle this common but complex problem. Having recognised that oxalate is the major player in the field of kidney stone disease, degrading this compound can bring about great dividends. The ability to degrade oxalate to less noxious substances could benefit a great number of individuals in the biomedical field. Unfortunately, there are no known naturally occurring oxalate degrading enzymes in humans. Fortunately, human gut harbours a collection of microbes known as intestinal microbiota. These intestinal bacteria convert oxalate into carbon dioxide and formate, the latter being further degraded and excreted in the faeces. These bacteria rely exclusively on oxalate, for energy. Hence in the absence of oxalate, these bacteria perish. Since the existing oxalate degrading bacteria are delicate and lack probiotic efficiency, the manipulation of gut flora with oxalate degrading bacteria may enable degrading oxalate and eventually prevent CaOx stone formation.

The discovery of oxalate degrading gene, oxalate decarboxylase (oxdC) from Bacillus subtilis (B. subtilis) raised a new hope to mitigate the increased urinary oxalate excretion. Since, B. subtilis is harmful to human health; the oxalate degrading gene alone was isolated and introduced into a well studied species of lactic acid bacteria, Lactobacillus plantarum. The genetically engineered Lactobacillus plantarum was capable of degrading oxalate available in intestine i.e. oxalate that was ingested via food commodities. However, this newly developed genetically modified strain cannot alter/degrade the oxalate synthesized within the human system. Thus, an alternative approach is required to alleviate the oxalate that is produced within the individual. Hence, using a common therapeutic tool, I wanted to target both, the oxalate that is ingested by the individual via food and the oxalate that is produced within. In order to achieve this, I chose kidney as the target site for degradation. Since all the oxalate that has been ingested and produced by the body has to come in contact with the kidney, the organ was the chief site to employ my therapeutic tool.

Therefore, I isolated the bacterial gene oxdC and introduced it into a human kidney cell. This newly constructed kidney cell line gained oxalate degrading efficacy. Since oxalate was degraded, the cell was protected from oxidative damage. The results were published in a peer reviewed
journal called, ‘Journal of Enzyme Inhibition and Medicinal Chemistry’. However further studies in animal models are essential to establish the effectiveness of \textit{oxdC} as a potential candidate gene therapy against CaOx stone disease.

This body can be compared to a temple. We have to nurture and care for it. We need to eat healthy, drink adequate quantities of water and squeeze in a few exercises daily to lead a healthy life.
The world population is about 7.4 billion and is growing with an average estimated rate of 1.18% annually. With increasing population, demand of energy is also increasing at a fast pace. Coal and petroleum have the largest share in energy sources but have serious environmental impact and global warming due to significant increase in average earth temperature. Therefore, world leaders decided to come together to reduce dependence upon these traditional energy sources by gradually switching to alternative and green energy sources which have minimum impact on the environment. From Kyoto to Paris, many protocols and agreements have been signed and finally, it was decided to invest more in solar, wind and nuclear energy. Wind energy sources have their own limitations and alone are not sufficient for complete energy requirements of the world which is 3.1 thousand kWh per capita as per World Bank’s electric power consumption report. Though nuclear sources have great potential but they have severe risk and world has already seen brutal accidents of Chernobyl (1986) and Fukusima (2011) in the near past. So, we have only one good alternative to traditional energy sources: Solar Energy.

Silicon-based solar cells were developed because of easy availability of silicon and low-cost technology. We have seen the installed silicon solar cells on the rooftops of houses and buildings. These solar cells have limitation of converting the sunlight to energy of about 15% only because the light conversion depends on the absorption of light in solar cell. Solar light falls on the earth in energy packets named as photons. These photons have specific energy corresponding to the
wavelength of light. For example, when we see a rainbow in the sky, every color of the rainbow represents a different wavelength and energy of sunlight. The bandgap of silicon is 1.12 eV which does not allow a major part of it to get absorbed in the solar cell and that's why bandgap is very important. The photons having energy more than this bandgap lost their extra energy as heat which not only increases resistance to electron flow but also degrades solar cells. In parallel, India does not have the technology to make solar cells and almost most of the cells/wafer is imported from China.

In view of this, researchers at Malaviya National Institute of Technology (MNIT), Jaipur decided to put their efforts in this direction. The work presented here is being done by a PhD scholar, Ankit Goyal under the supervision of Prof. P R Soni of Department of Metallurgical and Materials Engineering, Malaviya National Institute of Technology, Jaipur. The writer is a PhD scholar who performed the experiments and wrote the paper.

Si powder of 99.999 % purity was purchased for the study. The purchased powder was then ball milled in a high-energy ball milling unit for 4h, 12h and 20h, respectively in argon gas atmosphere to avoid oxidation of powder particles in it. It was considered carefully before the experiments that no contaminants shall enter in the mill. The mill chamber was coated with tungsten carbide and balls of tungsten carbide were used to avoid iron impurity in the silicon. Tungsten carbide is harder than silicon so it won't go in silicon lattice but can mill silicon very easily. The milled powders were then degassed to remove entrapped gases. The purity of the milled powders was checked by synchrotron X-ray florescence (XRF) facility at Beamline-16, RRCAT, Indore. The prepared powders were then characterisation to study their particle and crystallite size, and optical bandgaps in it. It was found that milled powders have smaller size than the initial powder. The crystallites size in the milled powder was of nanometer range as confirmed by transmission electron microscopy. The size of the powder particles was inversely proportional to the milling hours. The optical bandgap is measured and calculated by UV-Vis-IR spectrophotometer.

The results were encouraging as there was a logarithmic relation between bandgap and milling duration which suggest that by controlling the milling parameters, bandgap of the semiconducting materials can be controlled. The tuning of bandgap in infra-red region is possible by just varying the milling hours. Thus, the resultant powders can be used to capture the solar light efficiently in solar cells. This can improve the efficiency of solar cells by many folds. The prepared powders can be used in other silicon based opto-electronic devices and technologies too. The prepared powders were then used in fabrication of the functionally graded solar cell with grading of bandgaps to efficiently absorb major wavelengths of the sunlight. These powders can be used for fabrication of low-cost ultra-sensitive devices.

It is very important for India to work in the direction of solar energy as we have abundant sun energy available at most of the time in a year. Our government has set a target of 200 GW solar energy power by 2020 which can be achieved early if we have a technology which can provide higher solar power conversion efficiency. The indigenous technology will also help us to become independent and reduce imports from China.

Powder Metallurgy Lab at the Department of Metallurgical and Materials Engineering, MNIT Jaipur is working on the problems which can address and affect the masses. This is a
contribution in the direction of solar energy research.

The research findings stated here is being published by a repute international journal “Materials Letters” in 2018. A part of the work was presented at the international conference PM’17 organized by Powder Metallurgy Association of India and got reputed ‘GS Tendolkar’ award for work done in the field of fundamentals of powder metallurgy.

The research team includes Ankit Goyal (MNIT, Jaipur) and Prof. P R Soni (MNIT, Jaipur). The research work was supported by Indian Nano-electronics User Program, IIT Bombay, Central Electronics Engineering Research Institute (CEERI), Pilani, and RRCAT, Indore by providing necessary characterisation facilities.
Science Storytellers, I used to think many times that how my research would be useful to the society if not immediately at least in near future. Because of this, I am working in such a domain of theoretical analysis and optimisation in cellular networks. But, now, I have got a platform to express my research in a very simplistic way that even a person who knows very little English would understand. This story is based on my two papers that were published last year.

We are all using our mobile phones these days. On an average, there would be at least two mobile phones with the data connectivity nowadays and that will increase tenfold in near future. I am writing this story related to mobile phone communication in a different way.

As in the formal engineer’s way, let’s begin the story with a phrase “Let’s assume”. Assume what? Yeah, that’s the question now?

Please note that the technical explanations are in normal font and the analogy that I made is written in *Italics*.

Let’s assume and make some analogy

Our *child* as our mobile phones, technically mobile users,
*Parents & relatives* as the high power mobile towers, technically macro base stations,
*Teachers & Well-wishers* as small power mobile towers, technically small cell base stations,
*Society* as the environment that the children are growing in, technically the channel, and
*Friends* as other mobile phones, technically other mobile users.

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A beautiful creation of God is human being. A human is born to grow, love, interact, learn, achieve, give, get, enjoy and finally live their own life. In all the stages of life, there will be somebody or there will be some reasons for a human to achieve their self needs.

**What’s the role of parents and relatives, teachers and well-wishers and society in the life of our children? (or)**

**What’s the role of high-power macro base stations, low-power small cell base stations, and the channel for a mobile user?**

Both are same, right? Let’s clarify what’s the need of all

*A child is born and raised by the parents and sometimes with the support of relatives.* The same applies to the mobile user who gets it connected to high-power macro base station traditionally.

*But, parents and relatives alone cannot completely help a child to grow into a complete human, either man or woman. The children require a teacher to teach them good and bad and a well-wisher to cheer them up when they are down.* In the same way, the traditional high-power macro base station gives some basic form of coverage to the mobile user by spending high energy like parents keep a watch on their kids all the time. Now, these low-power small cell base stations will drag some of the children from the parents towards them by offering some additional incentives. In this case, these mobile users will get high speed as the children will learn from the teachers and develop with the help of their encouragement.

*Apart from these, the society plays a major main role in the child’s life. This society has the power to change all the good persons (parents, relatives, teacher, well-wisher) around the child to appear as selfish and bad people.* In the same way, the nature of the channel has the tendency to make some of the base station’s signal as interference, produce high distortions, attenuations, and path loss.

*What if only Parent or only Teacher cares about their child?*

*What if the mobile user is connected to only one base station?*

*In either case, the child will have insecure feelings for at least one. Either in home the child will be searching for a good teacher or in school the child will be looking for a good parent. The child would try to manage but would not be happy and efficient.*

The mobile user will be satisfied with the speed that it gets from one of the base station either it is macro or small cell but the speed will not be up to the mark.

*What if both of them are same (parent and teacher) or both of them spend the same time with the child?*

*What if the mobile user is connected to both the base stations?*

*If parent and teacher are same to a child or if they both spend exactly same time, then either he will get enough attention in both the places but same kind of information will be passed to the child making him feel bored or the child will be confused while listening.*

*If both the base stations are connected at the same time, then the mobile user’s coverage will increase (Coordinated MultiPoint Transmission (CoMP) - Joint Transmission).*

*What if both of them spend time individually with the child?*

*What if both the base stations allocate separate time to mobile user?*
Yeah, this might be an interesting case to look into. There is a quality of time spent by a teacher and the same quality of time spent by the parent that adds up and makes the child efficient in learning aspects of life as well as the vocational knowledge.

If both the base stations are connected to the mobile user individually, then the mobile’s speed will be increased (dual connectivity).

**What is my contribution in this?**

There will be some points where with less energy we can give maximum care and knowledge to the child. *One of my research publications was the proposal of those energy efficient points with the optimum time that both the teacher and the parent can spend with the child. The most interesting results that I got were, for one child this technique will increase the efficiency, but if you consider more number of children, then the overall efficiency of the group of children will decrease.*

Two or more base stations connected to a single mobile user will increase its coverage and throughput. But, if there are more mobile users in the system, then the overall system throughput decreases. We proposed time allocation for CoMP users and base station sleeping patterns for achieving energy efficiency.

*There should be an optimal time that the parent and teacher should spend with the child. Even in the presence of many children, every child will get to spend time with them. So, the efficiency of understanding personal aspects as well as outdoor knowledge will increase. So, this case will perform better than the case (B).*

The optimal time allocation to a mobile user by the base stations in dual connected mode is proposed and thereby proving this is performing better than the CoMP.

**And what’s the future has for us?**

*Last but not the least, in future, not only parents, relatives, teachers, but FRIENDS will also be a part in transforming a child into a human. The constructive friendship will make them to learn among themselves and grow by their own with the presence of their parents/teachers that will help the child to understand the society effectively.*

This is nothing but the device-to-device communication where the base stations make these mobile users to learn about the channel and instruct the mobile users to communicate with the other mobile user.
I was discovered way back in 1956 in a can of meat product, which was treated with large dose of radiation to remove hazardous bacteria. But I could sustain this treatment. That was when the world came to know about a bacterial species *Deinococcus*. Myself *Deinococcus radiodurans* (DR1), a pink colour, aerobic, tetrad-shaped bacteria. Since the discovery, I have fascinated the scientific world with peculiar properties and applications. The more you explore, the more I excite you. We are the only group of bacteria that holds a place in *Guinness Book of World Records*, as “the world’s toughest organism”. Are you excited to know what is so special about us? Let me explain, I can tolerate up to 5000 Gy (Gray denoted as Gy is a derived unit of ionizing radiation dose in the International System of Units (SI) ) of ionizing radiation and withstand nutrient starvation. We can live in vacuum for up to six weeks, stay dehydrated and live through fluctuations in pH. If you are wondering what is so special about this, for your information, 100 Gy of ionizing radiation can kill a human. These unique features make me stand out from other bacterial species. The world calls us the tough bacteria, indeed a very apt name! To add, we are not hazardous and do not cause any disease.

Although I differ from other bacteria in many ways, we lack the ability to form a biofilm. Wait, but what is a biofilm? Let us understand the term with a story, once there was an old man, who wanted to teach his three selfish sons a lesson. He got a bundle of sticks and asked his sons one by one to break the bundle. No one was able to break the bundle. But when he untied the bundle

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and asked them to break the sticks, there were able to do it easily. The moral of the story is united we stand, divided we fall. The old man thought a big lesson to his sons about the art of living in unity. Probably, humans may fail to know the importance of being in unison, but bacteriada not let it happen. Scientifically, biofilm can be defined as any group of microorganisms in which bacterial cells stick (aggregate) to each other and often to a surface. These adherent cells become embedded within a slimy matrix that is composed of extracellular polymeric substances (EPS). This polymeric extracellular matrix constitutes polysaccharides, proteins, lipids and DNA. These components help bacteria to adhere to a surface, sustain its life and replicate. In natural environment, almost 99 per cent of all microorganisms live as surface attached communities known as biofilms.

Do you know that the scalp that a dentist removes while scaling is a biofilm? But these biofilms are not required for any particular purpose (they are the ones that cause bad breath!) and they sometimes become harmful to us. The slime layer that forms in a water pipeline is another example. Biofilm formation is not restricted to a single species, it may sometimes comprise multiple bacterial species happily living together. Also fungi form biofilm. When the bacteria exist in the form of biofilm, they possess a lot of advantage. They become more robust and tolerate different environmental conditions. Do these properties have any relevance for the human use? Could this biofilm be used for environmental remediation applications? The effective usage of biofilm for bioremediation (bioremediation is defined as usage of microorganisms to break down pollutants) purpose has potential environmental clean-up applications. Use of biofilms for environmental remediation purpose has potential advantages than their planktonic counterparts.

As I have mentioned, I do, not have the innate ability to form a biofilm. A joint venture project by Anna University, Chennai and Bhabha Atomic Research Centre facilities, Kalpakkam has been successfully executed by a doctoral student Manobala. T.A genetically modified Deinococcus radiodurans R1 (denoted as DR1_bf+) has shown a biofilm forming ability. Hooray!!. This is the first time that I have been able to form a biofilm, Yes, it is the first report. Thanks to this new study. It has been a completely different experience for me. I was able to adhere to the surface and form biofilm in the presence of calcium ions and an antibiotic kanamycin. Initial studies with this biofilm have confirmed the role of outer cell wall proteins for the initial adhesion. A surface layer protein (slp) expression is comparatively increased in genetically modified DR1_bf+. A comparative protein analysis of DR1 and DR1_bf+ has confirmed the involvement of outer layer proteins in biofilm formation behaviour. And now I am in a great zeal that I am able to form biofilm, which we could not do earlier. The genetic modification by addition of gfp gene and kanamycin resistance marker has serendipitously given me this capability.

**Major outcomes**

I was wondering, how would this biofilm forming ability affect me. I am happy that there was no alteration in my metabolic abilities and characteristics. To my surprise, in the biofilm mode I was able to tolerate up to 1000 mg/L of uranium, which I could not do when I was alone. Because of high radiation resistance tolerance and also biofilm forming ability, I have potential application in
bioremediation. Initial studies were done using uranium. Our bioremediation results showed that DR1-bf+ biofilm had significant capability to remove uranium that too at very high rate which was ~75 per cent removal within 30 minutes post treatment. This observation implicates the potential of DR1_bf+ for the development of biofilm-based bioremediation process for uranium removal from radioactive aqueous waste solutions. The biofilm mode of DR1_bf+ has shown tolerance to high concentrations of uranium, up to 1000 mg/L. Biofilm could withstand very high concentrations of uranium solution, i.e. 1000 mg/L not only due to the fact that DR1 has significant heavy metal tolerance but also of the fact that biofilm mode of life reduces the toxicity to the microbes as compared to that of planktonic single cells. This DR1-bf+ biofilm-mediated uranium removal method showed significant higher efficiency in terms of both performance as well as time (75 per cent uranium removal within 30 min post treatment) as compared to its planktonic counter parts.

![Biofilm & Bioremediation](image)

*Figure 1: Cartoon representation of a biofilm and bioremediation process, were the biofilm is treated with uranium*

as well as DR wild-type strain. We do not require special conditions such as maintaining anaerobic condition in this removal process and tolerance to high concentrations of uranium makes DR1_bf+ biofilm-mediated uranium removal process highly promising.

Uranium is precipitated in the form of yellow visible precipitates (figure 2). The X-ray Photoelectron Spectroscopy (XPS) studies have shown the precipitates in the form of mineral crystals. Adsorption on the surface of the bacterial biomass is the initial step followed by the precipitation of uranium.
Acid phosphatase (Acid phosphatase is an enzyme that hydrolyses organic phosphates in acidic pH) activity is also observed in my biofilm, which aids in the bioremediation of uranium. For continuous uranium removal studies, scrapped biofilm in the form of columns has been devised and has shown potential field-level applications.

**Conclusion**

Since DR1 wild-type bacterium does not form biofilm, a genetically modified strain of DR1-
bf+ with biofilm forming capacity was tested for its potential to remove uranium from aqueous solution. It was also found that if DR1-bf+ grown in the presence of calcium, EPS production was significantly enhanced and it acquired extraordinary potential of uranium precipitation as compared to its planktonic counterpart. Without much change in the biofilm biomass, a proportionate age dependent increase in bioremediation process has proved the involvement of biofilm matrix whose composition changes over time. This observation implicates the potential of DR1_bf+ biofilm-based bioremediation process for uranium precipitation.

The biofilm forming capability has improved our bioremediation capability and I am sure this will help in the environmental clean-up. Hope, I will be able to help our environment get rid of the harmful contaminants.
Knock-Down Punch to Tuberculosis

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**Story of development of a “marvel” tool for TB research.**

We, as humans, have come a long way from being cavemen to a species capable of space travel to a point where we can incorporate intelligence into things. But would you believe me if I will tell you that there is a force which kills two people every three minutes and that we are unable to stop it? Well, that force is known as Tuberculosis (TB). TB is not merely an infectious disease but a social phenomenon. Putting up numbers won’t make a significant difference here as the impact of TB on our society is very much palpable. But, in spite of all the biomedical advancements, why do we still fail? Well, the causes are numerous; first being the character of the bug. *Mycobacterium tuberculosis* (causative organism for TB, which is usually referred as Mtb) is tremendously resilient and intelligent at the same time. Humans and TB bacterium have a historic relationship and this co-evolution has given TB an upper hand. Secondly, our weaponry of vaccines and drugs against it is too scarce to be called as sufficient. The main problem is that we don't understand the enemy we are fighting and this makes us incapable of developing any effective countermeasures.

Physiological wisdom about any given organism is usually derived from a number of well-performed genetic studies. This makes genetic manipulation as the single most important tool for a successful biologist. Mtb is resilient not only to the therapeutic agents but also to the genetic manipulations. Conventional “Gold Standard” for genetic studies is usually based on swapping the desired gene out by technique called as recombination (results into “Knock-out” of the desired

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gene). But this tool is particularly cumbersome in terms of designing and application. Although most effective, the technique suffers a blow as we cannot examine genes which are quintessential for the survival of bacteria (known as essential genes). Likewise, other popular techniques for genetic engineering also fall short from being ideal. Fresh attempts were made by our lab at Translational Health Science and Technology Institute (THSTI) under the supervision of Dr Nisheeth Agarwal (Associate Professor, THSTI) to address this problem and create a near-ideal platform for genetic manipulation in Mtb. Our efforts substantiated into successful implementation of “most ideal tool” CRISPRi in *Mycobacterium tuberculosis* and were published in the journal, *Nature Communications*.

### What is CRISPR?

CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats and is responsible for adaptive bacterial immunity against invading viruses. Let’s understand the concept of CRISPR with the help of a simple example. Have you ever visited a police station? Even if you have not, you must be aware that every police station has a notice board with pictures of the “MOST WANTED” star criminals of the locality (courtesy: Bollywood movies). The purpose of this board is to make all police officers and anyone who visits police station aware of the wanted criminals and catch them anyhow. So recognition, entrapment and execution are the steps to catch and prosecute a thief, right? CRISPR also works the same way, whenever any virus attacks bacteria (yes, they do!), bacteria cleave attackers genetic material into small pieces and incorporates it into its own genetic material (pictures of criminals) as a memory for subsequent attacks. Police here is a protein known as Cas9, which with the help of these pictures (known as crRNA and trRNA) recognises the invading organism, catch him (Cas9-guide RNA complex goes and binds with the foreign genetic material) and execute (Cas9 has an ability to cleave DNA). The whole system very well resonates with “Keep your friends close, but your enemies closer”.

Although existence of CRISPR was long known but “marvel” happened when scientists were able to repurpose it as an effective genetic engineering tool. The trick was to redesign crRNA and trRNA into a new sgRNA (photo of the criminal) so that Cas9 (the police) recognises its “own” (designated) gene instead of “foreign” gene. Another trick was played by taking away the ability of Cas9 (the police) to cleave the DNA to create new Cas9 called as deadCas9 or dCas9. Hence, dCas9-sgRNA complex now can only recognise and bind (catch) the desired gene in turn “knocking down” its expression inside the cell (even if you don’t execute the thieves, putting them in jail would also curb the mayhem, right!). This adaptation of using CRISPR to suppress the expression of target gene is known as CRISPRi (interference).

Our job was to break the resilience of *Mycobacterium* and successfully adapt CRISPRi as the new “Gold Standard”. We chose deadCas9 (dCas9) from *streptococcus pyogenes* our police. Use of dCas9 required codon optimisation for about 191 amino acids from the primary sequence (which simply means that we made it “suitable” to work in Mtb). Next, we constructed a plasmid (independent replicative DNA) as our delivery vehicle for the target sgRNA (“wanted” pictures). Once the system was ready, we tested its effect on expression of variety of genes to observe the
resultant “Knock-down” of target genes. We were also able to determine and optimise the critical factors responsible for maximal suppression. The fundamental advantage that our system creates is the reversibility as expression of dCas9 and sgRNA are under the control of an inducible promoter (which actually means that we can decide when and where to introduce both the police and the picture of the criminal). This function endows us with a remarkable ability to study and understand the workings of essential genes which most other tools lack. Not only this, CRISPRi was found to be effective in suppression of an operon (which means genes which are expressed together) i.e., if it’s a gang of thieves and you catch one, you eventually get all of them. CRISPRi also allows seamless multiplexing (suppression of multiple genes at the same time) which means you can really deliver multiple photographs at once.

Our study has established CRISPRi as “most effective tool” in all aspects for genetic manipulation in Mtb. CRISPRi provides us incomparable ease for designing, using and maintaining this system at the lowest possible cost. Concrete tool like CRISPRi usually lays the solid foundation and paves the way for assimilating necessary and comprehensive insight into the workings of an organism. Our aspiration would always be to turn these insights into wisdom which will expedite our dream of better therapeutics against TB and possibly deliver that “knock-down” punch.
India is one of the six high-burden countries of the world in terms of Tuberculosis (TB) load and accounted for 26% of global deaths due to TB in 2016. TB is a communicable disease that spreads through air and majorly attacks human lungs. Even though the disease is curable, people still lose their lives to this painful disease, which is caused by a bacterium called Mycobacterium tuberculosis (Mtbc). The treatment of the disease is also a dreadful process. The medications used for the treatment take a toll on the patient’s body resulting in loss of hair, appetite and weight, anxiety issues and depression. To add to their miseries, people lose their livelihoods and become socially disconnected. Children are forced to give up school, their outdoor hobbies and stay quarantined. All this at a time when the patient badly requires financial and emotional support. The complications magnify in the current scenario, with the high prevalence of anti-microbial resistance. Many strains of the bacterium have evolved over time to evade the effect of many medications prescribed for TB treatment, which is termed as development of anti-microbial resistance. In such cases, stronger medicines are prescribed for treatment that comes with their own set of enhanced side-effects.

A major challenge in eradicating TB is the lack of appropriate diagnostic methods. The conventional treatment strategy is based on a preliminary diagnosis after which the first line medication is started. But the confirmatory results come from a bacterial culture test which takes 6 to 8 weeks. For this duration, there is no clear idea about the infection levels in the patient’s body and about the type of strain infecting the patient. It might so happen that the patient is infected by a resistant strain and then the first line of drugs would not work. It is also possible that the patient

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did not have the disease but kept on taking the anti-biotics. This is one of the major reasons for the widespread development of anti-microbial resistance. A recent advancement in this direction has been the introduction of the Cepheid GeneXpert system which can provide TB test results in a couple of hours. But even after being highly subsidised by the government, a test on Cepheid GeneXpert is out of reach for people living in low resource settings; while it is these people who are highly prone to being a victim of TB owing to their poor hygiene and immunity levels. Therefore, it becomes imperative to develop diagnostic technologies that are affordable and deliverable to people living in such underprivileged areas.

We at ‘The Toley laboratory for microfluidic bioengineering’ at IISc, Bangalore, guided by Dr Bhushan Toley aim at enabling rapid, robust and inexpensive diagnosis for Tuberculosis. We are working on developing a ‘paper-based’ diagnostic tool that uses the DNA of Mtb as a target to confirm the presence or absence of TB.

The Cepheid GeneXpert system also uses Mtb DNA as the target but is very expensive because it employs the age-old polymerase chain reaction (PCR) for amplification of bacterial DNA. PCR is based on different temperature cycles, each cycle lasting for small intervals of time, which requires a sophisticated temperature control mechanism. We address this challenge by using a DNA identification technique which operates at a single temperature. The paper and plastic based TB testing device designed and fabricated in our lab, can be simply put in an incubator for TB testing, available even in the small labs. Fluorescent dye which forms a complex with DNA and shows a color change is used for the end-point detection. This simple detection mechanism is highly cost effective and the presence of Mtb DNA is indicated by the generation of green colored fluorescence at the end of the reaction, which takes just one hour. We envision that once produced on large scale, this will be a specific, sensitive, accessible to all, and user-friendly diagnostic tool for TB testing.

All the biological and chemical reactions are carried out in paper-based devices as opposed
to conventional tube-based reactions, because working with paper provides numerous advantages. Paper is flat, easy to engineer and can be easily designed and fabricated to suit different types of applications, without the need for specifically designed blocks or instruments required to handle tubes of different shapes and sizes. Since biological samples have limited volumes, the pore size of these porous membranes called paper, provide an appropriate sized reaction volume to carry out these biological assays. Another crucial gap that can be filled better by paper-based diagnostic devices is of the long-term storage. The low resource settings are generally miles away from a well-equipped laboratory and a pharmacy. It becomes very important that the diagnostic tools can reach to such places, at the point-of-care. Paper provides a substrate for the dry storage of the reaction reagents into the membranes which can be hydrated by the sample at the point-of-care to perform the test. We have been able to successfully conduct TB testing with reagents dried in paper, without any significant loss in efficiency.

Paper-based devices also show the potential to integrate the various steps involved in testing, which makes them highly suitable for development of point-of-care diagnostic devices. It is these point-of-care diagnostic solutions which will extend the reach of modern diagnostics to weaker economic sections. The current testing is done in a resource intensive clinical laboratory with expensive instruments and trained technicians. The patient sample undergoes various processing steps to remove the unwanted biological material and identify the intended target. If all this technology is to be taken to people sitting miles away from cities, with insufficient resources, the replacement must be automated to the maximum extent to make it independent of requirement of trained personnel. Paper to paper valves enable sequential delivery of fluids and automation of multiple user steps currently in use for diagnostic tests. While all these transformations are being made, cost is a significant governing factor. With this motivation, we are working on the development of cost-effective integration techniques to combine the various processes involved in biological testing, starting from sample preparation to obtaining the final result.

Tuberculosis is a huge national challenge and has many layers of associated problems to be addressed. With my research, I aim at providing the benefits of modern diagnostics to TB patients across economic barriers. Since the percentage of patients who discontinue TB treatment before completion is very high, rapid and specific testing can help doctors start with the right treatment in the initial phase of the disease. This will help in better management of the patients and will also prevent the spread of the disease to other people who come in contact with the patient. A specific test will also ensure that only people who are truly infected will take medications and play
a crucial role in reducing the possibilities of development of anti-microbial resistance. In cases of epidemics, availability of these quick and portable testing methods can save numerous lives in the field, helping doctors to take faster and more informed decisions. Successful commercialization of this research will mean that we would be far better equipped to combat the most deadly infectious disease of the world.
Community Radio for the Upliftment of Farming and Rural Communities in India

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Radio is still popular in rural India where it is seen as an effective medium to reach people with low literacy levels and scarce electricity supply. In the current social context where there is no dearth of information owing to electronic and digital media; radio has withstood the popular social media in providing information to the masses at little or no cost and in their local dialects. Another kind of radio which is “for the people, by the people and of the people” could be understood of as Community Radio. It is a major role player in information dissemination which is the closest and most easily accessible medium for the rural communities in their vicinity covering a diameter of 10-15 kilometers approximately. The operation of community radio depends on the purpose which it aims to serve. It could be deployed for the students of the university to discuss ideas and bring forward educational programmes, for the farming community to distribute and collaborate in educational and informative programmes for the farming community of the area, for the unemployed youth in educating them on entrepreneurial avenues in the area and related aspects. It can be operated by the local communities themselves and used for various issues of immediate concern related to development, health, nutrition, education, entrepreneurial avenues, farming, etc. Also, it helps to strengthen the folk culture of the community by providing a platform for the local artists to showcase their talent and skills helping in the development of positive social vibes resulting in the empowerment of the community.

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The Government of India approved a policy to set-up Community Radio Stations (CRS) by well-established educational institutions in 2002 which was later amended in 2006 to include non-profit organisations in its ambit. During the past few years, CRS has seen sustainable growth in the country. The present study was conducted to access the impact of the programmes broadcasted by one such community radio at *KrishiVigyan Kendra* in Patna district of Bihar which is operational since March 2011. This research was considered important to observe the contribution of traditional media like community radio in the current digital age where information is readily available at fingertips.

In the effective development of agricultural sector in India, information and knowledge could be understood as two major enablers that have helped the country to rise from a food importer to meet domestic requirements to a major food exporter with the increase in food production by over fourtimes since Independence. The dissemination of information through traditional media like the community radio has been studied and was implemented by *KrishiVigyan Kendra* (KVK), Barh, Patna, Bihar on FM 91.2 Mhz daily for a period of three hours since 2011. The programmes broadcasted through the radio includes a wide range of topics of interest to the men, women, children, and youth. The programmes like farmer’s arena, women’s world, children soaps, health feature and folk songs are produced in Hindi and local dialect covering topics on farming, government schemes, entrepreneurship, health and hygiene, environment, etc. The tagline of the radio is “Aapan radio, aapanawaz” (My radio, my voice). The various forms and formats in which the programme is developed are radio talks, interviews, panel discussion, call-in programmes, live broadcast of meetings in the community, radio drama, folk songs, etc. The topics are decided by conducting a baseline survey prior to the development of content to understand the needs and preferences of the audience.

In the present study, seven blocks in which the community radio is easily accessible were purposively selected for the study which is covering 390 villages and approximately 39,800 farm families. A total of 90 active listeners were selected following simple random sampling. The farmers were later trained at KVK, Patna on three aspects of vermicompost production, honeybee rearing, and mushroom production based on their interests and preferences. The data was collected directly from the participating farmers through a semi-structured interview schedule and focused group discussion during April–November 2014. It was observed that the knowledge acquired by farmers through the training increased significantly which was later implemented by over 20 per cent of the trainees in adopting the agricultural practice. The feedback of the farmers after the training was an important component which enabled the content creators of the community radio to design the program in an effective way stressing some issues which were earlier deemed irrelevant.

The findings of the study provide a roadmap to the content creators for reaching the rural communities in an effective manner. Ignoring the traditional media might result in a condition...
where there is a dearth of information for the specific community for which content is intended. The impact of the agricultural content broadcasted on the radio was strengthened with the training support at the KVK resulting in higher knowledge and adoption level among the participants. The study reveals that community radio is a major contributor to the development of the agricultural sector if it is well conceived by an extension agency with regular follow-up and service support. The study is of importance in the context of agricultural reforms in the country for getting the better impact of extension program through the implementation of community radio stations in every KVK of the country. India has a wide network of KVK in the country with as many as 695 KVKs operational in each district (as of September 2018). Such a network will help in the creation of a wide knowledge base for farmers from every district of the country resulting in effective problem solving and wide adoption of agricultural technologies developed by the research sector. It would further lead to the effective reach of agricultural developmental schemes to the intended farmers spread in the remote rural communities where it is difficult for the mainstream media to reach. The community ownership and management of the community radio provides a voice to the rural population helping them orient their own developmental goals for the benefit of the community.
Making Oil Flow Faster for Cheaper

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One of the most ubiquitous features of modern industrial society around us is the large scale transport of raw materials and finished goods from one part of the world to the other. Oil, gas and other petroleum products form the bedrock of an industrial society and hence, their efficient transportation is of the utmost importance for both economic and social reasons. This importance is clearly illustrated by the fact that more than 35,000 km long pipelines are devoted to transporting, both raw and processed, petroleum products in India. Maintaining and operating these pipelines, and the associated infrastructure, thus amount to a significant portion of the country’s gross domestic product. With the consumption of crude oil projected to keep growing in the coming years, reducing the cost of pumping involved is thus, an urgent need.

One method suggested to achieve this has been to add polymer molecules to the oil pipeline. Polymers are composed of thousands of repeated sub-units, and form the basis of the myriad things we see around us, most notably plastics. When such polymers are added, even in tiny amounts to a pipeline the resistance to pumping, the ‘drag’, drops remarkably, phenomenon dubbed as ‘Drag Reduction’. This has been observed several times, although the physical process of how this happens lacks a complete explanation to date. Even though it was first discovered in the 1950s, the wide applicability of this method has been hampered by a lack of understanding of the physical phenomenon involved. This makes achieving control and to repeat difficult, both of which are crucial for industrial applications. Since direct approaches to answer this puzzling question have failed over the years, we aim to answer the question of how the drag-reduced state is set-up through

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our research. But before beginning our research, we found; it is important to take a detour and examine the question of why it is so hard to pump oil over large distances.

A common observation which is made by every child, but the most famous first recording is in Leonardo da Vinci’s sketches, is that any fluid, water or oil included, when pumped faster and faster, it starts to develop random swirls and patterns and flows in a disordered fashion. This is the famous state of turbulence, during which aeroplane captains don't tire of warning you to wear your seatbelts. The same phenomenon, however, is encountered in oil pipelines when the flow rate at which oil is being pumped is large enough. When at small flow rates, an ordinary fluid, like oil or water, flows in an orderly fashion and hence, can be pumped effectively at relatively little energy cost. But when pumped fast enough, which is a requirement for transport over long distances, the extra swirls and disorder encountered cause additional friction in the pipe and the efficiency of pumping drastically reduces. A simple thought then presents itself, can the disordered state be avoided, or failing that the disorder minimized? If one could do that, one could maintain a larger efficiency of pumping. This is where the aforementioned polymer molecules, and our novel research work, come into this story.

We tackled the problem by studying a mathematical model that represents the presence of the polymer in a coarse-grained sense. This model provides an effective ‘memory’ to the oil; that is with polymers added the oil is a material that behaves both as a solid and a liquid! It has long been postulated that this unique behaviour is responsible for the drag-reduction mentioned earlier, although how has remained elusive. Our analysis, of this model, has shown that the presence of polymers can lead to novel patterns in the flowing oil in the pipe in sharp contrast to what was believed so far in the literature. We showed that these self-excited patterns are completely distinct from those that are found in ordinary oil at large flow rates, i.e. ordinary turbulence. These new patterns result from a subtle interplay of the fluid-like property of the oil dynamically interacting with the solid-like memory provided by the added-polymer molecules. We went a step further and quantitatively characterized the material properties at which these new patterns should be observed in the laboratory. In fact, these parameter values matched very closely with those reported by an experimental group a few years earlier who were studying the same problem in the laboratory. Their observations had remained a mystery so far. But wait, how did we discover these new patterns, you ask? That was thorough, and hence unfailing, mathematical analysis. This analysis gives us, for the first time, the knowledge to predict, quantitatively, what type of flow will be achieved in the oil pipeline. This was the crucial missing ingredient which had so far prevented a large scale adoption of this highly promising technique. Our research directly overcomes this hurdle.

By demonstrating this new pathway, which was hitherto completely unexpected in the literature, these results overturn some widely held beliefs. It was expected that the swirling state only changes a tiny bit upon the addition of the drag-reducing agent. This idea was so entrenched that most designs that tried to incorporate this effect assumed this and hence ended up being severely inefficient. Our results clearly demonstrate the contrary and hence for the first time open up an avenue to achieve, and hence control, the new random state. And you guessed it right this state is expected to have all the right properties thus enabling efficient design.
But like all good stories, this one has only reached the middle and a lot of work still needs to be done. Mathematics can only take you so far, and we are now planning to carry out our research by using computers to analyse the new swirling state itself. This would bring us one step closer to the Holy Grail actually designing cost-efficient pipelines by using the ideas we discovered. One would hope that the end moral of this story would be one all research stories aspire to combining scientific knowledge to solve pressing societal needs.
A Way Forward in Ornamental Fish Farming

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The ornamental fish sector is a small but unique and vital part of an international fish trade. Fishkeeping has emerged as the second most popular hobby in recent years, next to photography. There is a great scope for Aquaculture. By culturing imported exotic fishes locally, or tapping the resources of indigenous fishes, India not only earns foreign exchange but also enters into the world market of ornamental fishes. The contribution of India to the world ornamental fish trade is only at a tune of US$ 1.7 million, which is rather sparse considering the vast US$8 billion global market growing at an average annual rate of 9%. In view of India’s richness of fish biodiversity, geographic location and access through air connectivity to international markets, it wouldn’t be an understatement to say that India has not tapped these resources effectively. The demand for indigenous fishes is high in foreign countries. Our country is bestowed with climatic conditions ideal and conducive to growth, maturation and breeding of many indigenous as well as exotic ornamental fishes but India’s share in the global export market is insignificant.

The Western Ghats of India is one among the biodiversity hotspots of the world and one of the richest regions in terms of its biological diversity. The Western Ghats holds rich freshwater fish diversity with about 290 species belonging to 106 genera, 33 families and 11 orders. The Western Ghats also portrays 189 species of endemic fish fauna, belonging to 69 genera, 23 families and 7 orders. About 110 species of fishes reported from the Western Ghats have value in the ornamental market. Exploitation due to high export demands for the beautiful endemic fishes has put at risk of

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becoming endangered and even extinct. Hence, to serve market demand and save biodiversity the best solution is to develop seed production technologies for propagation and revival of valuable endemic fish species.

Advancement in breeding and aquarium technology has added new dimensions in the ornamental fish trade with more species and varieties being introduced to the aquarium trade. Though contribution of indigenous ornamental fishes is less in the total ornamental fish trade, possibilities for the development of indigenous ornamental fish trade is very high. Hence, in order to propagate and enrich the indigenous ornamental fish resources in Western Ghat, the fish species namely, *Sahyadria denisonii* (Kerala queen) and *Dawkinsia filamentosa* (Filamentous barb) of Kerala origin were selected for research. *Sahyadria denisonii* is the most popular and highly priced freshwater ornamental fish, it accounted for almost 60-65% of India's total ornamental fish exports. *Dawkinsia filamentosa* is endemic to Kerala, Karnataka and Tamil Nadu river streams; it also has a very good demand in the ornamental fish trade. These vibrant colour barbs are so popular that it has been requested in a majority of the trade enquiries and exported regularly from India. In order to ensure seed production year-round induced breeding techniques are necessary. The optimum dose of the hormone has been standardised by considering high potentiality at a low dose. Induced breeding technology developed by present research will lend a hand to farmers to generate elevated income by producing these valuable fishes.

Once after breeding larval, rearing is a risky task in farming practices. After yolk sac absorption, larvae prefer free drifting and tiny live animals as a feed, which is known as live food. Live foods are living nutrient capsules with rich nutrition and the larvae easily selects the live food which suits their mouth size. Most of the aquaculture industries are relying on artemia for larval rearing due to its commercial availability in cyst form. Even though several other live feeds culture techniques have been standardised, culture practices have not yet commercialized to a large scale. Cladocerans are the group of zooplankton rich in nutrients (fatty acids) which can replace artemia and could reduce the production cost. Hence, in order to support larval rearing practices in the present study mass culture technique for the Cladoceran (*Moina micrura*) was developed using microalgae (*Chlorella vulgaris*) as feed in system with recirculation and bottom line aeration facility. This simple farmer friendly technique will reduce the high production cost.

In ornamental fish culture, colour intensity is preferred more than the growth; carotenoid sources need to be supplemented in the fish diet to increase its enticing beauty. Several synthetic products are available in the market but the present study focused on the preparation of natural carotene ingredient (curry leaf, marigold petals, carrot peelings, and shrimp/crab shell extracts) incorporated diets to enhance colour. Natural carotenes work well compared to synthetic forms in captive culture conditions.

Using the conventional system such as smaller tanks and tubs for ornamental fish farming is becoming outdated. In order to produce more to make more profits (in a unit area), advanced culture systems are to be adopted in ornamental fish farming. Raceway farming would enable the sector to rise to a different level in our country. Raceways have various advantages like high stocking densities, zero water exchange system, suitability for mass culture and economical viability
compared to traditional systems, accordingly in the present study the nursery and grow out rearing was carried out in advanced production system like Raceway with re-circulatory facility for mass production of selected indigenous ornamental fishes with feed interventions.

The study was designed to develop a complete package of commercial farming technology which includes the induced breeding for year-round seed production, mass culture technique for live feed production for larval rearing and colour enhancement in captivity using natural carotene source for selected indigenous Western Ghats origin ornamental fish species using advanced culture systems like Raceways with water recirculation facility. The study introduces advanced sustainable farming technologies for ornamental farmers, breeders and entrepreneurs to enhance their production using cost-effective technologies in a small area with less use of valuable water resources. The present study also helps to introduce hatchery-bred seeds of valuable indigenous *Sahyadriya denisonii* and *Dawkinsia filamentosa* into the ornamental fish trade, thereby reducing the exploitation pressure on natural resources to a considerable level and contributing to the conservation of natural resources.
We the Termites of IISc

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We would like to draw your attention to some crazy researchers who are trying to find out how
do we construct mounds... ecologists and civil engineers together. Now, who doesn’t need
a home? Step out of your buildings and you will see animal homes in all their grandeur ... bird’s
nest, spider’s web, beaver’s dam, mice burrows, orangutan nests and so on. Our brethren make
homes by collecting materials from their surroundings (bird’s nests) or by secreting materials from
our bodies (bee hives) or by cementing collected materials with secreted materials (our mounds).
In recent times our homes are drawing human attention for their remarkable engineering and
architecture.

Our mounds are conspicuous in several landscapes in Africa, Asia and Australia. After all
who can miss a ten meters tall structure? Mind, we ourselves are a few millimetres in size. Dare
competing with us? You will have to make a building ten kilometres tall !! Taller than Mt. Everest
!! Our mounds can withstand weathering from rain and wind for decades. In fact the remains of
some mounds are known to stand for centuries. It is no mean feat. But guess what, we don’t bake
our bricks in kiln. We mix soil with our secretions and it becomes ten times stronger. A million of
us can be inside a mound and we live together as a big happy family.

In our family we have king and queen, workers and soldiers, young ones and winged
reproductive ‘alates’. The king and queen parent the rest of us in the colony. We workers build
mounds, take care of the eggs and young ones, go for foraging and tend to the fungus garden. The
soldiers defend our colony and the winged alates fly out after rains to start new colonies. Some

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of our fellows are of two types major workers with a large body and a large, dark brown head and minor workers with a small body and a small, light brown head. And we all work in synergy. We work without an architect, without a masterplan, in fact without even seeing the house we are building. Yes, we are blind!! Then how do we do all this?? Let humans scratch their heads for some time…

One fine day some researchers came to our mound and made an intentional breach. Now who likes a breach of privacy? So we started repairing the breach. We repaired the circular breach all along its circumference. We started from the periphery and reached the centre during repair. Can you construct hanging upside down? We can. For repairing breach we mixed our secretions with moist soil and made tiny balls with it. Humans have termed them ‘boluses’ (singular bolus). These are analogous to the bricks you use for your buildings. While we brought boluses for our work, humans snatched our boluses and measured them. To their surprise they found that we make two different sizes of boluses. But how can anybody make a building with two different types of bricks? We make a scaffold with the large boluses and fill the gaps with the smaller ones. This makes a dense and strong structure. But we are blind and we don’t have a masterplan. So how do we co-ordinate?? Simple, once we reach the site of construction we take cues from the local environment and decide on the spot what to do. This is called ‘stigmergy’. Humans have even designed robots for understanding this stigmergy; what we do effortlessly.
Now humans started treating us as their pets. You guys are indeed playful. They offered us a playground of different materials in their lab, right from tissue paper to agar gel to metal powders, sand, paraffin wax and what not… twenty four materials in total. God only knows what they were thinking. But little did they know that bolus making is hard wired in us. We ended up using almost all the materials for bolus making. Obviously, we could not use all the materials equally easily. They figured out our favourites.

But you will be surprised to know that we don't live in the mounds we build with such great efforts. We live deep underground. Now anybody living underground would suffocate unless sufficient provision is made for ventilation. Our mounds do exactly this. They harness the variation in temperature during day and night and use it for ventilation. See how smart we are!! Our homes are indeed cosy … air conditioned all round the year with moderate temperatures and high humidity (we are soft bodied and will die under dry conditions). Moreover, we have an entire fungus garden inside the mound where we grow our food. We are amused that you humans make your dwelling with expensive stuff and they turn out to be either too hot or suffocating. And then you spend additional energy for cooling and ventilation.

Infamous for eating up your furnitures and books (yum!!) you have often treated us as villains. Only in recent times you are beginning to recognise our significance… We don't just engineer magnificent mounds; we engineer entire ecosystems too we increase the fertility of soil and make ecosystems drought resistance. However, it is quite some time before you develop full understanding of the ecosystem services we provide. Our mounds are already inspiring construction of energy efficient buildings. We will also help you make cementing agents for construction, algorithms and robots for self-organisation, traffic regulation and construction in unreachable places like disaster hit regions or the surface of Mars (please tell Elon Musk)!! Since we grow our own food in fungus gardens, you might have guessed that we employ ingenious ways of weed control which can benefit your agriculture greatly. There is no dearth of secretes we are holding for you so come and explore our world. Who knows it might make a better world for your kind…

Reference:

Concerned About Privacy Leaks From IoT Devices? IIT Madras Researchers May Have A Solution!

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With the proliferation of Internet of Things (IoT) devices such as smart TV and smartwatches, the issue of privacy leaks looms large over our households. This is primarily due to the access that these devices have to sensitive information about our personal lives. Let alone preventing, even identifying such privacy leaks is still an open problem in the field of communications and computer science. Researchers at IIT Madras have come up with a new Blockchain design that can be used to identify privacy leaks from IoT devices. Although Blockchains have been used to solve a plethora of problems in the past couple of years, making Blockchains work in IoT (where storage and computational resources are scarce) has been a glass ceiling, which these researchers have now broken.

Privacy leaks have been widely speculated for a long time, but it was not until the Facebook-Cambridge Analytica data scandal that common people learned of its seriousness. Facebook-Cambridge Analytica scandal showcased that the seemingly harmless “which famous film personality are you?” type quizzes could be used to sway the outcome of the US presidential elections. Leading researchers in this field believe that there is a high chance that there may exist many such privacy breaches which are not yet known to common people. In fact, the research community has been well aware of this and has been working towards identifying and protecting against such privacy leaks. Even government agencies around the world have started taking

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notice of such privacy breaches and are working round the clock to protect sensitive information from leaking.

Many decades ago, researchers as well as companies invested much of their resources to answer the question ‘Does the device do what it is supposed to do?’ Due to the newness of computing technology, ensuring the correctness of computations was important. However, in recent times, the most important security question that needs to be answered is ‘Do the devices do something that they are not supposed to do?’ The answer to this question has eluded researchers for a while. Blockchains are seen as a promising technology to answer this question. In simple terms, a Blockchain is a tamper-resistant digital account book of critical/security events that occur in any IT infrastructure. Examples of such critical events include banking transactions, IoT device activities, and shipment activity of goods, depending on the scenario in which the Blockchain is deployed. For instance, when IoT devices are used in a house, the Blockchain will be capable of recording events such as activating air conditioner, switching on the microwave, and changes in temperature. The Blockchain will provide a comprehensive picture of the activities, based on which suspicious behaviour such as leakage of the temperature readings to the outside world can be detected and flagged. It is worth noting that accurately capturing the events is the challenging part, while there exists efficient methods in the fields of statistics to detect and flag suspicious activities.

Blockchains are not a completely novel technology but rather an ensemble of various data-structures and algorithms that have been well known for the past three decades. Researchers argue that, despite re-using known technologies, it is the unique combination of these technologies that help Blockchains achieve high levels of security. The Blockchain is a peer-to-peer technology where some IoT devices sense critical events and the other IoT devices verify and record them in the Blockchain. The key idea is that an event gets recorded if and only if a majority of these devices agree upon its correctness i.e. security is ensured when at least 51% of the devices are honest. Also, once the devices agree on the validity of a critical event and add it to the Blockchain, it is impossible to retract at a later point in time; thereby preventing attackers from tampering the log.

At the heart of the Blockchain is the cryptographic data structure called Merkle-tree, which was patented by Ralph Merkle in 1979. Merkle-tree efficiently verifies if a particular transaction is valid or not and also provides evidence supporting the claim. The Merkle-tree additionally captures the order in which transactions get accepted. “It is this data-structure that helps Blockchain help achieve security guarantees even when the participants are untrustworthy”, says Professor Kamakoti, who leads this project at IIT Madras. However, on the downside, the computational, storage, and energy consumed by Merkle-tree is significant. As a result, traditional Blockchain designs require a tremendous amount of storage, huge computing power and a good network connection, all three of which are scarce in IoT environments.

The problem of adapting Blockchains for IoT environments has baffled researchers for the past couple of years, which is solved by ApproxBC, the solution proposed by researchers at IIT Madras. ApproxBC requires very limited storage and computing resources and can work even when the Internet connection is intermittent. The ApproxBCBlockchain design works by replacing the computation- and storage-heavy Merkle-tree with alternative lightweight cryptographic data-
structures. The key insight here is that alternative data-structures that provide slightly lesser security guarantee will consume far lesser resources. The first variant of ApproxBC replaces the Merkle-tree with another popular data-structure, namely, the Hashtable. Unlike Merkle-tree, Hashtable only captures the evidence of transactions but does not capture their order of acceptance. This relaxation is acceptable in a lot of real-world scenarios and results in huge resource savings. The second variant of ApproxBC uses the data-structure called evidence Bloom-Filter (e-BF), which was invented at IIT Madras. Unlike Hashtable, the e-BF data-structure can only confirm the validity of a transaction with a high-probability (as high as 96%) and not with complete certainty. As a result, it may sometimes ‘claim’ that a security event happened, when in reality it did not, leading to inaccuracies. “One of the most difficult aspects of our research was to come up with an optimal design that achieves maximum possible space savings while still having an acceptable level of accuracy”, says Prof. Chester Rebeiro, an Assistant Professor at IIT Madras, who co-leads the project.

Applications that have severe resource constraints can use ApproxBC. Although there is a compromise on the level of accuracy, ApproxBC allows the application to enjoy all other security benefits of Blockchains. ApproxBC, when applied in an IoT environment, results in a conservative approach to ensuring security and privacy i.e. it may perceive a non-threat to be a threat approximately 4% of the time. The researchers argue that when it comes to privacy of common people, false alarms are acceptable. In response to an alarm, an audit can be performed on the ApproxBC digital account book to find out if it was due to an actual security event. In future, the researchers plan to extend ApproxBC to solve many real-world problems such as combating vehicle insurance frauds and power utility management systems.
Air Vehicle Which Flaps Its Wings and Flies

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The amazing phenomenon present in nature has inspired humans for years to invent many things for survival and ease problems. One of these inspirations from birds and flying insects led to the invention of air craft. The research discussed here is also inspired by the flight of the dragonfly. You may have witnessed and enjoyed the flight of the dragonfly sitting near a fountain in a park and amazed by it flying at high speed and hovering. The flight mechanics of the dragonfly is one of the most complex mechanics. A tiny creature, thus, opens many doors for research such as aerodynamics, material science and control system.

Translating the physiological phenomenon of this tiny insect into engineering design can pave a path to a non-conventional type of air vehicle which will have wings that will flap to fly and hover. The kind of air vehicle that is discussed here is generally called Micro Aerial Vehicle (MAV) which is a class of Unmanned Aerial Vehicle (UAV). Building a flapping wing MAV is a very large project. The research discussed here restricts to the mechanics of material involved in the flapping of the wings. The research being done will not only help to build the MAV but will also be used in other applications such as structural health monitoring and biomedical instrumentation.

While building any MAV there are numerous design parameters which are to be considered, such as flight duration, maximum height during the flight, distance travelled in a flight, etc. Currently available MAVs have complex mechanisms to control the flapping of wings, which increases the weight of MAV and eventually the parameters considered are compromised. This is the focus of our research to find a solution to minimize the complex mechanism and, therefore,

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minimize the weight of the MAV. The non-conventional or engineered materials theoretically proves to be a solution to this problem. The smart materials can be considered to completely replace the complex mechanism used to flap the wings.

Engineered materials are made artificially by adding two or more different materials having different properties. The material formed has properties different from those of the ingredients that help you achieve the property you wish to have in your material. One such engineered material is fiber reinforced composite (FRC) in which there are mainly two ingredients, one is matrix and the other is fiber. It is like the reinforced cement concrete (RCC) which is used in the construction of our houses. In RCC the steel rods play the role of fiber and the mixture of cement concrete plays the role of matrix. With this example it is clear that the role of matrix is to hold the fibers together just as the steel rods provide strength. The benefits of using RCC instead of just cement concrete lies in the name i.e., it provides extra reinforcement/extra strength to the bare cement concrete. In FRC the arrangement of fibers and the matrix is similar to RCC but at a very small length scale i.e. the fibers have very small diameters of the order of micrometer. So, to achieve a feasible size of the FRC to be used in the structure they are made up of layers just like the plywood used in our house or office to make furniture. The material used as fibers are glass, carbon, jute, etc. while the matrix material is generally resin, metal.

What if there is a layer at the top of the FRC which behaves differently than that of the other layers. By differently I mean if I apply pressure on that layer it produces electricity and vice versa i.e. if we apply electricity the layer expands or contracts. This phenomenon is known as piezoelectricity and is observed in some of the naturally occurring materials like quartz crystal, topaz, etc. and some chemically prepared compounds like lead zirconatetitanate, barium titanate, etc. You would have also observed this phenomenon in your kitchen. The lighter used to light the gas stove uses this phenomenon. You apply the pressure on the central rod of the lighter and the spark strikes as a result of the electricity produced in response to your pressure. Such, FRC’s with piezoelectric fibers comes under the category of smart materials. The top layer is prepared by adding the fibers of piezoelectric materials in the matrix. This layer plays a very important role of binding other layers. But, how? Imagine only two layers of same size, the upper layer with piezoelectric fibers and the lower layer with conventional fibers, both held together with proper adhesive bonding, restricting any kind of relative motion between them. Positive electric potential is now applied on the upper layer, the effect of which is the extension of the fibers and, therefore, of the layer. But as there is no sliding motion between the layers, the top layer will try to push the lower layer to form a convex shape. If the electric potential is reversed, then a concave shape is achieved. Now, imagine that one end of the layer is fixed by some means resulting it to behave as a cantilever beam. If the electricity is applied in a cycle of positive and negative electric potential the beam flaps up and down. Thus, a material is now available which can itself flap without any complicated mechanism by just applying electric potential across it.

But, this is not the happy ending! This is just the broader picture of the concept to be used in building flapping wing MAV. The main research lies within the layers of the smart FRC. The interaction between each fiber and the matrix surrounding it and the interaction between each
layer. These are the areas of research targeted by our research group at the Indian Institute of Technology (IIT), Ropar, supervised by Dr Srikant S. Padhee. As stated above, the research is divided in two parts, the first one deals with the mechanics of the fiber-matrix interface, and the other focuses on stacking of different layers and the mechanics at the layer interface. The author deals with the first part i.e. the fiber-matrix interface mechanics. As this study deals with dimension in micrometer scale, the analysis is called micromechanical analysis of FRC.

The objective is to find a solution to the problem, such as: 1) What happens when a single fiber breaks in the layer with the application of the load? Does it affect the other fibers? 2) What is the role of fiber arrangement in a layer of FRC? Do the randomly arranged fibers enhance the effect of fiber break? 3) What is the mechanics of the piezo fiber-matrix interface? 4) How to implement the current study in other applications as well? The answer to the first three questions will be addressed by developing mathematical equations which will be then validated using commercially available software. These mathematical equations that can prove to be a great help to other researchers and designers who encounter similar kind of problems. The benefits of this mathematical modelling will include reduction in the time taken by the commercial software to achieve the solution and, thus, will then be an easy task of number crunching.

The other part of the research is being done by Mr. Nishant Shikya. His research focuses on the 1) stacking sequence of the layers in the FRC and the mechanics involved in between the two layers, how the consecutive layers behave under different loading conditions. 2) How to amplify the bending and twisting effects due to the application of small electric field so as to reduce the weight of the MAV by avoiding larger power supply. 3) How to control the flapping of wings. As the other part of the research is on the stacked layers, it covers a larger dimension and, hence, the analysis is called the macro-mechanical analysis of FRC.

The research will be helpful in building a MAV without compromising on the design parameters. The MAV will find applications, like in defence, in traffic control systems, pollution inspection, police surveillance, etc. As mentioned earlier this research can be applied in the field of structural health monitoring and biomedical as well. Structural health monitoring means to check the reliability of the existing structures like buildings, bridges, railway tracks, etc. The reverse phenomenon that made the wings to flap, i.e., the applied pressure will generate electricity that in turn can be used to check the health of the structure. Similarly, in biomedical instrumentation one can think of monitoring the motion of the joints in the body and to predict the condition of the joints. One can check the health of the implants placed in the body. This can be digitalized, and one can check his/her joint conditions and implant strength through his/her mobile phone.
Sapna had to choose. Her father was a priest at the popular shrine, Kedarnath. The family never saw him after 15 June 2013, the fateful day when nature decided to raze all signs of human presence from the flood plains of the mighty Mandakini. Over 8,000 cubic meter of water gushed across the valley in about 3 seconds, erasing all signs of an anthropogenic past. His body was never found. Donations from patrons kept the family afloat for a while. The laughable government compensation did little to help their predicament. Especially, as her father had gone missing and was not dead, compensation was provided accordingly.

When her grief-stricken mother started showing symptoms of a full mental breakdown, Sapna moved closer to her relatives in the valley. The younger siblings, a boy of 17 and an 8-year-old girl, could no longer be entrusted to her mother’s care. Soon, the relatives’ empathy and finances dried up. Sapna, now had to find a way to support her family. It was at the precipice of this new endeavour that our paths crossed. We had just started studying for a postgraduate degree in remote sensing, geared towards natural hazard mitigation. As we sat in the class for our first day at university in the flood-battered state of Uttarakhand, each lecturer described the catastrophic disaster as a means to stress the significance of our chosen specialisation. At the end of the day, I expressed my admiration for Sapna’s apparent insouciance on what was obviously an emotional subject and my heartfelt condolences for losing her father. She looked at me with quiet determination and said, “He’s missing, not dead.”

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Scientists agree that the impacts of the “Himalayan Tsunami” of 2013 were intensified by unbridled and unplanned development in the river flood plains. The scale of the tragedy was apparently exacerbated by a monumental failure of inter-agency communication. Warnings were left unheeded, rising water levels in the glacial lake upstream went unreported. State officials delayed taking any action as the “pilgrim season” was underway and closing the gates to the shrine would cost them the precious spoils of tourism. I for one, have never been able to come to terms with the fact that most of the deaths from this catastrophe were preventable. It was then that I decided to specialise in hydrometeorological disasters like floods, determined to work towards more reliable early warning systems.

In pursuit of this arduous but rewarding goal, I was recently able to develop a new semi-automatic flood-mapping algorithm with others from the IITB Monash Research Academy, which promises significant improvements in accuracy over existing techniques. The algorithm explicitly utilises patterns of the radar backscatter, which are observed in the image, in addition to the recorded backscatter itself. Specific arrangements of backscatter values in the image are first identified and then optimised by using advanced mathematical techniques to amplify the information content that is used in flood identification. Finally, a fuzzy machine learning algorithm is used to classify the image into flooded and non-flooded areas, which also expresses the level of confidence in the flood mapping at each pixel. Validating flood maps that are generated by using this technique against aerial photographs demonstrated an improvement of almost 54% in some areas over traditional methods. These results are encouraging as the validation zone also included a notable portion of urban and agricultural land-use.

Urban landforms are, perhaps, the most challenging in radar-based flood detection and, arguably, the most crucial from a flood management perspective. While radar images are widely accepted as the most reliable resource for flood monitoring given their ability to penetrate cloud cover; they are notoriously difficult to interpret and are affected by a variety of uncertainties. Urban and vegetated landscapes, which present an inherently large number of potential scatterers to the radar beam, often result in complex images. Therefore, to arrive at any practicable intelligence, radar-based flood maps generated using automated methods often require post-processing by experts, trained in the physical principles of radar backscattering mechanisms. Automatic image processing chains have recommended the use of supporting datasets such as distance or height above the closest river channels, and land-use and cover information to enhance the accuracy of flood mapping. However, in developing countries where such ancillary information is seldom available with reasonable accuracy, this approach could potentially revolutionise rescue and response operations.

While disaster preparedness has evidently improved, given that the number of fatalities caused by floods of similar magnitudes has declined over the years, what has been accomplished is not nearly enough to cope with the increasing intensity and frequency of weather-related disasters under a rapidly changing climate. This is evident especially in cascading disasters such as flooding, when the rainfall event often leads to landslides, cutting off transport access and communication in the affected areas. If the downstream consequences, such as waterborne
diseases and the mental trauma suffered by flood-affected communities are also considered, floods can be viewed as the single most devastating natural disaster worldwide.

During the initial rescue and response operations, localised information on the whereabouts of flooding is critical in the ensuring of effective regional prioritisation and efficient resource allocation. However, one can intuitively imagine that travelling into flood-affected areas to gather such information during the event is far from safe. Satellite imagery is an attractive and cost-effective alternative to observing the inundated area synoptically. This can facilitate the planning of evacuation strategies and optimise the often limited resources that are available. For example, during the 2013 Himalayan floods, a rescue chopper with 12 Indian Air Force officials crashed, killing all on-board, delaying operations and compounding the magnitude of the disaster. The Himalayas, as well as other flood affected regions, are not easy to navigate without accurate localised information. We hope that by improving the accuracy of single-image flood mapping, we can contribute at least slightly to the safety of rescue workers.

This research constitutes the first part of my PhD project titled, ‘Towards a Comprehensive Data Assimilation Framework for Operational Hydrodynamic Flood Forecasting’. My research strives to integrate all the seemingly disparate sources of flood information presently available, such as satellite and crowd-sourced data, to arrive at more accurate and timely flood forecasts. I am undertaking this research at the IITB Monash Research Academy a collaboration of IIT Bombay, India and Monash University, Australia which was established to strengthen their bilateral scientific relationship. My research team includes A/Prof. RAAJ Ramsankaran from IIT Bombay; and Prof. Jeffrey Walker, Dr Stefania Grimaldi, and A/Prof. Valentijn Pauwels from Monash University. I hope that the model-data integration proposed in this study leads to the development of more reliable flood early warning systems which can allow timely evacuation. Never again should someone like Sapna have to deal with the disappearance of family members due to a flood and abruptly be thrown into dire straits with only false hopes to look forward to.

This article is based on a paper that was published earlier this year: ‘Towards operational SAR-based flood mapping using neuro-fuzzy texture-based approaches’. It was published in Remote Sensing of Environment, which is a highly reputed journal in the field of remote sensing.
Role-Mining the Moonlighting GAPDH Proteins in *Cucumber Mosaic Virus* Resistance in Plants

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“Research is to see what everybody else has seen, and to think what nobody else has thought”, this is a great description of research by the Nobel laureate, Albert Szent-Györgyi. I shall begin with the description of my initial foray into science which had been nothing short of one of the most innocent venture, enrapturement and excitement. Inescapable reasoning and logic in science being steadfast and dependable, explained all the questions that kept cropping up in my curious young mind. It was easy and satisfying and I felt I needed to comprehend and learn more. Science has evolved from an interesting textbook topic to one of the most intriguing and intense passion, woven into my life. Science, and more particularly research according to me are fluid, dynamic and challenging every day and everything that surrounds us.

Plants and viruses have always fascinated me. Hence, I chose to pursue plant virology as the topic of my doctoral study. It is one of the most interesting study topics as focus on this aspect of biotic stress is limited in terms of funding as well as understanding. Viruses work in such pluri-directional conduits that many a times to pinpoint its activity becomes tedious. This is why we try to perform immaculate research in our laboratory at CSIR-IHBT, Palampur to characterise elements which could take part is controlling the spread of viruses in endemic crops which could lead to viro-tolerant varieties of commercially important plants.

Moonlighting proteins are *coup de foudre* for researchers of a wide array of fields, as they participate in a humongous variety of functionalities across multitudes of mechanisms across the

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biological spectrum. Targeting these proteins constantly opens new opportunities for understanding their interactions with other proteins which can affect the structure of a particular mechanistic pattern. What makes their study even more unique is the fact that they function in a very intriguing manner their different functions are disparate and autonomous, opening up a plethora of possibilities in mining their roles in metabolism, developmental and defence processes. Such proteins have been proposed to vary in their functionalities according to their cell type, sub-cellular localisation, state and mode of action, difference in cellular component concentrates, presence or absence of ligands and cofactors and post-translational modifications. Metabolite binding to these proteins, protein-protein interactions or multi-protein complex formation can infer greatly upon their function, while these strategies not being mutually exclusive and can many a times take place in cohesion. Different annotations are conferred upon these moonlighting proteins and a very good example would be to analyse the three-dimensional structure of these proteins to superficially understand their molecular attributes.

Wanting more from our search for elements which could be targeted against *Cucumber mosaic virus* movement protein (CMV-MP), we came across the Glyceraldehyde Phosphate Dehydrogenase (GAPDH) which we fished out of *Cucumis Sativus*. Since its role was well elucidated as a potential moonlighting candidate, we hypothesised and empirically worked to check the interaction of the GAPDHs against the CMV-MP. In lieu of the above, our work focused on profiling of host genes showing interaction with CMV-MP (GAPDH in our study). Furthermore, GAPDH is a ubiquitous enzyme involved in glycolysis and the carbon reduction cycle of photosynthetic organisms. It also has non-glycolytic functions which include fusion of membranes, the exportation of nuclear RNA, the replication and repair of DNA, the bundling of microtubules, apoptosis, and viral pathogenesis. It also regulates the replication and translation of viruses as previous reports suggests, paving the way for its importance in understanding viral movement and pathogenesis. Plants contain several isoforms of GAPDH (GAPDH A, GAPDH B and GAPDH C) encoded by different types of genes (*GAP A*, *GAP B*, *GAP C* and *GAP Cp*) which are located in different sub-cellular compartments. *GAP A* and *GAP B* genes give rise to $A_2B_2$ and $A_4$-GAPDH isozymes of chloroplasts which participate in the Calvin-Benson cycle.

To transport the viral genome into adjacent cells, the viral movement proteins interact with the host proteins to increase the size exclusion limit of plasmodesmata. In another study performed in our laboratory, the association of a cell wall localised ascorbate oxidase from *Cucumis Sativus* with MP of CMV was reported. In a very crucial experiment using the GAL4-based yeast-two-hybrid (Y2H) system, we identified a GAPDH, one of the host proteins that interacted with CMV-MP in virus infected *Cucumis Sativus*. A gene fusion of GAPDH in pGADT7 and MP in pGBK7 expression vector was generated and introduced in yeast strain AH109. Interaction between GAPDH and MP allowed the reconstitution of the DNA-binding and activation domains of the GAL4 transcription factor thereby activating the reporter genes which enabled the yeast to grow on nutrient selection medium. Different concentrations of 3-AT were added in the selection media to suppress the leaky expression of HIS3 gene and detect the positive clones. The interaction was also confirmed using colorimetric assay for β-galactosidase enzyme in the presence of X-gal.
which resulted in the appearance of blue colonies of the yeast due to the activation of lacZ reporter gene.

The results were very promising as all the different isoforms of GAPDH showed a positive interaction with the virus MP. This investigation confirmed a hypothesis that pre-existing cellular factors within the host are imperative in participation with viral proteins to positively culminate into its spread and subsequent infection. As it is fairly well known, there are no sprays to stop the spread of viral infections in plants, antagonistic to the case of bacteria and fungi, exploring molecular mechanisms which participate in retarding the viral spread, is the best way currently known in virus spread impedance. We have proposed the need for genome editing in plants which could curate into an aspect, within plant immunity studies, to excavate possibilities in developing tolerance against ssRNA viruses which are majorly pathogenic to crop plants leading to millions of dollars' worth damage. Our Y2H study was preliminary, but it gave a high throughput analysis of the interactions that were checked and a confirmation that our search for plant agents conferring virus resistance was going on the right track.

An organism is majorly benefitted from the presence of multifunctional proteins as it reduces the number of synthesized proteins and also lessens the DNA required for replication. The amalgamation of the functionalities gives rise to various pathways to initiate, control and coordinate diverse cellular processes including starkly independent ones such as signalling and metabolism. These aspects of studies directly take part in plant immune system responses which can be studied via various omics approaches. Our laboratory, therefore, focuses on these aspects which can lead to crop improvement and usher in a phase of basic science research which, through plant factor manipulation, can control the viral pathogenesis and contribute to healthier and better varieties of important crops. Maybe, one day, our pursuits will lead us to crack the code on why viruses are so heartless in avenging and revenging, or maybe, just maybe, it is us the humans whose uncouth interventions have become competition of sorts to the viruses just to see who is more evolutionarily conserved and fit.

This, in short, summarises my research findings but in the early stages of my doctoral study, I really hope for something significant by the time the fruits of my hard labour ripens. I am being positive and optimistic with future goals and aims of doing something beneficial for the society at large in sight. I wish that by the end of it all I would be able to make my intellect useful to common people and fulfil my dream of being a proud and satisfied ‘Plant Virologist!’
When we dare not teach in a room without light, why teach in acoustical darkness? Several generations of students and teachers have battled the inherent problems caused by noise and poor room acoustics in critical listening spaces. 100 years and more of research on classroom acoustics have passed by and yet we still encounter communication and listening problems in classrooms today. This has a bearing on the learning outcomes, performance and productivity of both students and teachers alike. Without sensitively understanding the aural comfort needs of the classroom users, many classrooms today are acoustical treated and overdesigned at very high costs. These unsustainable practices can be avoided by careful planning and consideration, early on during the design phase of the educational building.

Classrooms are complex learning environments with a myriad of factors influencing speech perception and intelligibility. The accurate transmission of information in the classroom is imperative for learning and academic success. However, there are many factors in classrooms which hinder effective communication. In tropical climates like India, classrooms are typically naturally ventilated with large open windows and are also fitted with noisy ceiling fans to keep the occupants comfortable. The speaker’s speech level although audible in most cases across the classroom, however may not be intelligible. Distortions in speech are caused by the persistence of reflections in the room, a phenomenon known as reverberation. Hard surfaces typically encountered in the classroom such as desks, benches, blackboard, glass windows, concrete walls are all responsible for

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reflecting off the incident sound energy back into the room. These reflections arrive at the listener’s ears from different directions at time intervals that are milliseconds apart. This creates a smearing of the sound and makes it difficult for the brain to distinguish the primary speech information and disseminate it from the reverberant portion. The problem is exacerbated in the presence of high ambient noise levels. Ambient classroom noise levels degrade the speech quality by reducing the signal to noise ratios at different student locations in the classroom. The farther away you sit from the speaker, the more likely you are to experience speech perception difficulties. Apart from these internal factors, open windows also contribute to their share of degrading the acoustical environment in classrooms by bringing in a plethora of noises from the outside world, such as, vehicles honking, construction noise, people talking outside etc. Different noises have different effects on speech perception and intelligibility depending on the frequency content present in these sources.
Since majority of learning in classrooms occurs through verbal communication of ideas and information, words or sentences missed during a distractive noise event can never be brought back into a student’s life again and that is information lost forever to him. Many students miss up to 1 in 4 words spoken by their teacher due to poor intelligibility as a result of degraded listening conditions in classrooms. Reducing ambient noise levels in the classroom also makes it easier to teach and significantly reduces vocal fatigue and the stress imposed on the teacher. Thus, poor acoustical conditions in classrooms hinder the teaching learning process considerably.

In an attempt to characterize the acoustical quality of naturally ventilated classrooms in India, the author got involved in conducting experiments, as a part of the research program at IIT Madras, involving measurements of reverberation time and ambient noise levels in selected classrooms of varying geometry and characteristics under both unoccupied and occupied conditions. Typical values recorded for reverberation and background noise are higher than most values found in literature. The A-weighted background noise levels observed vary from 35 dBA to 63 dBA in university classrooms and 57 dBA to 63 dBA in school classrooms. The signal to noise ratios range between +34 dB to +7 dB in university classrooms and +12 dB to +7 dB in school classrooms. The reverberation time measured in the 1 KHz band range from 0.37 to 2 seconds in university classrooms and 0.65 to 1.44 seconds in school classrooms. The ANSI S12.6 2002 standard recommends unoccupied reverberation times in the range of 0.6 – 0.7 seconds and unoccupied ambient levels of not more than 35 dB $L_{Aeq}$. The NBC 2016 has recommended unoccupied reverberation times at 500 Hz to not exceed 1.1 seconds. The measured reverberation times do not comply with the ANSI standard and the NBC 2016.

Occupant absorption plays a significant role in bringing down the reverberation times to acceptable or near acceptable values especially at the high frequency bands beyond 1 KHz. This becomes favorable to speech communication as majority of the consonants lie in the frequency range of 1000 – 4000 Hz and consonants contribute to 75% of the information that is delivered in speech. Measurements of reverberation times in occupied conditions indicate that reverberation times decrease with increasing occupancy and it is seen that average mid frequency reverberation times are brought down by 0.4 seconds. However, this reduced reverberation time along with the ambient noise levels needs to be brought down further for comfortable speech communication in classrooms.

Speech intelligibility is the single most important measure of communication success in classroom environments. It is the degree of match between the intention of the speaker and the understanding of the listener. There are many methods employed to measure intelligibility. The most straightforward way is to make the listener repeat the word, phrase or sentence spoken by the speaker. The number of correct words is scored and speech intelligibility score is indicated as a percentage. However, these subjective evaluations are time consuming and need considerable human effort. An objective evaluation of speech intelligibility is commonly used instead and is known as the STI (Speech transmission index). The speech transmission index is a single number rating of the effectiveness of the communication channel and ranges between 0 and 1, where 0 corresponds to worst intelligibility and 1 corresponds to best intelligibility.
STI was measured as part of the experiments in unoccupied classrooms. A calibrated signal generator featuring human head-like dimensions was used to generate the signal instead of natural speech. The generated signal has an output level of 70 dBA at 1 meter and consists of frequencies similar to that of the human speech spectrum. At the receiver locations i.e. typical student seating positions, in the place of the receiver, the integrating sound level meter was positioned to capture the STI value. The STI value was found to decrease with increasing distance from the sound source. The STI values were higher when all ceiling fans in the classroom were turned off, as this increased the signal-to-noise ratio at the receiver locations. At the rear end of the classrooms STI was found to be very low indicating poor intelligibility at these locations of the classroom.

In order to enhance the intelligibility especially at the rear portions of the classrooms, speakers resort to the use of sound reinforcement systems. If not set up carefully, this more often only adds to the list of existing problems. The acoustical defects of the classroom also tend to get amplified in the process and make the situation worse. Occupants from adjacent rooms also get annoyed at the amplified noise levels received from the classroom. Moreover, different speakers have different speech characteristics and intelligibility varies across speakers significantly. Speech intelligibility tests are not robust enough to capture these subtle variations. For feeble speakers, voice training and other voice management techniques may help improve communication success. Such speakers would have to rely on acoustical surfaces in the classroom which can help enhance early reflections by channelizing them to different parts of the room having acoustical energy deficits. Reflectors positioned in classrooms at locations near the speaker can help improve the signal quality and reduce listening effort considerably. Thus strategic positioning of absorptive and reflective surfaces in the classroom can significantly improve the overall acoustical climate of the classroom and improve the speech intelligibility across the room.

The studies on classroom acoustics reveal that with a little thought to design and with minimal interventions, we can transform our classrooms and make teaching in ‘acoustical darkness’ a thing of the past and experience the joy of teaching and learning in ‘acoustically bright’ listening environments.
On a show on Discovery channel telecasted in May 2010, a person was sitting in a wheelchair attached to a computer to assist him to speak in a robotic voice “Hello, My name is Stephen Hawking, physicist, cosmologist and something of a dreamer. Although I cannot move and have to speak through a computer, in my mind I am free.” Because of my keen interest in biology, this voice intrigued me to know about the disease he had more than the ‘big bang theory’ he discovered. I learnt that at the age of 21, he was diagnosed with the disease known as “Amyotrophic Lateral Sclerosis” (ALS) or “Lou Gehrig’s Disease”. In our childhood, we have seen people who are paralyzed, and who have lost the sensation in some parts of their body. On reading, I realized that ALS is a condition that involves loss of control over motor function. A person with ALS can sense the outer stimuli but fail to respond to it. The cells, known as neurons or more specifically motor neurons that process the signal from brain to the muscle and other body parts, become weak and degenerate with time and lead to loss of motor functions.

* Mr. Abhishek Vats, Ph.D. Scholar from Sir Ganga Ram Hospital, New Delhi, is pursuing his research on “Role of Protein Homeostasis Pathways in Amyotrophic Lateral Sclerosis.” His popular science story entitled “Damage of Brain Wiring in Amyotrophic Lateral Sclerosis” has been selected for AWSAR Award.
This can be explained by taking a simple example, movement of an electrical fan. If we consider a case where a mouse cuts the wire connected to a fan, no matter how hard you press the switch, the fan will not function. The fan is equivalent to our muscle or body part, the on/off switch is our brain and the electric wire is the motor neurons through which the impulse travels. If this wiring is damaged (degenerated) as in ALS, the brain is not able to send the signal to the muscle and leads to loss of muscle movement as illustrated below in the right panel. Unfortunately, this drastically affects the daily life activities in ALS patients and eventually makes them dependent on family members/caregivers. If limbs are affected, the patient becomes wheelchair-bound, need assistance for activities including holding a spoon, pen and buttoning a shirt. If bulbar muscles are involved, patients find it difficult to speak or swallow food. Most of the ALS patients die within three to five years and very few live over 10 years with the life support system like ventilator for breathing support. After knowing about ALS, I felt that the disease of the nervous system is probably more frustrating and devastating than deadly cancer. This motivated me to pursue research in the field of neurodegeneration.

I got an opportunity to work on ALS during my Ph.D and focused on what causes disconnection between the brain and muscles or other body parts. Undiagnosed or suspected ALS patients usually come to the neurology clinic with their family members with doubts, anxiety and fear but in hope as well. In my study, I proposed to evaluate the blood cells of ALS patients with the expectation to see if examining these cells can tell us about this brain disorder. I saw some changes in blood cells which reflect the changes in brain cells of ALS patients. My work took another direction when a brother and sister visited the neurology clinic at Sir Ganga Ram Hospital. While noting the family history, we found out that the father and an elder sister had died due to similar conditions. It appeared to be a rare familial form of ALS. I decided to study the family to see if any genetic change is associated with the disease in the family. I requested them to participate in the study and they gladly agreed for the betterment of science. I analyzed the genes which have been shown in other populations to be responsible for causing ALS. Surprisingly, no one had examined these genes in the Indian population so far. I found a new genetic change in SOD1 gene in both the siblings which might be the root-cause of their condition. A genetic change is similar to a presence of a red pearl in a white pearl necklace as shown in upper left panel of the illustration. The necklace loses its regularity and appearance. The genetic changes involve abnormal changes in the sequence of the nucleotides (i.e. ATGC) in the DNA. Here, in these siblings the nucleotide guanine (G) replaced by thymine (T) alters the sequence of nucleotide codon from TTG (decoded into Leucine (L) amino acid) to TTT (decode into Phenylalanine (F) amino acid) at 84th position in the SOD1 protein (L84F SOD1). Bioinformatics analysis suggested that this genetic change might be the causal factor of the disease. I, further, wanted to see the penetrance of the genetic change in the family. Without disclosing the genetic change, the neurologist approached the patients and described my interest to study the whole family.

The affected brother who was already on a wheel-chair was highly supportive and gathered his family. I collected the blood samples of 11 members of the family and did the same genetic analysis. Unfortunately, two of the family members: the 23-year-old son of the male patient and
the 28-year-old daughter of the deceased female were having the same genetic mutation. These members did not show any symptoms of ALS. One of the younger sisters of the siblings was not available to give the consent at that time and recently visited the neurology clinic with similar symptoms. After genetic analysis, I found that she and her 11-year-old son also carried the same genetic change. This took a huge emotional toll on me but I took it as a challenge to see how this genetic change in one gene can cause such a devastating disease. One interesting aspect I realized while comparing the clinical features of the three affected siblings. Despite the same mutation, there was difference in the age of onset, the site where symptoms appeared first, severity of disease and survival time after the onset of the disease. All this suggested that ALS is a complex disorder and involves interplay of genetic and additional factors. Though identification of mutation solved one part of the riddle and can be equated to the mouse who chews the electric wire of the fan but what are the molecular consequences of the mutation still remained a mystery. This is a huge concern for the younger asymptomatic members who have this causal mutation and may develop ALS.

As it is difficult to examine the motor neurons from the patients, I decided to develop a motor neuron cell model to study the effect of the SOD1 mutation present in these patients. I cloned and expressed the mutation in motor neuronal cells and examined them. Inside the cell, two subunits of normal SOD1 (wild type) join to carry out the function. Interestingly, I observed that SOD1 mutation destabilizes the protein and it does not form the functional dimer. Moreover, this mutant SOD1 protein becomes sticky and forms clumps (aggregates) in the motor neurons as
illustrated below in middle left panel. Even clinically, similar protein clumps have been observed in brains of people who died of ALS. Hence, these clumps appeared to be the culprit. These protein clumps are equivalent to the trash/garbage of the cell and needs to be removed. At our homes, absence or inefficiency of the garbage truck/person leads to heap of trash which results in unhygienic and unhealthy condition. As shown in lower left panel of the illustration, cells have well-defined mechanism for garbage disposal and if this mechanism is hampered, the unwanted or aged stuff from the cells is not removed. This accumulation of unwanted material in the cell can lead to diseased condition. The mutant SOD1 clumps are also not cleared by the cell and cells undergo degeneration. I found that these cells are under oxidative stress. I, further, examined the protein degradation machinery (garbage disposal system) which has two components: autophagy and ubiquitin proteasome system. Interestingly, modulating the protein degradation machinery had an effect on mutant SOD1 clumps. This machinery can now be further studied to see if it can be exploited to develop effective therapies for this devastating disorder in the future.

To summarize, I have been able to place the three pieces of the puzzle: genetic mutation, protein aggregates and protein degradation pathways. However, ALS is a complex disorder and requires many more pieces to be joined to explain the disease. This is the reason why it is difficult to predict the outcome of a mutation in members who do not show any symptoms. This makes the counselling a challenge for the clinicians and genetic counsellors.
From the time modern humans evolved, a few million years ago, the human population on earth has grown from nought to 1.6 billion. Thanks to the contributing factors including increased birth rate, decline in the death rate, fertility rate, morality rate, life expectancy and better health care standards because of which the population shot up to 7 billion in less than 100 years. In accordance with the demographics, the world population is approximately 7.5 billion at present and is estimated to rocket up to 11.2 billion by 2100.

This uninhibited increase in the population is one of the most pressing environmental concerns that have aggravated issues like depletion in earth’s resources. This effect of depletion in the resources has further led to loss of biodiversity as we humans have stripped every nook and corner of the earth for its resources. A report by World Resources Forum shows that we have nearly extracted 40 billion tons of resources from earth. The imparity in the biodiversity has given rise to increased greenhouse gases mostly CO₂. In 20th century, where the world encountered ~5-fold increase in population, it witnessed ~14-fold increase in CO₂ emissions. The world releases 40 billion tons of CO₂ annually.

As India’s rapid growth continues, we will see a 20-fold increase in carbon emissions. This pattern would repeat from Africa and other nations that are rapidly modernising. This comprises 2/3rd population of earth increasing emissions by 20 tons. That’s a 12-time increase in CO₂. This would breach greenhouse safety levels and could cause a runaway reaction that’d be detrimental to
life on earth eventually resulting in climate change. Drastic global climate changes exacerbate and amplify the risk of life; it is simply suicidal! The increased temperature levels have resulted in rising sea levels, droughts, flooding and heavy precipitation. The statistics says that every year the world is experiencing at least 400 extreme events due to climate change. From 2017, roughly 41 million people have been severely affected by floods and more than 150 million people live below sea level threatening almost quarter of the entire population.

Second crucial factor that is directly interconnected with the exuberant increase in the population is enormous production of waste. A report from World Bank Group on waste management shows that world currently produces ~3 billion tons of municipal solid waste every day and the total household wastes accounts to ~1.5 billion tons every day. India produces approximately 60 million tons of waste every year calculated at 0.7 kg per capita per day. On gross, 77% of this waste is dumped without proper disposal and other 23% is processed by using landfills. The landfills disposal method uses soil bacteria to decompose the waste and produce manure. But often, these landfills produce tons of methane gas. Methane is a deadly
greenhouse gas with global warming effects several times higher than CO₂. This encourages zero-waste products; a process equivalent to the way resources are reprocessed in the nature.

Another paramount factor that is closely knit with the increase in population is “Energy Demand”. Energy is at the spearhead of the global agenda and at the pedantic heart of almost every developmental, economic and environmental issue. An intricate association endures between a country’s economic growth and energy consumption. It is pronounced that a sustained and convenient supply of energy is a prime requirement for a tenable society. In accordance with BP’s statistical review of world energy, in 2017 world’s gross primary energy consumption was 13.6 billion tons of oil equivalent with an annual growth rate of 1.5%. India stands fourth amongst the major energy consumers in the world. In 2017, India’s average primary energy consumption increased to 0.75 billion tons of oil equivalent, contributing to 5.6% of the total world’s primary energy consumption.

At present, majority of global energy needs are met by burning of fossil fuels. As the humankind has fallen heads down for fossil fuels, the menace it has caused has affected the world irrevocably. A world steered by fossil fuel has led to the forefront factor like: energy scarcity. The ideology of scarcity spreads over the entire civilisation; indeed basic idea of any movement has ever hung on the understanding that nothing lasts forever. Crude oil reserves are diminishing at the rate of 4 billion tons every year. At this rate of consumption, world will run out of crude oil deposits by 2050. As a result of macroeconomic expansion, India has become one of the fastest growing energy markets and a study predicts India to be second largest contributor towards the global energy demands by 2035 accounting to 20% increase in energy consumption and demand. Considering this growth trend, the effective conversion of the fossil fuels into lucrative energy lags much behind the ever-increasing demands. Global ingress to productive energy is still one of the major areas to be peremptory hit for a sustainable future. It is imperious to prioritise and address this cardinal without any further delays. One of the crucial factors allied with energy sustainability is effective and judicious management of available energy resources and an indispensable segment of efficient management of existing energy resources is; energy storage. This redefines the energy scarcity problem to energy storage problem thus intensifying the requirement of developing a cost-effective and clean energy storage device. The development of novel ESDs not only facilitates the energy storage but also helps in alleviating the dependency on fossil fuels. It also contributes to grid energy storage thus elevating the use of renewable sources. The best method of storing energy currently is to use batteries.
The tagline is obvious: “The more energy we need, the more energy we find.” Despite continuous handwringing about the shortage of energy, the world has now started to relook and reconsider the renewable sources to satisfy its demands. Thus, a novel energy storage technology is of utmost important as it plays a crucial role in supplying a buoyant, clean and low-carbon energy supply by extending its hands in enabling the reliance on green, clean and renewable sources of energy. It is foreseen that the cost of generation of energy from renewable sources to reduce. Hence, for the judicious use of these sources and integrating them to the regions with a bleak grid infrastructure necessitates new energy storage. In the report “Energy storage trends and opportunities in emerging markets”, prognosticate that worldwide demand for energy storage to shoot up to ~40% in a decade in order to meet the energy requirements.

Our work focuses on reducing the problem of waste management by incorporating its use in fabricating effective storage devices: supercapacitors and thus alleviating energy storage problem. In our research, we are finding alternate uses of bio-waste. One of the discoveries is that when bio-waste materials are heated in an inert atmosphere, it produces a unique allotrope of carbon called Carbon Nano Spheres (CNS). Carbon precursors are preferred for the electrodes because of its availability, low cost, pore volume distribution and good surface area. CNS are spherical nanoparticles with a diameter of ~50nm. They have a good surface area and exhibit excellent electrical properties. These properties make them ideal candidates for ESDs. Supercapacitors made from CNS synthesised from bio-wastes are devices that can charge rapidly and release energy as and when needed. They have a much longer life than batteries. They can thus store more charge and provide energy for a long duration. The main requirements for fabrication of the supercapacitors are novel precursors and advanced configurations. One of the prime criteria in choosing the precursor is surface area and pore size.

CNS is synthesised from bio-waste precursor by heating the same in an inert atmosphere at a constant heating rate. Electrodes made from CNS synthesised from bio-waste make for a perfect material for supercapacitor electrodes due to their large surface area, excellent electrical properties, life cycle and stability. Templated porous CNS has a combination of micropore, mesopore and macropore sizes with a neat tailored hierarchical structure making it an apt material for the electrodes of the supercapacitor. By developing electrodes from bio-waste materials, these “cells” can be sustainable, environmentally friendly and biodegradable. Supercapacitors made of bio-waste materials have both balanced energy and power density making it an apt for energy storage devices.

<table>
<thead>
<tr>
<th>Bio-waste</th>
<th>Specific capacitance (F/g)</th>
<th>Electrolyte</th>
<th>Cycle life</th>
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<tbody>
<tr>
<td>Coconut fibre</td>
<td>236</td>
<td>1.0 M KOH</td>
<td>&gt;10,000</td>
</tr>
<tr>
<td>Coconut stick</td>
<td>208</td>
<td>1.0 M KOH</td>
<td>&gt;10,000</td>
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<tr>
<td>Coconut leaves</td>
<td>116</td>
<td>1.0 M KOH</td>
<td>&gt;10,000</td>
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<tr>
<td>Lablab Purpureus seeds</td>
<td>300</td>
<td>1.0 M KOH</td>
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The future is electrifying!! Novel energy storage plays a vital part in meeting the prudent objectives of the world. A potential driver of the energy storage demand is the use of renewable energy for clean energy mandates. Thus, supercapacitors made of bio-waste materials would be a perfect bomb diffuser for both disposal of waste and energy storage.
It was early 1990s. There were sporadic reports in the newspapers about the greatest boxing legend suffering from a disease which had a fancy name. It struck my imagination as a little kid who had just started learning primary school biology. As a child, I was intrigued both by the man and the disease where you lose motor control of your limbs. I couldn’t fathom what that meant for a champion whose greatest strength were his hands which now kept having tremors. The man was Muhammad Ali and in 1984 he was diagnosed with post-traumatic Parkinson’s disease attributed to his near-fatal boxing matches in the late 1970s. During that time, the cause and general idea of the disease were sparse but the fact that a world-famous sportsperson was afflicted by it made headlines and curiosity peaked among the public.

Fast forward 2016. I was in the fifth year of my PhD studies when Muhammad Ali died. His was a long and painful battle with Parkinson’s. In the last thirty years, the disease has acquired some recognition in general public and a lot has been done for the patients to ease the pain as the disease progresses in later stages since no cure has yet been found. Around 10 million people are living with Parkinson’s and the scientific community has a lot of interest in studying the underlying causes of the disease. The battle has only just begun.

Our bodies are remarkably evolved structures, which have an intricate network of organ systems, working towards maintaining the balance necessary for survival. The cells that make-up the tissues, and eventually the organs, have mechanisms to produce, degrade, recycle, and transport various molecules such as proteins, lipids, etc. essential for their holistic functioning. These molecules are responsible

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* Ms. Sayani Sarkar, Ph.D. Scholar from Bose Institute, Kolkata, is pursuing her research on “Structural and Biochemical insights into Ubiquitination Activities by Ring E3 Ligases.” Her popular science story entitled “The Decline and Death of the Protein Empire: Molecular investigations in Ubiquitination Pathway” has been selected for AWSAR Award.
for catalysing and participating in various chemical reactions which keep turning the wheel of life. Just as physicists study the sub-atomic particles to understand the physical phenomenon in the universe, we biologists, using various techniques, understand how proteins work inside cells. They are crucial to find how cells trigger diseases such as Parkinson’s.

One such family of proteins is essential in maintaining the homeostasis inside a cell by degrading non-essential proteins just like a garbage disposal system. The balance between the production and degradation of proteins is highly crucial since the accumulation of non-required proteins hamper the normal cellular pathways. Life on earth evolved ways to utilise minimum energy to produce maximum products and hence not waste unnecessary efforts in producing proteins that are not required. These proteins, which target other proteins for degradation, are called Ubiquitin E3 Ligases. The word ‘ubiquitin’ derives from the Latin word ‘ubique’ meaning ‘everywhere’ as it is found ubiquitously throughout all organisms. Ubiquitin is a small protein which was first discovered in 1975. It found its enormous importance through the work of Avram Hershko, Aaron Ciechanover, and Irwin Rose who in the 1980s showed that ubiquitin attached itself to proteins which were meant to be degraded and shuttled them to a barrel-like structure, called proteasome, where the proteins were chopped up and recycled. For their seminal work, the trio received the 2004 Nobel Prize in Chemistry and opened avenues hitherto unknown in the ubiquitination pathway.

Ubiquitination involves a cascade of enzymatic reactions which begins with a large protein called the Ubiquitin Activating Enzyme or E1. It brings the single ubiquitin and positions it onto a second player called the Ubiquitin Conjugating Enzyme or E2. The third player involved in this degradation process is the Ubiquitin E3 Ligase. Finally, the E3, laden with the ubiquitin, approaches a target protein and loads the ubiquitin molecule on top of it. This process happens multiple times and the target proteins have a chain of ubiquitins on top of them. Various E3s have designated E2 partners and their crosstalk determines the specificity of the ubiquitin attachment.

As you can imagine, the specificity of this machinery is near astronomical. To keep the cycle churning efficiently, there are around at least thousand different E3 ligases working to capture degradable targets inside cells. Drug companies had their eyes latched onto these E3 ligases since targeting them for drugs meant eradicating diseases which involved the rogue or anomalous behavior of proteins. It was a haven for pharmaceutical dreams. The holy grail for biologists. Finally, we had begun our journey in understanding mysterious and incurable diseases just like Parkinson’s, Huntington’s, etc. In 1998, a gene called Parkin was discovered to be the causative agent in autosomal recessive Parkinson’s disease. Twenty years later, we now know that Parkin is an E3 ligase which targets specific proteins for degradation but in spite of the crystal structure of Parkin where we can visualise the protein we are miles away from designing any therapeutics against the disease.

Our structural biology and biochemistry-driven laboratory works on a group of E3 ligases in humans called RING E3 ligases. These are enzymes with a domain called RING hence acquiring their particular name. Over the last decade, information has slowly gathered regarding the structural and biochemical map of RING ligases. They follow the basic ubiquitination 3-enzyme cascade as described above. There are two E1s, about 30 E2s, and about 1600 RING E3s encoded by the human genome. E3s target a huge number of substrate proteins downstream of the cascade and
the specificity is tightly controlled by E2-E3 pairs. The enzymes may work on a similar catalytic principle but our studies have shown that the E2-E3 interaction is not universal as it was previously thought to be. Each E3 has its own signature and, unless we establish the biochemistry, simple brute force targeting of enzymes might lead to fruitless attempts at blocking cellular pathways.

We have employed multi-protein complex crystallisation and subsequent X-diffraction of the crystals to determine the structures of E3 and E2. This enabled us to visualise the interacting interfaces of the proteins. On close inspection, we visualised minute yet significant differences in the interactions with already published data. This led us to employ various biophysical and biochemical methods to identify if the differences in structure led to any difference in their enzymatic properties. And indeed replacing single amino acids in not just E3s but also in E2s created massive differences in the enzyme activity and their binding affinities with each other. Engaging isothermal calorimetric titrations, fluorescence anisotropy, circular dichroism, and other biophysical techniques, we elucidated the thermodynamic parameters and structurally dynamic nature of E2:E3 interactions. We found that among the RING E3 ligases there were sub-groups determined by the absence or presence of the particular amino acids at the E2-E3 interfaces noted from our crystal structures. Any mutation of these crucial amino acids led to the abrogation of E3 activity hence proving that even though the cognate E2 partner of E3s may be same, but the subtle changes in the interfaces of the E2-E3 leads to huge differences which were earlier unknown. This was the most exciting and challenging part of our study.

So, not only does our study promotes the inculcation of all available methods to understand enzymes, but to also keep an open mind about proteins being highly dynamic and specialsed molecules even though they might seem to work in a similar manner in a particular cellular pathway. On one hand, crystallography helps us visualise proteins with their partners and helps us see the amino acid architecture, while on the other, it is true that a structural view is just one snapshot of a protein in a particular orientation. Proteins are in constant molecular movement inside cells. If we get a hundred or even more snapshots of a protein pair only then can we equate our findings to a real-world scenario. But it can be very difficult to generate such a large amount of structures and hence using biochemical techniques is crucial in augmenting visualised molecular architecture with the chemical phenomenon. Our studies showed us an insight into the evolutionary selection of proteins based on their requirements inside a cell. A pattern can be formulated as to why certain enzymes retained particular aspects of their structure and others lost them. It all comes back to the nature’s beautiful design of utilising the minimum energy pathway.

In a nutshell, progressive steps towards developing drugs in diseases require the concurrent knowledge from both basic and applied sciences. Our work in understanding the basic tenets of the molecular mechanisms of enzymes involved in the protein degradation pathway will build a solid foundation for future experimental design involving specific protein targeting keeping therapeutics in mind. It has been 34 years since Ali was diagnosed with Parkinson’s. A lot has been discovered, experimented, and investigated since then but there is a lot to be done to reveal the molecular mysteries inside living cells and it can only be achieved with continuous in-depth analysis of the interacting proteins at the molecular level.
I watched the movie *Extra-terrestrial* (ET) when I was very young and was fascinated by two things: the idea of space travel (because I wanted to be an astronaut, like many young children) and the scene where ET and Elliott, the central characters of the movie, fly on their bicycle which is one of the most iconic images of the movie. Part of the reason why this is so attractive is that everyone knows that bicycles are not supposed to fly. It has its designated function it can only move on the ground. This is true of most things in the physical world everything has its specified role which can’t be changed.

Surprisingly and fortunately for us, it turns out our brains and their cognitive functions can show such flexibility. Under certain conditions, parts of the brain can learn or be trained to take over new roles something similar to a bicycle learning to fly. This ability of the brain to change known as neuroplasticity generated a lot of interest among researchers and the general public in recent years. There has been an onslaught of studies showing that “training” the brain, even for a few weeks, on a complex task can drastically alter core cognitive functions like attention or memory. Now there are also games that can be played on the smartphone which claim to enhance your cognitive abilities with continual practice of the game. This means that although our physical world is severely constrained, the mental world maybe not.

One remarkable example of naturally-occurring neuroplasticity is in hearing-impaired individuals. Studies have shown that because the Deaf can’t hear, they start “seeing” better. How is this possible? Since there is no audio input in the Deaf, the part of the brain mostly responsible

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* Ms. Seema Prasad, Ph.D. Scholar from University of Hyderabad, Hyderabad, is pursuing her research on “Attention and Unconscious Processing.” Her popular science story entitled “The Changing Brain - Neuroplasticity in the Deaf” has been selected for AWSAR Award.
for processing sound (known as the auditory cortex) is essentially out of a job. But it would be a waste to leave those neural resources unutilised. To avoid this, nature has devised a clever mechanism through which the auditory cortex takes over other functions. One of those functions is visual processing. A lot of visual stimuli our brain through the eyes. These need to be sorted and forwarded to higher areas of the brain for more complex processing. In normal-hearing individuals, a region known as the visual cortex is involved in this task. But in the Deaf, such visual processing is also carried out by the auditory cortex, in addition to the visual cortex. When two brain regions take over a task, the efficiency increases and leads to a visual advantage in the Deaf.

Vision fulfils several functions in humans. It helps us perceive the colour, size, brightness and location of an object. It also helps us to pay attention to objects in the world. While the last 30 years of research on the Deaf tells us that they indeed display better visual abilities, exactly which of these aspects of vision is enhanced is not entirely known. To answer this question, a team of researchers from the University of Hyderabad comprising Seema Prasad and Prof. Ramesh Mishra collaborated with Dr Gouri Shankar Patil from Ali Yavar Jung National Institute for the Hearing Handicapped, Secunderabad. The researchers measured spatial attention through eye movements in congenitally deaf (individuals who are born with hearing-impairment) and normal-hearing participants. Spatial attention is the mechanism by which we selectively process the location of the objects in the world for example, quickly noticing an incoming car while crossing the road. The study published in *PLOS One* found that the Deaf were better at paying attention to visual information compared to normal-hearing individuals. Using a classic task routinely used in attention studies, known as the Posner cueing task, the authors found that the Deaf were faster at detecting the presence of target circles on the screen when they were followed by visual cues in the same location. This can only happen if the Deaf were better able to orient their attention to the visual cues, compared to normal-hearing individuals.

In another very interesting study published recently in *Nature Scientific Reports*, the same team of researchers found that the deaf were also more sensitive to briefly presented visual information using a priming paradigm. In this paradigm, visual cues presented for as short as 16 milliseconds can influence a participant’s responses. For instance, you are more likely to press a button on the left side of the keyboard when a left-arrow is shown to you even if you can’t consciously “see” the arrow. While this phenomenon in itself is astounding and has been heavily debated and researched
upon, the authors found that this “priming effect” was stronger in the deaf. In short, the deaf were more strongly influenced by almost-invisible information. This was one of the first studies to show that the visual advantage observed in the deaf is not limited to the conscious domain but also extends to information not accessible to conscious awareness. While this helps researchers dig deeper into the depths and limits of the visual processing advantage in the deaf, it also has far-reaching implications on our understanding of consciousness itself.

Apart from contributing to our fundamental understanding of neuroplasticity and visual systems, the knowledge gained from such studies can also be used to improve the quality of life of deaf individuals. For instance, researchers can work closely with clinicians and speech pathologists to develop educational tools for deaf children based on such findings.

The fact that our brains can be rewired to adapt to newer contexts and tasks is mindboggling. It casts aside older notions according to which we are born with certain attributes which are, for all practical purposes, unchangeable throughout our lifetime. These new theories and scientific research tell us that our brains can change and grow. This issue is at the heart of our quest to understand human behaviour. How much of what we are is limited by the kind of brains we have? How much can an individual change through brain plasticity and what does it take? Can a hardened criminal, for example, be reformed enough to be confidently rehabilitated back into civil society? We don’t have the answers to these questions yet, but we are getting there.
Ever heard of the quote, “Finishing a marathon is a state of the mind that anything is possible”? Well, for a fruit fly, it’s more much more than just that.

Buzzing off incessantly in search of food, mates and sites to lay eggs, the humble fruit fly is indeed capable of ‘flying’ marathons. Researchers from the lab of Prof. Gaiti Hasan at the National Centre for Biological Sciences, Bangalore, have identified molecules in the fly brain that help it fly for such long periods of time, thereby giving them an advantage in the wild. This work was recently published in PLOS Genetics, grabbing the attention of readers with a striking image on the journal’s cover page.

How long are these fly marathons? On average, tethered fruit flies can fly for as long as 10 minutes, uninterrupted! A minor fraction of these flies can fly for much longer, even up to 30-40 minutes, under lab conditions. But how do these flies do it? One would imagine that flying demands tremendous energy. Well, in this study, the authors have discovered that a protein called FMRFa receptor (FMRFaR) helps keep some neurons in the brain active, so that the fly can continue to fly for long periods of time. So, what happens when a fly does not have this protein? The authors found that a fly lacking the FMRFaR was unable to maintain flight for long. In fact,

* Ms. Preethi Ravi, Ph.D. Scholar from National Centre for Biological Sciences, Tata Institute of Fundamental Research, Bengaluru, is pursuing her research on “Molecular and Cellular Components Underlying Dopaminergic Regulation of Flight in Drosophila Melanogaster.” Her popular science story entitled “Fly Marathons” has been selected for AWSAR Award.
the FMRFaR mutants, as they are called, could only sustain flight for half the time as that of their wild-type siblings.

FMRFaR is a G-protein coupled receptor (GPCR) that sits on the plasma membrane of cells. GPCRs are synonymous to our doorbells, in the sense that they transduce messages from outside to the inside. For example, GPCRs receive signals in the form of hormones, neurotransmitters or other small molecules from the cell’s exterior and convert them into appropriate responses within the cell. FMRFaR does exactly this job, but in a very specific class of neurons.

Fruit flies have an elaborate neuronal network in the brain, with different neurons making different signaling molecules to help convey specific types of information to one another. Like humans, they too have a class of neurons that are dopaminergic. These neurons typically synthesize and signal using the molecule called dopamine. In humans, dopaminergic neurons are well known because of their association with Parkinson’s disease. Similarly, in fruit flies, behaviors such as locomotion, learning and memory, motivation, have all been linked to proper functioning of the dopaminergic neurons.

Interestingly, the authors found that the FMRFaR was specifically enriched in certain dopaminergic neurons of the fly brain. When FMRFaR levels were reduced in these neurons, the flies were unable to sustain flight for long periods. In fact, genetic experiments allowed the authors to identify that loss of FMRFaR in dopaminergic neurons during the adult stages led to severe loss of flying ability, so much so that the flies could only fly for less than 3 minutes.

The question then is: what signal does FMRFaR generate within these neurons? Like many GPCRs, an inactive FMRFaR can be stimulated by specific peptides from the external environment. This results in the production of a small molecule called Inositol trisphosphate (IP$_3$) within the cell that diffuses and binds to its receptor partner called Inositol-trisphosphate Receptor (IP$_3$R). The IP$_3$R is on an intracellular compartment called the endoplasmic reticulum, where it functions like an ion channel and releases calcium stored within this compartment. The resulting elevated calcium levels in the cell somehow changes the membrane potential of the neurons, making them active. This process termed ‘neuronal excitability’ facilitates active neurons to release factors such as neurotransmitters, which are the signaling messengers between neurons.

Loss of FMRFaR hampers this very process of neuronal excitability. To understand this aspect, the authors introduced two different fluorescent proteins, one that reports the levels of cytosolic calcium and another that reports changes in membrane potential. Fluorescent proteins are probes that change fluorescence intensity to reflect changes in levels of molecules of interest. Dopaminergic neurons lacking the FMRFaR showed reduced ability to respond to a stimulus that would otherwise cause membrane excitability. However, when these neurons were genetically supplemented with a protein that would enhance neuronal excitability, flies lacking the FMRFaR in dopaminergic neurons could fly for moderately longer. These experiments convinced the team that FMRFaR stimulated release of calcium was required in dopaminergic neurons to maintain optimal membrane excitability and thereby flight.

Membrane excitability primarily depends on the function of ion channels that are present on the plasma membrane and that allow influx and efflux of calcium and other ions such as potassium.
and sodium. Thus FMRFαR stimulation can directly or indirectly affect membrane excitability by altering the function of these ion channel proteins. To test this idea, the authors introduce us to another molecule called, Calcium-calmodulin dependent Protein Kinase (CaMKII), which is a calcium sensitive protein that adds phosphate groups on other proteins to make them either active or inactive. Supplementing FMRFαR deficient dopaminergic neurons with CaMKII ameliorated the flight defect observed in adults. This led the authors to propose that CaMKII is an active participant and functions downstream of the FMRFαR signaling cascade. In fact, genetic and imaging experiments led the authors to believe that CaMKII could be activated upon FMRFαR stimulation in these neurons. Interestingly, inhibition of CaMKII in dopaminergic neurons also led to reduced flight bouts in adult flies.

The authors put forth a model wherein stimulation of FMRFαR in dopaminergic neurons leads to calcium elevation that activates CaMKII. Further down, this could either directly or indirectly influence plasma membrane resident ion channels that are the key regulators of neuronal excitability. Many more questions have sprouted from this new discovery, keeping the authors on the hunt for answers. But one question that is deeply intriguing is: what is the initial trigger that stimulates FMRFαR and where is it coming from? The authors believe that although the peptide, FMRF is known to activate the receptor, the exact neurons that release it or the context in which it is released remains to be identified.

Overall, this study puts FMRFαR at the critical interface of receiving and transmitting information in neurons, thereby enabling the neuron to be in an excited state a state that enables flies to fly marathons! So then, just like a protein supplement for humans, would providing more FMRFαR genetically help the flies fly even longer? “Well, that is a completely different story for another day!” says Preethi, the lead author of the paper.

The work was conducted by Preethi Ravi, a graduate student, under the guidance of Prof. Gaiti Hasan at the National Centre for Biological Sciences, Tata Institute of Fundamental Research, Bangalore. This work was also assisted by Dr Deepti Trivedi at the Fly Facility, NCBS.
Rising sun with its gentle light marks the arrival of morning. Birds’ chirp and the time on our clock, sometimes with a blaring alarm, confirm the arrival of morning. Each of these, among several others, is an indicator of morning. But can we know about morning by following only one indicator? Let’s deliberate. What if the sky is cloudy and we don’t see the sun rising, will this mean that morning is yet to come? Of course not! Our alarm will remind us of morning irrespective of whether there is sun or not. But what if, on some occasion, our clock doesn’t work. In that case, birds may chirp or sun may rise or our near and dear ones may remind us that it’s morning already. So in essence, we usually don’t look for only one indicator, rather we consider several indicators. If one indicator fails, we can check another and thus be sure. It is very unlikely that all the indicators will fail simultaneously.

So the best way to get an idea about an event, it seems, is not to rely on only one indicator. Rather, observe several indicators and depending on their collective state, arrive at a conclusion. In this way, we deliberately add redundancy in order to get reliable results. This is exactly what we do in fault diagnosis of machines. Fault diagnosis is a broad term that addresses mainly three questions. First, find out whether there is a fault in the machine or not. If fault is present, next question is to find the location of the fault. Once location of the fault is found, finally, find out the
type of fault and its severity. In this article, we will only limit ourselves to the last aspect. But for simplicity, we will still use the term fault diagnosis to address that particular problem.

The method

To determine the health of a machine, we collect a set of indicators that best explain the condition of the machine. In scientific jargon, we call those features. Before discussing further let’s first discuss what are those features and how they are calculated.

First, data needs to be collected from a machine whose health needs to be assessed. Data might pertain to vibration level of the machine or its temperature distribution or the sound produced by the machine or something else. Sensors are needed to collect each type of data. By analogy, a thermometer, which is used to measure body temperature of humans, is a sensor that measures temperature. Likewise different types of sensors are available to measure different quantities of interest related to the machine. From research it has been found that vibration based data are more suitable for fault diagnosis as compared to other types of data, say temperature or sound. So in this article, we will limit our attention to vibration based fault diagnosis. And the sensor that is most commonly used to measure the vibration of a machine is called an accelerometer. From the data collected by accelerometer(s) we calculate features like the maximum level of vibration, similarly, the minimum level and other statistical features like skewness, kurtosis, etc. It is not uncommon to collect 10-15 features.

After feature collection, the next task is to find out what type of fault is present by using those features. One way to do this is by comparing the obtained feature values to pre-existing standards. But standards are available for few specialized cases when each feature is considered in isolation. For multiple features, no concrete information can be obtained from standards. The way out of this problem is to come up with an algorithm that takes all feature values as input and produces the output related to the type of fault present.

Construction of such an algorithm requires prior faulty and non-faulty data of similar machine be fed to it. The algorithm should ideally work well on this prior data. Once fine-tuning of its parameters are done, new data are fed into the algorithm and from its output, we infer the fault type. If the algorithm is carefully constructed, error in prediction of fault type will be negligible. In some cases, it is also possible to get perfect accuracy. The problem just considered is a subclass of a broad field called pattern recognition. In pattern recognition, we try to find underlying patterns in features that correspond to different fault types. This type of pattern recognition tasks are best performed by machine learning algorithms. The simple technique just described works fine for a large class of problems. But there exists some problems for which the features previously calculated are not sufficient to identify fault. However, it is possible to modify the technique by using transformation of data as well as features. Transformations are a way of converting the original data into another type such that after transformation more insight is gained. This is similar to using logarithms in mathematics to do complex calculations. While direct computation of complex multiplications and divisions is difficult, using logarithm we transform the original problem into
a simpler form that can be solved easily in less time. The transformation trick along with pattern recognition methods, are surprisingly effective for most fault diagnosis task.

Some recent advances

Up to this point, we have argued that redundancy is important. It helps us take reliable decisions. However, it requires collection of huge amounts of data. Thus, continuous monitoring of machine, also known as online monitoring, is not feasible. So we seek an algorithm that is capable of finding fault types using only a few measurements. One way to do this is to select a few important features that can perform fault diagnosis. Research shows that it is indeed possible. But merely finding best features is not enough, because to calculate the features, even though small in number, we need to collect all data. Hence issues related to online monitoring will still exist. A way around this problem is not to collect all data but only a fraction of it randomly in time. And the data should be collected in such a way that all information regarding the machine can be extracted from these limited observations. An even optimistic goal is to reconstruct the original data from the limited collected data. By analogy, this is similar to reconstructing the speech of a person, who speaks, say, 3000 words, from 300 random words that you have remembered of their entire speech. The problem just described is known as compressed sensing. And no matter how much counter-intuitive it may seem, encouraging results for this problem have been obtained in signal processing and these methods are beginning to get applied to problems of fault diagnosis. The problem is still in its infancy in fault diagnosis field.

What we learned (and what we didn’t!)

In summary, we have learned that to diagnose faults, we need multiple features and sometimes we have to transform the data into different domains for better accuracy. We then observed that we can get rid of the redundancy inherent in this method by using compressed sensing methods. All these techniques come under data-driven methods. It is called data-driven because all analyses are done after we collect relevant data from the machine. These methods are quite general purpose and can be used to diagnose faults in different components, say detecting faults in cars or in other machines.

Apart from data-driven methods there also exists another class of techniques that go by the broad name of model-based methods. In model-based methods, we formulate a full mathematical model of the machine and then try to find out how the response of the model changes if a fault is introduced and using this fact, try to find the nature of fault for a new problem. Though model-based techniques are important in their own right, in some cases it becomes very difficult to find an accurate model of the system. In contrast, data-driven methods are more robust against external noise and flexible, meaning we can perform different analysis using the same data and obtain different insights. Another advantage of using data-driven methods is that the whole process of fault diagnosis can easily be automated.
In this article, we have only considered the field of fault diagnosis. In fault diagnosis, faults are already present and we wish to either detect them or segregate them depending on fault type. But there exists another branch that deals with ways to predict the time of occurrence of fault in future, given the present state. Basically, they determine the remaining useful life of the machine. This sub-branch is called fault prognosis which is also an active area of research.

Given the advancement of research and scope for automation, it may be possible, in not so distant future, to get updates on your phone about possible malfunction of a part of your car while driving your car or while enjoying a ride in a driverless car, maybe!!
Looking through the college magazine, Dr Tripathi, a retired college principal couldn’t recognize many faces including some of his favourite students during his tenure. Tripathi sir started feeling uncomfortable about his situation since his retirement from service. Sometimes he forgets the name of his wife, children and grandchildren and at times a sudden panic strikes him without a reason. The person who never forgot a route that he once drove on, now blacks out in the middle of the road every now and then. He used to have a good memory and never had problems remembering. However, after being persuaded by his relatives he reluctantly agreed to consult a doctor about his problem. They fixed an appointment with a renowned neurologist in town. On the day of the appointment, he was taken to the clinic and the doctor was briefed about the problem. After listening, the doctor decided to conduct MRI and CT Scan tests. Also, he was asked to answer a few personal questions in writing drawing from his current experiences. And made to draw a clock marked with readings. He was asked to visit the doctor the next day for test results and reports.

The following day when he visited the doctor, he was told that he is suffering from Alzheimer’s Disease (AD) and needed to take immediate medication. Tripathi’s world came crashing down as he was aware of the consequences of the so called “forgetful disorder” The doctor informed that the medication can only stop memories from being erased for a short time but the inevitable cannot be avoided. On the way back home, he was cursing the situation he was in, especially for someone who spent most of his time reading and teaching.

* Ms. Anjali Raj, Ph.D. Scholar from JSS College of Pharmacy, Mysuru, is pursuing her research on “Alzheimer’s Disease and Olfaction.” Her popular science story entitled “The Smoke that Kills Smell and Fade Memories” has been selected for AWSAR Award.
He was wondering how and why it happened and what will be his future now. Could it be the smoking but then he thought that smoking would protect his brain.

A decade ago, it was a general belief even to scientists that cigarette smoking though it is harmful to the body, is beneficial to the brain due to certain ingredients contained in cigarettes. Many reports at the time gave smoking a heroic posture for the memories of human being and to boost the levels of intellect. However, later the hero of the story turned out to be the villain when Alzheimer’s Association declared cigarette smoke (CS) as one of the causative factors for dementia including Alzheimer’s Disease (AD).

On reaching home, Tripathi started to browse the internet to find out the possible causes of his disease before he forgets. AD had a lot of definitions by many sources but he knew that Webster’s Dictionary would give him a better insight. Unfortunately, the History professor failed to understand much of the associated technical terms. He found the words “plaques and tangles” being highlighted and understood that these things are currently in his brain too. What are these things and how are they harmful?

On further research he found that plaques and tangles are actually manifestations of certain types of proteins called Amyloid Beta and Tau, both of which are otherwise produced naturally, but in the disease condition tends to accumulate heavily and cause death to the neurons. He also found out that just like how we verbally communicate, the neurons communicate through impulses using messengers called neurotransmitters, which are also affected negatively in this condition. Obviously, he came across the association’s warning against smoking and scolded himself for his carelessness.

In his quest to find out about the effects of smoking, Tripathi stumbled upon the fact that it could cause AD. It was a starting point.

We needed evidence to convince many Tripathis that this villain is not a local “rowdy” but actually a “monster” who will snatch everything including health, wealth and peace of mind. Since scientific evidence always holds strong but we couldn’t use human subjects, we decided to rely on animals (mice (rodents)) to gather proof.

A widely used cigarette brand among the Indian population was selected and the animals were made to inhale it while kept in a non-ventilated chamber. We also discovered that this smoke kills our sense of smell more drastically than even the memories. Interestingly, a parallel investigation led us to the fact that the human brain shares an intense relationship with the nose and it can access the higher center directly where the information remains stored for a much longer time and any injury or trauma to the brain affects the sense of smell first. Hence, we took the lead and studied the inhalation effects of cigarette smoke on memory through its effects on smell for a period of four months (as revealed from prior information). Animals were subjected to find out behavioral aspects, they were trained beforehand for some specific tasks. As expected the culprit was caught red handed in causing memory degradation as well as weakening of the sense of smell.

But what sparked the curiosity was that smoke faded the sense of smell much before it affected the memories in the exposed animals. This element is easier to prove in an animal than humans because animals use sense of smell to perform most of their activities. The post-mortem
study revealed more interesting details which included the detection of the so called “plaques” both in the memories specific area of the brain called Hippocampus and also in the structural connection of smell to brain called olfactory bulb. Most importantly, the plaque density was higher in the bulb than Hippocampus and some of the earlier mentioned chemical messengers said to involve in maintaining good memory (which also includes smell since they are stored as memories to an extent) were found in less level in both the structures.

Results of our investigation indicated to smoking being harmful not only to memory but also to our sense of smell, which could pose a serious problem. Since we also “smell threats” and deal with them without noticing it consciously. Without a proper sense of smell, we may not be able to taste and subsequently enjoy food.

Our study has been backed with several reports which proved that 85 – 90% of AD cases (irrespective of the cause) reportedly are suffered from an initial loss of smell but this fact is generally neglected. Probably every smoker complains of a reduced sense of taste but most of the time never identifies/ignores their loss of smell which actually occurs much earlier and can indicate to a possible memory loss/dementia. We don't know whether Dr Tripathi experienced any such smell variations or not but if he could have atleast been careful with his body responses quite a while ago and reported to the doctor earlier, medication could have prevented him from advancing to AD. Our body always warns us well in advance that it needs help, but more than half of us don’t take it seriously and delay to act upon it.

Our lab aims at identifying alternative mechanisms to neuro-degenerative disease, mainly Alzheimer’s disease and also actively research on alternate/combined therapies to treat the disease with minimal side effects to patients, all in animal models. The research team for the above work included Anjali Raj (Research Scholar), Dr S.N.Manjula and Dr M.V.S.S.T. Subba Rao from JSS Academy of Higher Education and Research, in Karnataka.
Bacteria are ubiquitous and the first form of life to appear on earth. Bacteria exist in different shapes like spherical, rod and curve. These cells exhibit the potential to live in extreme and hazardous conditions like radioactive waste, volcanoes soon after eruption, in Antarctic ice to boiling hydrothermal environment. Bacteria can be found in symbiosis, in a kind of friendly relationship with the host or may be parasitic, that is, may cause damage to the host. Good bacteria is essential for human body especially in the digestive system to help in breaking down substances that the human body cannot. They are also required for the survival of plants as they serve the function of nutrition supplementation and promote growth. Bacterial endophyte forms a part of our environment possessing epiphytic as well as endophytic nature.

Environmental pollution has now reached its peak, contaminating the land, water, air. Recent incidence of toxic froth formation in Varthur Lake, Bellandur Lake are the hideous effects of the polluted water bodies. Various activities like discharge of effluents from industries especially textile and chemical industries, release of domestic waste to flowing water bodies, leaching of heavy metals are major reasons for water pollution. This complex organic compounds access our food chain leading to serious health issue. It was reported by Boivin and Schmidt in the year 2005, that complex organics like 2, 4-D, an herbicide has potential to accumulate in surface water bodies.

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Accumulation later followed by bio-magnification in the human body followed by uncontrolled multiplication of meristamatic cells, inhibiting DNA and Protein synthesis as proposed by Tomlin in the year 1994. Finally leading to various types of carcinoma, damaging endocrine glands and testicular cells leading to decreased sperm count in testis. Reports also suggest of mother's milk being contaminated with 2, 4-D on exposure. Azo dyes released from textile industries are also known to be carcinogenic, and thus it is essential to study, in detail, the breakdown and the metabolite formed as the result of the breakdown.
Biologically these problems can be treated by employing methods like enzymatic degradation, phytoremediation and microbial bioremediation. Employing plant for the degradation is termed as phytoremediation. This is a cost-effective method of degradation and environmental friendly concept. Phytoremediation has a drawback as plants lack mobility, possibility of remediation is only when the contaminant is in plants vicinity. Enzymatic degradation is an expensive method supplementation of appropriate enzyme would be required for the breakdown of a compound. Concepts of fungal bioremediation is also effective and less expensive provided the only constraint is the delayed multiplication rate of fungal cell thus directly influencing the time required for the degradation. Bacterial bioremediation is quick, cost effective method with high rate of degradation. Usually majority of the studies collect bacteria from contaminated site like for example in case of oil degradation the bacterial cells will be isolated from the site contaminated with oil spill. In case of dye degradation the bacteria will be isolated from the site of textile effluent. The possibility of collecting the pathogenic strains are more in this method. The present study, isolation is carried out from ethno-medicinal plants that are usually consumed by humans and thus the strains isolated are also safe for humans and the environment.

This is a first report of bacterial degradation of a diazo dye, Direct Blue-14 dye by endophytic bacteria. The concepts of employing endophytic bacteria for dye degradation followed by the optimization of dye degradation, prediction of the probable pathway of degradation and the analysis metabolite formed and finally the assessment of the toxicity of the formed metabolite is studied. A complete picture of the bioremediation of Direct Blue-14 dye is explored in the present study.

*Centella asiatica*, also known as Indian pennywort, is a well known etho-medicinal plant. Among the four types of bacteria isolated from *Centella asiatica*, only one strain had the capability to grow and breakdown the dye. Bacteria named *Bacillus fermus* was isolated from the plant and was used in degrading Direct Blue-14 dye. After finding the appropriate bacteria it was essential to know the requirement of the bacteria to degrade the dye. It was found that *B. Fermus*, enjoyed sucrose as source of energy than other source like maltose, lactose and fructose. The possible reason was since it is a plant bacteria it was used to sucrose as it is the most abundant source of carbon in the plant. Better degradation of dye was observed in presence of sucrose. Later, it was essential to understand the amount of dye the bacteria can resist and degrade. It was noted that after the limit of 70 mg/L of dye a drop in degradation was noticed also indicating the reduction of bacterial cells. It was also noted that as the bacterial cells increased the degradation dropped suggesting competition for nutrition. The best degradation was further subjected to understand the break down by bacteria using analytical methods like LC-MS, FT-IR, Spectrometry that revealed the bacteria had broken down the azo bonds that strengthens the structure of the dye was broken thus leading to complete decolourization of the dye. Thus the formed product was subjected to test the toxicity of the metabolite as well as the dye on the genetic material of the cell. Onion cells were used for the purpose of the cytogenotoxicity studies. It was observed that after degradation product or the metabolite was less toxic in comparison to that of dye.
As it is clearly evident from the above picture that endophytes can completely degrade dye in a day, it is possible to completely treat water from effluent and use it for agricultural purposes. Research is essential in this aspect, as we are aware of water shortage problems that has to be immediately attended. Therefore, I would like to conclude by saying that nature has its defence, all that is required is to research and to understand a method that can reduce the problem that we face today in a simplest way possible. These endophytes are equally good in degrading more complex compounds then dye. Good results were also observed in degrading 2, 4-D pesticide. It is essential to identify the right condition and the right bacteria for a particular compound.
Welding Research: Effect of Joint Design on the Corrosion Resistance of Welds

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Introduction

Before reading the actual story of the research carried out and its outcomes, let us familiarize ourselves with the characters involved in this story. Whenever we have to join two or more materials together permanently, one word comes to the mind; yes that’s right! ‘Welding’. Since welding joins materials permanently unlike other methods such as nuts and bolts, it is important in our lives. Welded structures are all around us. Let us see some of the examples: LPG cylinders, frames of bicycles, bikes, cars, buses, metallic structures under flyover bridges, etc. Apart from these common observations, welded structures are used in engineering applications like in aircrafts, nuclear reactors, space vehicles, etc. When two materials are to be joined together by welding, extreme heat is used to melt the materials and an extra material is supplied from outside in the joint area. Since the materials are getting melted by the heat used in the welding, their structure (technically speaking: 'microstructure') gets changed. Due to these changes, the joint made may prove to be superior or inferior (in terms of properties) than the original base material joined, that depends upon numerous factors. We have to be very sure that the welded structures are of superior quality and should be capable of withstanding the service conditions in which they are subjected to, has the capacity to lift loads, bear corrosive environments, etc. This is done by performing

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simulations and experiments for specific applications before actual welding is performed on the structures meant to serve in actual practical conditions.

The present research was focused on “understanding the effect of joint design and high-temperature exposure on the corrosion performance (means the ability to withstand against corrosive environment) of the welded joints of 304L grade stainless steel”. First, let us understand the meaning of “joint design” in context with welding procedures. Have a look at Figure 1 given below; there are two plates that we want to join together by welding, their edges are straight; these are not ready for welding. An additional step is required, i.e., cutting the straight edges in such a way that a groove or seat is formed which will be filled by additional material (called as filler material) during welding as mentioned above. The shape of the groove cut on the plates is called the “joint type or design”. There are various joint types, the selection of which is based on various requirements, but single-V and double-V types are the most commonly used and also were used in this work. See how two types of joints were made, one was single-V and the other was double-V as evident from their shape.

Figure 1: Diagrams of two types of weld joint designs used in the present work.
Background of the problem

The term “corrosion” is a disease to materials just as various diseases to human bodies. This can cause materials to fail during service applications and it can become a cause for accidents or failures of structures. There are different corrosion types depending on the environment. The severity of different corrosion types on materials can be understood from various accidents which have resulted in the loss of human lives. Let us see some of such accidents from the past in which corrosion of materials was one of many factors responsible: Bhopal gas tragedy-India (1984), Prudhoe Bay oil spill-USA (2006), Carlsbad pipeline explosion-New Mexico (2000) etc. Thus prevention against corrosion is a major challenge and it is a key area of research. The knowledge of how a material is going to behave when it is subjected to a corrosive environment is required beforehand. The material used in this research was “304L stainless steel”. When we read or hear the word “Stainless Steel”, one thought comes to our mind that they do not corrode or they are not affected by rust. That is true in case of normal environmental conditions because for a steel to be called “Stainless”, it should have at least 12% chromium in it to resist corrosion. Stainless steels are basically materials that are made up of elements like carbon, chromium, nickel, and iron apart from the addition of various other elements. Most common stainless steel used is the grade 304 (belonging to the so-called Austenitic Stainless Steels family), also known as 18/8 steel. The utility of this steel is seen from its applications ranging from most common ones like thermos flasks to highly advanced ones like in satellite launch vehicles. One of the most important problems affecting this steel (and also other austenitic stainless steels) is Sensitization. If these steels are exposed to high temperatures like in the range of 600°C-850°C for a certain period of time, its elements, namely chromium and carbon combine together to form compounds. Now this compound formation will create regions in steel that are deficit in chromium (as total chromium content is going to be the same, compound formation means chromium content in certain regions will increase and in certain regions, it will decrease); now these regions will no more resist corrosion as already discussed; we need at least 12% chromium for corrosion resistance. The occurrence of such compound formation is termed as sensitization which if it occurs makes these materials prone to corrosion attack and the material is said to be sensitized. “Degree of sensitization (DOS)” is the technical term used to indicate the extent of sensitization in a material. Higher the value of DOS, it means more sensitization in the material and vice-versa. Apart from exposures to high temperatures, sensitization in materials can also occur during their welding. Another type of corrosion that this material is prone to, is pitting corrosion. Pitting corrosion is a highly dangerous form of corrosion which damages the materials. This usually occurs in the presence of a corrosive environment especially containing chloride ions; for example sea water.

Research conducted and its findings

Now, we have become familiar with the terms like joint design, sensitization, pitting corrosion, degree of sensitization (DOS), we can move forward in knowing the aim of the research carried out and its outcomes. The present work focused on knowing the effect of joint design and high-temperature
exposures on the sensitization and pitting corrosion resistance of 304L stainless steel welded joints (metal inert gas (MIG) welding was used). The objectives of this research are presented in the form of questions for clarity and answers are given after each question. This represents the actual output obtained from this research. The complete results of this research are published in the form of a scientific article in the *Journal of Manufacturing Processes*.

Q: 1) If we use two most commonly used joint designs namely single-V and double-V to weld 304L stainless steel, which joint type will give more corrosion resistant weld joints?

Ans. Single-V joint design can prove to be a better selection for better corrosion resistance.

Q: 2) What is the effect of time duration when these steels are exposed to high temperatures on the corrosion performance of these welds?

Ans. It was found that as the exposure time increased, welds became more prone to sensitization and pitting corrosion, thus indicating that, higher the exposure time to high temperatures, higher will be the vulnerability to sensitization and pitting corrosion attack.

Q: 3) If 304L stainless steel weld joints are exposed at 750°C in a furnace, and we have to cool them to room temperature with the following options available: 1) Just let them in the furnace (slow cooling), 2) take them out of furnace and leave in open air (relatively faster cooling) and 3) put them directly in water for instant cooling (fastest cooling); which method will be highly desirable/undesirable in affecting the corrosion resistance of weld joints?

Ans. Slower cooling like in case of a furnace is not desirable. Faster cooling should be done for prevention against sensitization.

Q: 4) Is there a correlation between a stainless steel getting sensitized and its vulnerability to pitting corrosion attack?

Ans. Yes, there is. The results of the experiments revealed a clear relation between the extent of sensitization and pitting corrosion attack. Higher the sensitization in a material, lower will be its pitting corrosion resistance and vice-versa.

Knowledgebase generated from this research is beneficial to the scientific community. “If we have a component made up of austenitic stainless steel, which is going be welded and subjected to a corrosive environment, selecting single-V joint design over double-V design could prove to be a better decision”. The technical reason behind it is that the total heat required to complete welding was less in case of the single-V joint type. In a nutshell, those welded joints are good that require less heat input for their welding and better corrosion resistance could be expected from them as compared to the joints made using relatively higher heat input.
Application of a Biomaterial (Urease) in Medicinal Field and other Industries to Remove Urea from Synthetic and Real Sample

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Urea was prepared from urine in the year of 1817 by William Prout and it is the major nitrogenous waste product generated due to protein breakdown in human liver.

\[
\text{Protein} \rightarrow \text{Amino Acid} \rightarrow \text{Ammonia} \rightarrow \text{Urea}
\]

As the so-produced ammonia is toxic to our body, it is converted into harmless waste product (urea) through urea cycle.

\[
\text{Ammonia} \rightarrow \text{Urea}
\]

This Urea is eliminated from the body through urine by the action of kidneys after glomerular filtration. And the measurement of its concentration in urine and blood is clinically important in the assessment of kidney functioning. Increased level of serum/plasma urea concentration depends on two major organs: increased production of urea by the liver and decreased elimination of urea by the kidney. The increased production of urea is also related to a high amount of protein intake, tissue breakdown during starvation to provide an energy source, ageing, etc. Excessive drinking of alcohol, having a trace level of urea, causes elevation of blood urea level.

A normal level of blood urea is 2.5-7.8 mmol/L. But when this level goes beyond this limit, many problems arise in the human body.

Keeping this in mind, researchers of an analytical section of Visva Bharati have developed a new material immobilised urease (urease immobilisation on silica gel) by which blood urea level has been detected successfully in vitro. Pure urease, due to its high cost, lack of stability,

* Ms. Sneha Mondal, Ph.D. Scholar from Department of Chemistry, Siksha Bhavana, West Bengal, is pursuing her research on “Enzyme Immobilization.” Her popular science story entitled “Application of a Biomaterial (Urease) in Medicinal Field and other industries to Remove Urea from Synthetic and Real Sample” has been selected for AWSAR Award.
limited availability, difficulties in recovery from a reaction mixture was not used. Urease enzyme is an enzyme which is derived from a leguminous plant source named Jack bean. JB Sumner first identified urease in a crystallisable form. This research group has immobilised or attached enzyme urease on an inorganic material, silica gel through covalent attachment. This newly synthesised material was applied in both human urine and blood samples. Immobilised urease hydrolyses urea (a specific substrate for urease) into ammonia and carbon-di-oxide like pure urease.

At first this research group proved the conversion of urea into ammonia by newly synthesised material in synthetic solution, i.e., they loaded measured amount of material into a glass column, then urea solution was continuously rambled through the column and the column eluate was estimated spectrophotometrically at 380 nm wavelength (absorbance value was near about 0.2 units). They also measured the spectra of pure ammonium chloride solution which also gives a peak at the same wavelength (absorbance value 0.2 units). Thus, conversion of urea into ammonia was successfully carried out and the activity of the synthesised material was surprisingly found to be 3-fold higher to native enzyme activity.

Then, they applied the above-mentioned protocol in some real samples like blood and urine. In this case, the same amount of material as in case of column study was given to blood (serum/plasma) samples, containing the same amount of urea as was given in case of a synthetic sample and the absorbance value was found to be same. They also followed the same procedure in a human urine sample and obtained the same results. From these experiments, they found that the efficiency of newly synthesised material was 3-fold higher in comparison to pure enzyme activity.

This research group is still working to explore new technique as dialysis in the human body system utilizing this newly synthesised material. The main function of the kidney is to remove excess fluid including urea from our body. But, when the kidney fails, dialysis is the alternative treatment at the end-stage of kidney functioning. But this method is expensive and time-consuming. For this reason, they had decided to use immobilised urease in combination with zirconium phosphate which can adsorb ammonium ion. As zirconium phosphate has not enough potentiality for the complete removal of blood urea, it can’t replace dialysis in patients with no renal functioning. Besides these, the use of zirconium phosphate has the following advantages: reduces the time period of dialysis, and replaces the onset of dialysis therapy for the patients having some renal functioning.

There are also various applications in which our synthesised material can work.

1. A single domain antibody L-DOS47 was found in Jack Bean urease. When the cancer cells undergo catabolism, urea that is present within these cells also catabolises resulting in the production of ammonia and hydroxide ions. This ammonia production is responsible for the increase in pH of the medium surrounding the cancer cells. These metabolites provide a stress for the cancer cells (lung and breast cells). This stress is mainly due to the toxic effect of ammonia, increased lactic acid production and lack of removal of metabolic acids resulting in an acidic environment surrounding the cancer cells.

2. This enzyme could be used as an antigen as it is able to stimulate a strong immunoglobulin response. H. pylori. causes ulceration diseases, possibly gastric cancer, which is inhibited by the catalytic activity of this plant enzyme, Jack Bean urease.
(3) The occurrence of Ethyl carbamate of wine imposes a harmful effect on human beings, which is derived from ethanol along with urea. This causes a carcinogenic effect on humans, mainly during the storage timings. In this case, acid urease is effectively working. So, as a precautionary measure, wine is first treated with a preparation of acid urease. This acid urease removes urea from wine, which is the potential source of ethyl carbamate.

(4) Biosensors have wide applications such as biomarkers which are used for medical diagnostics. Various pathogens and toxins are also detected by biomarkers. They have several properties such as it is highly specific and sensitive, user-friendly, low cost and compact in size. With the use of urease enzyme-based biosensor blood urea is measured.

(5) Nowadays, the use of enzymatic procedure gets high attention for the removal of phenolic pollutants from aqueous solution. Industrial fertiliser, rich in urea, is treated with immobilised urease. In this case, urease is immobilised onto polyester through chemical coupling method.

(6) In plants, urease is involved in urea metabolism. Urease within plants uses externally and internally generated urea as a nitrogen source. Urea derived nitrogen is easily available to plants only when it is hydrolysed by plants. In this way, urease plays an important role in the germination and seedlings nitrogen metabolism.

So, this research group is working hard to apply their synthesised material as an alternative to dialysis, lung and breast cancer treatment and also in the case of wine industries.

The research team includes Dr B Mandal, Dr Sneha Mondal, Dr Susanta Malik, and Dr Mousumi Chatterjee. The work is still in progress.
Most of us while playing with the sand, tend to make fascinating structures with it be it magnificent castles, caves or mountains. Despite knowing that these structures are not eternal and bound to collapse either by the sea waves rolling over the shores or by the slight touch of our mischievous friend, most of us would still desire to see our creation sustain forever. In 1834, John Scott Russell, an engineer and naval architect was the first man to witness such a fantastic piece of nature (a special kind of water waves), now called solitary waves which try to sustain themselves indefinitely. Solitary waves are way different and unique in their properties than the waves we encounter in our day to day life. Once generated, unlike ordinary waves, these waves try to maintain their shape being unperturbed by any disturbances in the surrounding. When two of such waves collide, each one of them passes through each other without feeling the presence of one another, keeping their identity intact.

You must be thinking what makes these waves magically so robust? To answer this, let’s imagine the moment when we drop a pebble in a still pond. It generates a wave which travels as an expanding circular ring on the water and fades as it moves away from the source and eventually dies out. This water wave can be thought of as it is made up of many small waves where each of this wave tends to travel with different speed. Thus, some of these tiny waves would move fast, and some would move slow making the overall shape of the wave (initially generated) to change and continuously spread over the larger area while propagating. This phenomenon is called dispersion.

* Ms. Gunjan Verma, Ph.D. Scholar from Indian Institute of Science Education and Research, Pune, is pursuing her research on “Dynamics of Bose-Einstein Condensate in Linear and Nonlinear Regime.” Her popular science story entitled “Journey of Solitary Waves in Quantum World” has been selected for AWSAR Award.
Spreading of the wave eventually causes it to die and disappear. Now if somehow the speed of these small waves can be adjusted appropriately such that the waves which tend to move slow and lag behind are pushed forward while the waves which tend to travel faster are slowed down, the overall shape of the initial wave can be preserved forever. When water (medium) acquire such powers to modify the speed of small waves in it, it is called as a nonlinear system. Thus when nonlinearity balances the dispersive behaviour, robust solitary waves are formed.

These waves not only exist in water but found to exists in a variety of systems starting from tiny cells of living beings to optical fibers (cables used to transfer light signal from one place to another) to massive and huge rotating neutron stars etc. These waves proved to be of enormous importance in our today’s multi-billionaire telecommunications industry where the information through the optical fibers is sent as light pulses in the form of a solitary wave which helps to keep the information intact. On the other side, these solitary waves bear the understanding of much-feared tidal waves (Tsunamis) in oceans, signal propagation in neurons and formation of majestic phenomena such as Morning Glory Cloud (hundreds of km long cloud wave) etc. As these structures were found to exist in various domains and proved to be of great worth, scientist wondered about there existence in the quantum world too. Indeed, these solitary waves were found to exists in the much fascinating quantum world, and I joined the excitement of the scientific field and conducted my PhD research to understand their behaviour in the quantum world. You must be thinking what a quantum world is? Is it different than the world we live in?

We know that everything in this universe is made up of atoms and atoms are so tiny that we can’t see them individually with our naked eyes. Whatever entity we see all around us is generally made up of a vast number of atoms. We call this as the classical world, but when we observe thing close to the level of individual atoms, we approach the quantum world, and these two worlds are very different from each other! To give an example, in a classical world if we throw some balls on a wall, the balls are supposed to bounce back. Also, if we can measure the ball’s initial position, speed and at what angle we are throwing the ball, using the rules of classical mechanics we can very well predict the complete fate of the ball such as where it is going to land finally. But for the same case, in the quantum world, we can never precisely tell where the ball is going to land beforehand and can only tell what is the probability of it in landing at a certain place. Also, in the quantum world, there will always be a finite probability that some of the balls would tunnel or pass through the wall to the other side which is entirely counter-intuitive to the behaviour seen in the classical world.

Truly speaking quantum world is weird and very non-intuitive but today it is a well-established fact that the strange rules of quantum mechanics govern the movement and behaviour of every single particle in our universe. The question arises why don’t we see these effects in our day to day life? According to the laws of quantum mechanics, every particle possesses both wave and particle-like properties. This is called wave-particle duality. One cannot determine the particle’s position and its momentum (velocity) at the same time. The better we know the precise location of the particle, the less we know about its momentum (velocity) and vice versa. This is called uncertainty principle. Individually every particle in this universe is bound to show these quantum mechanical properties, however when a large no. of particles come together in a system; they tend to behave
incoherently, suppressing their unusual quantum features and leading to the reality of our classical world.

As it is challenging to isolate a single particle and observe the quantum world and this raises the question of whether we create a quantum world with a large number of particles or not? Yes! Indeed we can. If we can make the large number of particles in a system to behave coherently such that every particle mimics the behaviour of every other particle in the system, allowing it to look like a single giant atom, it can result in a quantum world. In fact, as a part of my PhD work, we regularly created such a quantum world in our lab which is called Bose-Einstein Condensate (BEC). We form Bose-Einstein condensate by cooling a gas of few thousand atoms (bosons) to a temperature of about 100 billion times lower than the temperature of ice in your fridge. Einstein predicted the idea of this quantum world or quantum system in 1925, based on the calculation of our very own Indian scientist Satyendra Nath Bose. We build our own cooling machine with the help of Lasers and Magnetic fields. It took almost 75 years for scientists to first demonstrate such a working cooling machine since the prediction of BEC which later also fetched two Nobel Prize in 1997 and 2001.

Once we generate the quantum world which is about 100,000 times larger than the biggest atoms in the universe in our lab, we look at the behaviour of solitary waves in it. Solitary waves are of many different types, and we study one of its kind in the condensate, called dark solitary waves. Usually, waves in water are seen as a bump or heap on water, but dark solitary waves are peculiar as they look like a depression (absence of particles) in the medium (water or condensate). In my numerical calculations, I found dark solitary waves sustain only if the quantum world (BEC) is shaped like a thread and if we shape the quantum world like a sheet or a ball, the waves become unstable. Once the waves become unstable, they start to bend like a snake and finally break into a chain of vortices (like hollow cores). We notice, these hollow cores wander in the quantum world and collide with each other where they burst into ordinary waves finally disappearing in time. This behaviour is not observed in classical systems. While studying these waves, we also figured out a new way to generate these waves in the condensate. Our findings contribute towards the understanding of solitons in the less known quantum world. We expect in the long run such contribution will help us to build the complete picture of solitary waves which in turn would allow us to harness their full potential. In future, we would implement these theoretical findings in our experimentally created quantum world!

This article is based on my published research papers as mentioned below.

Title: Generation of dark solitons and their instability dynamics in two-dimensional condensates (Physical Review A, Vol 95, Issue 4, Page 043618)

Title: Bose-Einstein condensation in an electro-pneumatically transformed quadrupole-Ioffe magnetic trap (New Journal of Physics, Vol 17, Page 023062)

Title: A compact atomic beam based system for Doppler-free laser spectroscopy of strontium atoms (Review of Scientific Instruments, vol 88, page 033103)
An accidental discovery of X-rays in the year 1895 by Roentgen is one of the most influential contributions to the modern science and technology. These high energy electromagnetic waves quickly revolutionized many diversities of scientific research from bio-medical research to experimental quantum mechanics. Without any exception, X-ray astronomy is now a major area of interest in the field of Astronomy. Ever since the birth of X-ray astronomy in the year 1962, thousands of celestial bodies are being studied which are emitting X-rays with fascinating physics encrypted in it.

While the scientific importance of understanding the X-ray universe is justified beyond any debate, the practice of X-ray astronomy is challenged with major technological limitations. Unlike the X-ray sources we have in our laboratories, celestial objects are often very faint and hence we need large area sensors to increase the efficiency of observation. But the major difficulty in building X-ray sensors lies in the development of mirrors which can efficiently reflect X-rays. As X-rays have small wavelengths, they pass through practically all substances with very little interaction. This makes building sensors and mirrors difficult for X-ray astronomy. This issue is traditionally addressed by using grazing incidence mirrors where X-rays reflect at a very small angle (<0.5°) from the surface. Crudely, this is analogous to a stone bouncing off the surface of the water when it is put at some slant angle.

While grazing incidence X-ray optics is very popular in X-ray astronomy community, however it has many limitations. Telescopes made with these types of mirrors have a small band

* Mr. Panini Singam, Ph.D. Scholar from Indian Institute of Astrophysics, Bengaluru, is pursuing his research on “Development of Multilayer Mirrors for Space based Astronomical Applications.” His popular science story entitled “Multilayer Mirrors: A New Horizon for Astronomical X-Ray Optics” has been selected for AWSAR Award.
width, small effective area and are very bulky. Combined with the fact that X-rays from celestial objects don't enter earth's surface because of thick atmosphere, all X-ray telescopes have to be places in outer space. This technique is not only costly but lays severe limitations on size and weight of the instrument. To address this issue, we (in collaboration with IIA, ISRO, and RRCAT) have developed multilayer mirrors which can efficiently reflect X-rays even at very high angles. Multilayer mirrors, as name suggests, contain a series of thin atomic/molecular layers of different materials on top of each other. When X-rays are incident at higher angles to the mirror, only small fraction rays are reflected while most of them just get transmitted. Since there are multiple layers of different materials on the top of each other, at each layer interface, the wave gets divided into transmitted and reflection components. Over a large number of layers, all the reflected component of X-rays at each layer gets added up to give an overall enhanced reflectivity from the mirror.

Typically all the mirrors we have fabricated consist of alternative metallic and non-metallic layers which are stacked to form a multilayer structure. We have fabricated Tungsten/ Boron Carbide (W/B4C) multilayers which contains a series of Tungsten layers alternating with Boron Carbide layer. The contrast in densities of Tungsten and Boron Carbide materials provide an excellent condition for maximizing overall reflectivity of the mirror. We have fabricated these mirrors at RRCAT, Indore by a technique known as magnetron sputtering. In this technique, a substrate (a smooth Silicon wafer on which multilayer structures are deposited) is exposed to vapours of different materials (Tungsten and Boron Carbide in our case) alternatively under controlled conditions. During each exposure of the substrate to these vapours, a thin layer of the order of a few nano-meters (nm) gets deposited on the substrate. This process is carefully repeated until a few hundreds of layers are deposited. An utmost care and optimization of coating conditions are required for multilayer structures with low interlayer roughness and minimal discontinuities in the layer.

We have fabricated a variety of multilayer mirrors by changing the thickness of each layer and with the different number of total layers. Multilayer mirrors show narrow band reflectivities at specific angles (Bragg peaks) at X-ray wavelength. As the thickness of each layer is varied, the angle at which these Bragg peaks occur varies. Physical properties like the surface roughness, stability, adhesion in the layers, and reflectivity varies significantly with the thickness of the layers. Hence, we have fabricated and studied their properties for multilayer mirrors with the thickness of layers varying from 0.8 nm to 3 nm. All these mirrors are tested at X-rays from energy 0.7 keV to 16 keV at Indus synchrotron radiation facility RRCAT to understand their behaviour. Multilayer mirrors with a wide range of thickness have their applications for specific requirements in astronomy. Small thickness multilayers have the reflectivity at high angles which are used for developing large effective area telescopes, while large thickness multilayers are observed to have higher reflection efficiencies. These results are reported in the Journal of Optics in 2017.

As we are developing these mirrors for space applications, it is very important to know their stability in the space environment. A major factor that can affect the performance of these mirrors is the rapid change in the ambient temperature of the telescope during satellite’s orbit around the earth. Satellite in a typical low earth orbit experiences extreme temperatures from \(-40^\circ\) C to \(+50^\circ\)
C over a span of 90 minutes. As these mirrors contain layers of contrasting materials, they may experience differential interlayer thermal expansion/contraction over the orbiting period. This may increase the interlayer roughness and discontinuities among layers which will degrade the performance of mirror over time. To understand this effect, we have subjected our mirrors to the temperatures as experienced during the orbit of a satellite in regulated thermal chambers at ISITE-ISRO. We have studied multi-wavelength X-ray reflectivity of these mirrors before and after the thermal treatment. We have observed that the mirrors with small thickness layers are more stable and immune to the thermal treatment. We have reported these results in Journal of Astronomical Telescopes, Instruments and Systems, (JATIS), 2018.

One of the direct applications of these mirrors in astronomy is X-ray polarimetry. X-rays, like any other electromagnetic wave, have electric and magnetic fields perpendicularly oscillating normal to the wave propagation. The orientation of the electric field/magnetic field gives the information about the polarization state of the light. In astronomy, polarization information of the light gives unique and important information about the properties of the celestial object. For example, X-ray polarimetric studies of an accreting black hole give precise information about the orientation, spin and mass of the black hole. Similarly, a variety of astrophysical sources like, Neutron stars, Magnetors, Pulsars, Active Galactic Nuclei (AGN), etc. are expected to produce polarized X-rays with fascinating physics behind it. But in X-ray regime, it is difficult to extract polarization information from the radiation. A mirror acts as a polarizing element when it reflects X-rays at 45°. But as discussed earlier, the reflection of X-rays happens only at a very small angle (< 0.5°). Since now we have technology and recipe to develop multilayer mirrors to have X-ray reflectivity at large angles, X-ray polarimetry is not far from reach. Towards this, we have developed a unique conceptual design of multilayer mirror based soft X-ray polarimetry which can operate less than 1 keV. There is no other technique currently available which can do the job without multilayer mirrors. We have published this design concept in a special edition on astronomical X-ray polarimetry by JATIS, 2018.

Our progress in understanding the behaviour of multilayer mirrors helps in developing next-generation astronomical X-ray instruments with enhanced capabilities to understand the mysteries of high energy events from the cosmic objects. Multilayer mirrors also contribute in opening a completely new window of observing the universe such as soft X-ray polarimetry. Capacity to fabricate a variety of good quality multilayer mirrors has reinvigorate new possibilities in the otherwise saturating field of astronomical X-ray optics.
Unravelling the Mysteries of CRISPR Memory Generation

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Adaptive immune response plays a vital role in the survival and evolution of a living being. This mechanism helps to fight against various pathogenic infections and ensures their abolishment upon future occurrences. Our micro co-inhabitants, like unicellular bacteria and archaea, do face such life-threatening challenges by phages (virus made up of proteins and nucleic acids like DNA or RNA). These viruses make fatal use of bacterial cellular machinery for their propagation. To protect themselves from extinction, bacteria have acquired and developed an adaptive immune system called as CRISPR-Cas (Clustered Regularly Interspaced Short Palindromic Repeats - CRISPR associated genes).

This immune system contains a CRISPR locus, which is present within the genome of bacteria. It harbours numerous short repetitive DNA sequences termed ‘repeats’. Upon phage infection, the Cas protein machinery (Adaptation complex) uptakes small fragments of nucleic acids that are specifically derived from the infecting phages and incorporates them at the first repeat of the CRISPR locus. Such incorporated sequences (called ‘spacers’) partition the array of repeats (refer Figure 1). This process instils the molecular memory of infection within the bacteria. The leader sequence in proximity to the first repeat encompasses a signal for expressing the spacer and repeat information in the form of regulatory CRISPR RNA. Another set of Cas proteins (Maturation complex) processes this CRISPR RNA to generate functional guide RNA (gRNA). This active form of gRNA contains the sequence of a CRISPR repeat and a single spacer. The repeat region of the gRNA signals the assembly of various Cas proteins on to it, thus forming an RNA-

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protein surveillance complex. Upon recurring phage infection, CRISPR-Cas surveillance complex can identify the phage genetic material by sequence similarity to the spacer. This detection signals the interfering Cas nuclease to silence the infection by rapid degradation of phage genetic material. This, in turn, protects the bacteria from fatal phage encounters (refer Figure 1).

By incorporating new spacers, CRISPR memory expands during each phage invasion. This repository of infection memory passes onto the next generation of bacteria and ensures their fitness against evolutionary pressures such as phage attacks. The spacer located in the proximity of the leader is known to achieve immediate response against the infections. Manoeuvring this bias, CRISPR machinery incorporates the spacers derived from fresh phage invasions at the leader proximal repeat (amidst presence of numerous repeats in CRISPR array). This process maintains the chronology of spacer insertion events such that the spacers corresponding to newest infections are located at the leader proximity. Despite being such a vital step in the CRISPR mediated immune response, the molecular events guiding the directionality of spacer insertion remains elusive.

Figure 1: Pictorial depiction of CRISPR-Cas mediated adaptive immune response against phage infections
A research team at Indian Institute of Technology, Guwahati (IIT-G) sought to understand the mechanism by which CRISPR-Cas machinery identifies the first repeat as target site of spacer insertion in a bacterium named *Escherichia coli*. A complex formed by the two proteins namely, Cas1 and Cas2 is known to select spacers and insert them at the target region (i.e., first repeat). Various genetic and *in vitro* experiments performed by Dr. B. Anand’s research group have resulted in identifying the involvement of a protein called Integration Host Factor (IHF) in the expansion of CRISPR memory. IHF is a DNA architectural protein that sharply bends the linear DNA (in the shape of ‘U’) upon recognizing a specific sequence (IHF Binding Site IBS). Employing various biochemical assays, the research team could identify IBS in the CRISPR leader and monitor the bending upon IHF binding. While investigating the indispensable requirement of this structural
architecture for spacer insertion, the research team also discovered another key sequence in the leader (IAS - Integrase Anchoring Site). In addition, the research group demonstrated that IAS is crucial for recruiting the Cas1-2-spacer complex and is distantly located from the spacer insertion site (refer Figure 2). Observations made by the team have proven that IAS is brought in close proximity of spacer insertion site by IHF mediated bending of CRISPR leader. This structural change recruits the Cas1-2-spacer complex around the first repeat and promotes the directional incorporation of the spacer. The molecular interplay of key regions in the leader, Cas1-2 and IHF ensures spacer insertion at the first repeat alone. In turn, these mechanistic features empower the bacteria with a quick immune response against recent viral attacks and ensures a productive fight to evade infections.

The current research exploration in the area of CRISPR-Cas immunity opens up the possibility of developing novel applications in a plethora of fields ranging from therapeutics to digital memory storing devices. An upcoming area of therapeutics, called phage therapy, employs virulent phages to specifically target and kill disease-causing bacteria in humans. Many of these bacteria possess CRISPR-Cas immune response and can successfully evade phage invasions, thus leading to the failure of medical treatments. Understanding the molecular events leading to CRISPR-Cas immunity paves the way for designing drug inhibitors to silence CRISPR-Cas response and helps to promote the efficacy of phage therapy. Recent research generated from George Church’s lab at Harvard University, harnesses the potential of CRISPR-Cas system to integrate spacers. The scientists utilise the spacer integration ability of the immune system to transform bacterial cells into data storage devices. Usually, the electronic devices such as, hard disks store the data in combination of binary codes ‘1’ and ‘0’ which corresponds to the positive and negative polarity of a magnet, respectively. Combination of these binary codes can be assigned to a character of a data, pixel of a picture or a frame of a video. The sequential arrangement of these binary codes stores this digital information within the electronic memory device. Scientists have developed an analogous system utilising various combinations of nucleotides (building blocks of a DNA polymer) i.e., Adenosine triphosphate (A), Guanosine triphosphate (G), Cytidine triphosphate (C) and Thymidine triphosphate (T). In the proposed concept of a DNA digital data storage device, various nucleotide combinations are assigned to a data. As the CRISPR-Cas system has the ability to collect and store short spacer DNA information, scientists have repurposed this mechanism to store synthetic spacers that are encoded with the desired data module in a sequential fashion. Using advanced sequencing techniques, the spacer information encoded within the CRISPR locus was read in a serial order and the output was obtained in the form of images and videos. In this context, the research performed at Dr B Anand’s lab in IIT-G helps to shed light on the molecular mechanism by which spacer information can be stored in a sequential order within a CRISPR locus. Empowered with these mechanistic details of CRISPR memory generation, the scientific community could potentially fine-tune the DNA storage devices to achieve utmost precision in data capture and storage.
In May 2017, two distressed families approached our hospital to get their respective sons, aged 7 and 12 years examined. These young boys, hailing from small suburban villages of Andhra Pradesh and Odisha, were requested by their school heads to consult a city doctor. Reportedly, there was a sudden decline in their scholastic performance and attention span in school. From being bright and intelligent children without any medical issues post birth, they had suddenly become inattentive and dull in just a matter of 6 months. The worried parents tried to counsel their children but every attempt failed. Unable to meet the expectations of the parents and teachers these boys became socially withdrawn and eventually refused to go to school. Soon, one of them developed a problem with walking and had multiple falls. His speech was unclear so he stopped talking and going out to play with his friends. His mother observed that his skin colour was darkening day by day. The other boy could not see the blackboard as his vision had started blurring. He repeatedly visited the washroom at home and in school. Parents scolded him for being careless and considered it as a pretext to escape from studies but did not realise something was wrong with him until one day he could not recall recent or past events. Both the families had an income which was below the poverty line so they could only consult a doctor in their town who gave them some vitamin syrups and left them in this condition for another one month. As things worsened, they were referred to a neurologist in the city which was closest to their hometown. Magnetic

* Ms. Archana Natarajan, Ph.D. Scholar from National Institute of Mental Health & Neurosciences, Bengaluru, is pursuing her research on “Mass Spectrometry-Based Targeted Metabolomics for the Diagnosis of X-Linked Adrenoleukodystrophy.” Her popular science story entitled “Screening for X-Ald by Tandem Mass Spectrometry using Dried Blood Spots” has been selected for AWSAR Award.
Resonance Imaging (MRI) and other neurological evaluations were carried out where doctors suspected X-Linked Adrenoleukodystrophy (X-ALD). With a referral letter, these patients were sent to NIMHANS, Bengaluru for a check-up. Detailed evaluation was done at the neurology, neuroradiology and neurochemistry departments to investigate into the issue these boys were independently facing with some overlapping symptoms.

MRI revealed changes in the brain associated with a genetic disorder, X-ALD where very long chain fatty acids (VLCFA) accumulated in the body leading to symptoms coinciding with some of those described above. It could affect the nervous system, create hormonal imbalance, weaken their muscles and cause many other complications. It can affect all age groups but mainly affects young boys/adult men and women above the age of 50, who inherit the faulty gene. The symptoms are not visible after birth but can appear at any time in the later stages of life and if left undiagnosed at the right time, it can even lead to permanent disability and death in some cases. Apart from suspecting X-ALD based on MRI and neurological evaluations, clinicians suggest for plasma VLCFA estimation by a technique called gas chromatography mass spectrometry (GC-MS), which is expensive and requires more blood volume to be collected from the patient.

We could understand the mother, Binodini’s, from West Bengal, distress when she found out that her son was suspected to have X-ALD. Seeing her 21-year-old son (A: earlier it says 12?) run away from home after aggressive outbursts on multiple occasions made her visit different doctors and get him checked. Post his MRI testing in Kolkata, he was sent to our hospital (A: the name?) where the clinicians suggested a plasma VLCFA after which they would get the diagnosis confirmed by genetic testing. Unable to pay INR18,000 for the test, she requested the doctors to discontinue the evaluation and left for her hometown. We requested the patient to make a visit to the hospital again but being illiterate and from a poor financial background they could not understand the importance of the test.

Meanwhile, we had received the funding from the Department of Biotechnology to establish a low-cost test method for screening of X-ALD which could be quick and a procedure that would cause less pain to the patients during blood sample collection. Our method included the testing of the by-products of VLCFA, called VLCFA-LPCs (lysophosphatidylcholines) in dried blood spots (DBS), where a finger prick could get us close to 0.5-1 ml of blood. Collecting spots on the filter paper, drying them and measuring multiple analytes in just a small 3 mm spot of blood from it is a well-known method for performing newborn screening of children for many inherited metabolic disorders. For a decade, our laboratory has been offering the testing facility for the screening of inborn errors of metabolism by tandem mass spectrometry, not just for patients consulting in NIMHANS but also from other parts of India at a very low cost compared to other private laboratories. We wanted to establish another diagnostic test with a similar concept to screen patients for X-ALD. So, we coupled DBS technology with liquid chromatography tandem mass spectrometry (LC-MS/MS) technique and used it to our advantage where multiple samples can be tested quickly at a lower cost when compared to the conventional plasma VLCFA testing by GC-MS. When the patient has been pricked multiple times sample collection from veins becomes extremely challenging. In such conditions, collecting blood as dried blood spots by a finger prick
can help in easing out the situation by causing less discomfort to the patients. After drying the blood spot cards, these samples can be sent by post to Metabolic Laboratory, Department of Neurochemistry, NIMHANS. So, patients who are unable to come to our hospital could also be screened for X-ALD, currently for free of cost but comparatively at a much lesser cost than the plasma VLCFA estimation by GC-MS.

After the test was established and validated in our laboratory, the clinicians called Binodini and convinced her to bring her son for clinical check-up along with DBS based biochemical screening for X-ALD by LC-MS/MS, done free of cost. Unfortunately, his symptoms had worsened by then as he had severe behavioural problems which were difficult to manage. He threw childish tantrums, had stopped eating food, remained attached to his mother always, became violent, used curse words, wanted to talk to only girls and constantly asked his mother to get him married. He was facing issues because of the adolescent onset of this condition. His test results turned out to be positive which correlated with his MRI findings. Since they were not able to pay for genetic testing, the clinicians had to continue his evaluation based on our test reports only. The other two boys
aged 7 and 12 years were also screened positive for X-ALD by our DBS-based LC-MS/MS method and were also confirmed positive by genetic testing. We have been able to screen 21 such patients as positive for X-ALD by our method. We hope that the progression of their disease condition could be clinically managed because after a certain age even bone marrow transplant would not work as a method for treating X-ALD.

DBS method of sample collection for measuring VLCFA-LPCs the better markers for biochemically screening patient for X-ALD by LC-MS/MS will be a potential method to screen children at birth for this disorder. It could be added as a mandatory test to be conducted for every newborn along with the other metabolic screening tests which are conducted post birth. One blood spot has a potential to test for many disease conditions which could be managed with clinical intervention right from the time a child is born. Some of these inherited metabolic diseases, if left untreated, undiagnosed or misdiagnosed can lead to severe neurological conditions which when left unmanaged can also cause death. This could avoid financial and emotional distress to the family whose child is suffering. Continuous research initiatives like these which are patient-centric need to be given utmost priority in our country where so many diseases are yet to be managed and many are left undiagnosed. Our testing technique could provide a ray of hope especially to those families who cannot even afford a bare minimum meal. As citizens of this country it is our responsibility to contribute towards research that is able to bring a positive impact on the lives of the citizens belonging to all sections of the society.
Today’s WASTE is Tomorrow’s WEALTH: Recovery of Rare Earths from Waste Magnets of Wind Turbine

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The role of “METALS” in the development of human civilization is well-known. Metals are the solid material known for its malleability, ductility, electrical and thermal conductivity. Starting from agriculture to automobiles, computer to construction, electricity to equipment, mobile to medicine, to spacecraft, television to transport and wires to weapons, metals in combination of other materials and alloys are used as an integral and essential part of modern technologies. Our everyday life and its comfort cannot be imagined without the use of metals.

Among 118 elements discovered yet, there are few metals having special properties. The addition of small quantity of these metals can drastically change the quality or performance of the product. For the past decade, we have observed that fluorescent tubes/ CFLs/ LEDs have replaced lightbulbs for lighting in our homes. There are some important metal present inside the coating of fluorescent tubes, LEDs, etc., which produces bright white light. These special metals are known as “Rare Earth Metals”. One fluorescent lamp contains only 1-2 gram of rare earth metals, but the presence of this small quantity drastically improves the lighting performance.

Have you ever thought about how data is stored in the hard disk of a laptop or computers? Hard disk contains one critical component i.e. “Rare Earth Magnet” which is responsible for

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storing and retrieving the digital information. In a hard disk, around 10-20 g of rare earth magnets is used for storing the digital information. These rare earth magnets are known as “Neodymium-Iron-Boron (NdFeB)” magnets. NdFeB magnets are also used in speakers, earphones, generators of wind turbines, motors, etc. In generators of wind turbines, around 250-650 Kg of NdFeB magnet is consumed to produce 1MW of electrical energy. Around 16% of the rare earth metals produced worldwide is utilized for the production of NdFeB magnets used in wind turbine.

NdFeB contains 23-27% of Neodymium (Nd), 63-67% Iron (Fe) and ~1% Boron (B). Neodymium is one of the important rare earth elements used as ingredient of magnet. The combination of Iron with Neodymium in NdFeB magnet generates superior magnetic properties. These magnets require 70-90 times lesser volume in comparison to conventional magnets (AlNiCo and Ferrite magnets) for producing the same magnetic strength. Therefore, the use of NdFeB magnet is continuously increasing in various applications to minimize the size and weight of the product. Currently, NdFeB magnet industry is developing with a growth rate of 20% per annum.

In recent times, Rare Earth Metals are like “Salt and Pepper” of modern technologies, due to their special chemical, magnetic and fluorescence properties. Rare Earth Metals are a group of 17 chemically similar elements (Scandium, Yttrium, Lanthanum, Cerium, Praseodymium, Neodymium, Promethium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium and Lutetium). Rare earths are not actually “RARE” in nature. The word “rare” came from the difficulty experienced in separating the 17 rare earth metals from minerals. The first rare earth metal was discovered in 1787 and it took more than 100 years in identifying all rare earths as individuals due to their similar chemical properties.

Due to growing application of rare earth metals in various applications, their global demand is increasing continuously. Currently, around 96% of rare earth metals are produced by China. Researchers around the world are striving to develop an indigenous process to recover valuable rare earths to fulfill their domestic demand. India has 3.4 million tons of rare earth reserves mainly available in beach sand. But the processing of rare earths from primary ores involves mining and multiple process steps, leading to overburden and affecting the environment.

To address this situation, researchers at CSIR-National Metallurgical Laboratory have identified the “waste NdFeB magnets generated from the wind turbine industry” as potential source of rare earths. India has an ambitious plan to generate wind energy of 100GW by 2030. Therefore, the installation of wind turbines is continuously increasing in southern parts of the country. In wind turbines, strong magnetic field is required to convert the mechanical energy in to electrical energy. For this, NdFeB magnets in huge quantity (250-650 Kg for 1MW) are used in generators of wind turbines. After a certain year of life span, the magnet assembled in the generator loses its magnetic property due to continuous exposure to air or heating environment. These bulk quantities of discarded magnets can be utilized as secondary resource for the recovery of valuable rare earths.

The researcher at CSIR-NML obtained the waste magnets from Regen Powertech Pvt. Ltd., a leading wind turbine industry of India. They developed a simple process to recover rare earths from the waste magnets with minimum consumption of chemicals. Iron oxide is obtained as by-product
of this process. The recovered rare earth oxide and iron oxide can be recycled for the preparation of fresh magnets and many other applications.

The received discarded magnet was in the form of rectangular blocks. The magnet was characterized in the laboratory to understand the property of material. It was found that the magnet was made of rare earths majorly Neodymium (23%) along with Praseodymium (5.6%) and Dysprosium (0.4%) and iron (67%) in the form of Nd$_2$Fe$_{14}$B alloy (homogeneous mixture of metals having single phase). A process was developed to selectively recover rare earths from Nd$_2$Fe$_{14}$B phase. Firstly, the magnet block was heated at 310 °C in order to remove residual magnetism. Further, the magnet blocks were crushed and ground to obtain magnet powder of certain size range. The magnet powder was then heated in air inside a furnace at 850 °C. As a result, Rare Earths and Iron initially present in the metallic form are completely converted into Rare earth oxide (RE$_2$O$_3$) and Iron Oxide (Fe$_2$O$_3$).

The solubility of rare earth oxide is higher than iron oxide in acid solution; so this property is used for the preferential dissolution of rare earth oxide in solution. Hydrochloric acid is used for dissolution of oxidized magnet powder. Different parameters such as acid concentration, temperature, solid/liquid ratio and time are optimized in such a way that rare earths are selectively dissolved in aqueous solution with minimum consumption of acid. It is observed that for selective recovery of rare earths, selection of parameters during dissolution process is very critical; otherwise iron could also dissolve in solution as impurities. After dissolution, remaining solid is separated from the solution by filtration process. When the obtained solution is chemically analyzed, it is found that solution is rich in rare earths comprising Neodymium along with Praseodymium and Dysprosium. More than 98% of the rare earths is recovered in the solution with only 0.02% of iron impurities. These impurities are removed during further precipitation step.
Oxalic acid was added in rare earth rich solution for precipitation (to make the solid compound of rare earth). By heating of precipitates, brown colour oxide of rare earths (containing Neodymium, Praseodymium and Dysprosium) is obtained. The purity of produced rare earth oxide is ~99%. The solid residue obtained after filtration is the by-product of the developed process which is found in the form of Iron oxide ($\text{Fe}_2\text{O}_3$) of purity ~93%, which could have direct application in pigment industry. The process is developed in closed loop cycle, so no acidic/toxic effluents are generated. The result of the work was recently published in Waste Management Journal in 2018 led by Aarti Kumari, AcSIR, CSIR-NML, Jamshedpur. The research team constituted Aarti Kumari, M. K. Sinha, S. Pramanik and S. K. Sahu from CSIR-NML.

Overall, waste NdFeB magnet of wind turbines found as potential source for recovery of rare earth metals. A complete process flowsheet is developed at laboratory scale for recovery of valuable rare earth oxide along with iron oxide from waste NdFeB magnets with minimum consumption of acid. This indigenous process could be helpful to meet the domestic demand of rare earths in the country, which could lead to fulfilling the dreams of “Making RARE EARTHS in INDIA”.
Various deadly diseases have infected the world population. One such alarming disease is chikungunya which spreads because of mosquito bite. Heavy rain and subsequent flooding are factors that contribute to mosquito breeding. Mosquitoes are transmitters of various disease causing germs and chikungunya virus is one such germ which causes chikungunya. Chikungunya virus is spread by the commonest mosquito in India known as *Aedes*. It transmits the virus from one person to another. The symptoms associated with chikungunya include fever, rashes, headache, weakness, severe joint pain, muscle pain and swelling. This severe pain and swelling sometimes last from months to years causing lifelong disability. Since the first outbreak of chikungunya in Africa in 1952, urbanisation, deforestation and global warming formed mosquito breeding grounds and globalisation of travel further spread the virus worldwide.

Recent report by “Centers of Disease Control and Prevention” confirms the presence of chikungunya virus in more than 100 countries across the world. Twenty eight out of twenty nine states in India have reported the presence of chikungunya virus where seasonal outbreaks lead to an increase in number of infected patients to more than 1 million annually.

The global spread of chikungunya and increase in chikungunya-infected patients led to significant research around the world but these endeavours couldn't deliver any drug or vaccine for chikungunya treatment. Therefore, the treatment given to the patients is directed towards recovery from the symptoms of fever, pain and weakness by giving anti-pyretics, analgesics and

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* Ms. Swati Gupta, Ph.D. Scholar from Defence Institute of Physiology and Allied Sciences -DRDO, Timarpur, Delhi, is pursuing her research on “Anti-Chikungunya Effects of andrographolide: Inhibition of Viral Replication and Mitigation of Associated inflammation.” Her popular science story entitled “A Wonder Drug Discovered for Chikungunya Treatment” has been selected for AWSAR Award.
Considering the unavailability of a licensed drug or vaccine for chikungunya treatment, present study was designed to meet the global demand for an anti-chikungunya drug which could inhibit the multiplication of chikungunya virus and reduce the symptoms of fever, stress and arthritis.

A magical compound for chikungunya treatment: A team of scientists including Dr Lilly Ganju, Dr KP Mishra and research scholar Ms Swati Gupta at Defence Institute of Physiology and Allied Sciences (DIPAS), DRDO, Delhi, reported an extraordinary compound for chikungunya treatment in well-known journals including “Asian Pacific Journal of Tropical Medicine”, “Inflammopharmacology” and “Archives of Virology”. They searched the remedy of chikungunya taking help of Ayurveda and ancient folk remedies. They found a medicinal plant known as *Andrographis paniculata*, which has been used by folks as traditional medicine for the treatment of various infectious diseases. The common name of this plant is kalmegha or Bhunimba in Sanskrit, Kalmegh or Kiryat in Hindi, Chirayetah in Urdu and Creat or king of bitters in English. A major bioactive compound of this plant known as “Andrographolide” (Andro) was used in the study. Because of the bitter taste of andro, the plant is known as king of bitters. A 98% purified form of andro was purchased from a company named Sigma-Aldrich, USA and following tests were conducted to elucidate the effect of andro in the treatment of chikungunya.

**Andro as anti-pyretic (anti-inflammatory) agent:** Chikungunya virus causes high fever and joint pain in infected patients. The reason behind this fever and pain is “fire” (inflammation) induced by chikungunya virus. Chikungunya infection induces release of various “fire inducing chemicals” (pro-inflammatory cytokines) which ignites “fire” inside the cell. To inhibit fever and
pain, it is essential to restrict the “fire” and release these “fire inducing chemicals”. Therefore, the study was designed to elucidate the effect of andro on “fire” and “fire inducing chemicals”. In the study, first a safe dose of andro was estimated to avoid its side-effects on cell. Considering this, various doses of andro (10, 5, 1 and 0.5 microgram/ml) were given to mouse cells. The study revealed that lowest dose of andro i.e. 0.5 microgram/ml did not cause any harm to the cells in comparison to the higher doses and hence the lowest dose was considered safe to use. Then, the safe dose was tested for its effect on “fire” and “fire inducing chemicals” in mouse cells. The results showed that andro treatment amazingly reduced the “fire” and “fire inducing chemicals” in the cells. Thus, the role of andro as anti-pyretic agent was confirmed.

**Andro as anti-chikungunya virus agent:** Virus enters inside the cell for increasing their number and also induces “fire” by releasing “fire inducing chemicals”. For chikungunya treatment, it is essential to inhibit virus multiplication and release of “fire inducing chemicals”. Therefore, the study was designed to investigate the effect of andro on chikungunya virus multiplication and virus induced “fire”. Before studying the anti-viral effects of andro in humans, the safe dose of andro was confirmed. Considering this, various doses of andro (10, 5, 1 and 0.5 microgram/ml) were given to human cells. Surprisingly, again the lowest dose of andro, i.e. 0.5 microgram/ml, was found safe and effective in human cells. Now using this safe dose, the effect of andro on chikungunya virus-infected human cells was explored. Andro treatment substantially reduced virus multiplication and release of “fire inducing chemicals” in chikungunya infected cells. Along with human cells, andro treatment in chikungunya-infected mouse pups reduced the virus multiplication, virus induced “fire” and increased the number of virus killing immune cells thus eliminated the perpetrator virus from the animal. Thus, these experiments confirmed that andro is a potent anti-chikungunya virus agent.

**Andro as anti-cellular stress agent:** Viruses are dependent on host for their propagation. They hijack host “food” (proteins) for their multiplication and as a result generate stress inside the cell. To reduce stress and fulfill the continuous “food” demands, cell prepares more “food”. But, sometimes these increased demands result in formation and accumulation of “under-cooked food” (unfolded proteins) which generate further stress to the cell. In order to survive and come out of the stress, cell tries different ways to reduce stress (unfolded protein response pathway) and when it fails to do so then it undergoes death (apoptosis). Virus being very smart, induces death of the cell for their propagation. Through cell death, virus gets released from one cell without coming in contact with the virus killing immune cells and gets the access to infect the new neighbouring cells.

Chikungunya virus, like any other virus, hijacks the host “food”, induces cellular stress and also takes advantage of cell death in infecting the nearby cells. To treat chikungunya, it is essential to reduce chikungunya virus induced cell stress and cell death. Considering this, effect of andro on virus-induced cell stress and cell death was explored. On infecting the human cells with chikungunya virus, andro treatment was given subsequently. Interestingly, this charismatic compound efficiently mitigated the chikungunya virus-induced stress and also reduced the virus-induced cell death. Thus, the role of andro in inhibiting virus multiplication by reducing cell stress and cell death was validated.
Andro as anti-arthritis agent: Chikungunya virus infected patients suffer from severe joint pain, muscle pain and swelling. To treat chikungunya, it is essential to treat these symptoms of arthritis. Therefore, the study was designed to elucidate the effect of andro on arthritis. In mouse, arthritis was induced by an injection of compound “complete freund’s adjuvant” (CFA). Injection of CFA in mouse footpad induced various symptoms of arthritis which include joint swelling, disability in movement and aggression in animals due to pain. Following CFA injection, andro treatment was given subsequently. Interestingly, andro treatment reduced footpad swelling, far better than dexamethasone, a well-known drug for arthritis treatment. On further investigations, it was revealed that andro reduced the generation of chemicals involved in causing joint pain and swelling. Thus, the role of andro as potent anti-arthritis agent was confirmed.

The study, therefore, confirmed the role of this miraculous compound andro in treatment of chikungunya by reducing virus multiplication and associated symptoms like fever, stress and arthritis. Hence, andro can be a great hope for millions of patients infected with chikungunya virus who have been waiting for a remedy for the last 60 years. Considering the global demand for a remedy of chikungunya and hopes generated by the findings of the present study, further investigations using this wonder compound are the need of the hour for early development of an anti-chikungunya drug.
Our world has experienced several catastrophic events; and perhaps the earliest account of one such event is “The Great Flood”, which finds its place in the folklore of several cultures across the world. This global flood, which is believed to have wiped almost the entire life on earth, is also considered to mark the beginning of a new life cycle in several cultures. The accounts of “The Great Flood” are incomplete without the mention of *Noah’s Ark* a ship that was able to survive the global flood, and helped in reviving the life back on the earth. While there are mixed opinions on whether or not Noah’s Ark existed, it has become a symbol of rescue. Do you think that Noah’s Ark exists? Well, let me share with you a set of events that I came across in a test tube while investigating the world of nanomaterials; interestingly I found that these events bear a close resemblance to the story of *Noah’s Ark*!

The scale at which these events occurred was extremely small around one-lakh times thinner than a human hair! What were these events? How did I come across these?

Let me take you through my journey, which took an unexpected turn and led me to these events.

In my research, I was investigating a famous material Magnesium diboride (MgB$_2$). Hmm! You may be thinking what is so special about this material. Well, this compound is a well-known superconductor; it can conduct electricity with no resistance. Its specialty is that it shows superconductivity at a higher temperature compared with other superconducting materials.
One day, I was curious to know whether this material can withstand water or not. To test this, I placed the MgB$_2$ crystals in water, and to my surprise, I observed that the crystals were disappearing in water and forming a golden yellow solution. It was as if a flood had destroyed the crystals. I was even more surprised to see that the yellow colour was not permanent; it started fading and turned into clear water again. What could have happened to the MgB$_2$ crystals after experiencing the catastrophe? I started to closely observe the solution to figure out what could be happening, but I could not see anything. Then I realised that something is happening beyond what we can see with our human eyes. I tried to observe the solution under a normal microscope. To my disappointment, I was not able to see anything again. Then I remembered my teacher telling me that there exists an advanced microscope, called an electron microscope, which can help us see what happens in the atomic world. Following this, I started observing the solution under an electron microscope. Did I start seeing something? Yes, what I observed was unbelievable. There were a large number of extremely thin structures floating in water the thickness of all these structures was very small, \(~\) one-lakh times thinner than a human hair! On the one hand, I was happy because I could finally see something. On the other hand, I was puzzled, because I saw that some of these ultrathin structures were very small like dots, some structures were a bit larger like discs, and some structures were even larger like sheets. However, I was unable to understand how these were forming.

For a long time, I could not understand this mystery, until one day when I was observing the pictures side by side, in a flash, I was able to connect all the dots.

I realised that I was witnessing a miracle in the Nanoworld. In essence, when the MgB$_2$ crystals were placed in water, they lost their structure and disintegrated into atoms, as if these were hit by a catastrophe. These atoms started communicating with each other and worked together in a united form to assemble in the shape of nano-boats. These nano-boats were very special because water was not able to disintegrate them further, and because of this, they happily kept sailing in water. Did these atoms also know about Noah’s Ark?!

Whether Noah’s Ark exists or not, I realised that the Nanoworld was trying to tell us that with unity and resilience, it is possible to overcome any challenge. Although the entire crystal lost its identity, it came back together in the form of nano-boats; like how new life comes into existence after “The Great Flood”. This phenomenon truly captured the saying that, “Every ending has a new beginning.” The newly formed nano-boats started showing properties, which were not present in MgB$_2$. I have started to find that these nano-boats have the ability to not only store hydrogen gas but also generate hydrogen gas, which would help several existing technologies. I am now investigating...
if we can utilise their storage ability to prepare batteries of much higher capacities, paving the way for an electric future. I also found that these nano-boats were boron-rich and naturally forming the honeycomb structures of boron, which are analogous to graphene. These boron-rich nano-boats also can overcome the current limitations of the fuel-rich propellants for space exploration.

I have always believed that everything happens for a reason; one small curiosity to understand how the material would behave in the presence of water led us to the above discovery. If we keenly observe nature, there is so much to explore and find many new wonder materials, which may transform our way of living.

Our efforts of discovering a simple route to produce two-dimensional honeycomb planes of boron from a simple binary compound MgB$_2$ when put in the water adds a great knowledge to the growing science on two-dimensional boron nanomaterials as well as to the science of superconducting material-MgB$_2$. This discovery was published in the journal *ChemPhysChem* by Wiley publishers in 2018.

**Citation:** Gunda, H., Das, S. K., & Jasuja, K. Simple, green, and high-yield production of boron based nanostructures with diverse morphologies by dissolution and recrystallization of layered magnesium diboride crystals in water. *ChemPhysChem* 2018, 19, pp 880-891.
The need to lay low before the combat

In 2005, newspapers reported that a farmer from Mirzapur district (400km from Lucknow) wrote a letter to the President of India seeking permission to euthanize his four sons suffering from the disease Duchene muscular dystrophy. The poor father could not manage the four bedridden children who needed assistance for all their day-to-day activities. This is just one among the several stories about this genetic disorder in which patients and their families go through so much agony. This disease is caused by mutations in the dystrophin gene and leads to the production of a defective muscle protein, which is necessary for muscle strength and contractility. This results in the weakness of all skeletal muscles in the body. According to NIH, one in every 3500 males are affected by this and the number of females affected is relatively less. All the males having this disease are born healthy, but around the age of five muscle weakness begins to show when they get involved in rigorous physical activities. In adolescence, the patients are completely confined to wheelchairs and need assistance for practically everything. Parallel development of breathing problem and other medical complications lead to the demise of patients in their late teens or early 20s. The patients’ parents and kin are subject to a lot of emotional trauma as they see the suffering first hand and feel helpless. To know how this genetic problem creates muscle wastage and subsequently leads to death, we should know how normal skeletal muscle is maintained in healthy people.

One of the most worked parts of our bodies whose contributions often go unnoticed in good health is our skeletal muscle. They are indispensable for any movement in our bodies, ranging

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from the slightest twitch in the face when we smile or frown, to the extensive, sustained movement required for running a marathon. Skeletal muscles constitute 40% of our body mass, and face constant wear and tear due to continuous movement and injury. However, most of the time, we do not even feel the potential break down because our bodies have self-healing mechanisms that repair muscle tissue a process called muscle regeneration. The heroes of this process are the Satellite cells—the muscle stem cells housed in little niches along the length of muscle fibres. To use an analogy, let’s imagine these satellite cells as the soldiers protecting the country. They will be less active when there is no war but are always alert anticipating an emergency. Similarly, the Muscle Satellite Cells (MuSC) stay in a sleep-like quiescent stage as if silently waiting to be called in the event of an injury. Whenever there is an emergency situation, these soldiers are active in the field doing their duty. Likewise, apart from major traumatic injuries by accidents, even minor stretch injuries when we exercise our muscles by lifting weights in the gym are sufficient to send a wake-up call to the satellite cells. When called, they are activated and undergo cell division to replace the lost muscle in the injured tissue.

Once the emergency situation is over, the surviving soldiers go back to the resting state for rejuvenating themselves, which is essential for the active participation in forthcoming situations. Similar to this, some of these activated satellite cells go back into the dormant state, to replenish the stock of quiescent satellite cells which will be required to repair injuries in the future. While in this sleep-like state, the satellite cells do not multiply in number but keep the machinery ready to multiply whenever the signal comes.

So what happens in the muscular dystrophy condition? Let’s go back to the soldier analogy again; imagine a situation where the war never stops and the soldiers don’t have a choice but to keep fighting. They don’t have time to go back to the resting phase and rejuvenation. The continuous activity tires them which reduces their performance, eventually leading to death and losing the battle. This is exactly the situation in muscular dystrophy, the genetic mutation in dystrophin makes this protein non-functional or completely absent in skeletal muscle. This makes the patient’s muscle a never-ending battlefield with frequent injuries, wear and tear. Our muscle soldiers, the satellite cells are active continuously to repair the injury. Because of the persisting injury, the satellite cells do not go back to the resting or quiescent state for self-renewal. This results in a reduction in their number and quality of performance. In the end, the patient’s muscle weakens due to the deprivation of rejuvenated satellite cells, which ends up in muscle wastage. Hence, it is clear that this sleeping state is very critical for the performance of satellite cells. Thus an in-depth understanding of this quiescence state and the self-renewal of these satellite cells is crucial to devise strategies for combating muscular dystrophy.

How these satellite cells maintain the quiescent state is still not well understood. Prof. Jyotsna Dhawan’s lab in CCMB, Hyderabad, mainly focuses on studying the mechanisms of quiescence. Interestingly, my research in this lab found that there is a molecular switch inside the nucleus of the satellite cell that controls the switch between active and quiescent states.

We published the finding recently in Science signaling. This molecular switch consists mainly of three proteins, specifically transcription factors that bind DNA and switches genes on and off.
These transcription factors are tightly regulated by external signalling cues. More specifically, in the activated satellite cells, transcription factor Lef1 partners with β-catenin which is controlled by the activation of the Wntsignalling pathway. This partnership turns on genes required for the active proliferation and terminal differentiation of these satellite cells to form muscle. When these active cells go back to the sleep state, the Wntsignalling pathway has to be turned off, leading to the absence of β-catenin. Hence Lef1 which was previously bound to β-catenin switches its partner to a different molecule Smad3. This is under the control of another signalling pathway called TGF-β. This Lef1-Smad3 transcription factor complex switches on genes required for the quiescence and self-renewal of satellite cells. Thus, the same molecule Lef-1 binds with different partners and controls the fate of satellite cells.

Surprisingly, our study also clearly showed that removal of β-catenin in activated satellite cells leads to the enhancement of Lef1-Smad3 partnership which makes these cells go back to quiescence and thus increasing their self-renewal ability. This is critical to ensure the reserve cells are there if required for future unpredictable bouts of repair study has shown one of the mechanisms which maintain the resting state in these satellite cells. As explained before, a major issue in the case of muscular dystrophies is the absence or reduction of these quiescent cells. Our findings have made it clear that switching Lef1-βcatenin to Lef1-Smad3 partnership will enhance the quiescence and
self-renewal of satellite cells. Further studies can be done to identify therapeutic strategies (possibly a drug) to enhance the molecular partnership of Lef1-Smad3 in the active satellite cells in muscular dystrophy patients. This will help return the cells to the quiescent state and can potentially improve muscle regeneration and reduce muscle wastage. Thus, the lifespan and quality of life of the patients can be improved. As of now, there is no cure for muscular dystrophy besides steroid treatment for improving muscle strength to a smaller extent which comes with large side-effects. Stem cell therapies are under clinical trial and will take years before actually being applicable. This research emphasizes that it would be impossible to find solutions to incurable ailments without delving into the details of how our cells function and thoroughly understanding the mechanisms behind them.
Towards an AI-Assisted Peer Review System

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THE AUTHOR

“Dear Mr Harsh, Thank you for submitting your manuscript ‘Impact of …’ to the ‘Journal of ….’
After careful consideration by our editors, we regret to inform you that we must decline this
submission on editorial grounds and have subsequently decided to not send the paper out to external
peer reviewers.” … blinked his email. Another desk rejection!! Harsh let the email sink in slowly. It
was his third rejection in a row and that too from the editor’s desk. He could not believe that after
three months of submission this is what he got in response to his correspondence. The editor did
not even consider sending his manuscript to the reviewers. It pained him to realise, not only did
the editor dislike his toil; he disliked it sufficiently to circumvent its progress through the review
process. What is going wrong with me? He mumbled At least he bothered to read it! My guide is not an
expert in this field; he is finding very little time for me. What if …

THE EDITOR

“Dear Sir, You would be pleased to know that I have been elevated to the position of Associate
Editor in the highly reputed Journal of …” Dr Saha finished typing her email to Director IIT...
and Professor-in-Charge Public Relations. Another one ticked off my bucket list…. she looked out
of her cabin window, smiling. Little did she comprehend that this job could be so demanding.
Regular classes, evaluations, meetings, PhD students, invited talks, Professor-in-Charge Guest

* Mr. Tirthankar Ghosal, Ph.D. Scholar from Indian Institute of Technology, Patna, is pursuing his research on
“Investigating AI Techniques in Various Aspects of Academic Peer Review.” His popular science story entitled “Towards
an Artificial intelligence Assisted Peer Review System” has been selected for AWSAR Award
House, and now an added responsibility. To go through these huge number of submissions to this popular journal, check plagiarism, decide relevance, find suitable reviewers, coordinate and write responses... an array of non-escaping tasks. She found most of the submissions are uninformed ones, not falling within the aims and scope of the Journal of ... and even if they fall, most are average-merit, not warranting further review. Sometimes I wonder how people could write so much trash and send these many irrelevant articles. Why don't they just consult the published papers and decide wisely about their work? What if... she sighed in exasperation.

THE REVIEWER

_Two deadlines already missed..._ Dr Moorthy is having a hard time to manage everything. He recently came back to India after his second postdoc and joined this reputed private university. But work pressure has taken a toll on him. Too many engagements! And, on top of that, these pending paper reviews. He is struggling to find a spare time to go through this seemingly interesting paper. _What if there was an AI that could read the article and point out significant contributions?_ Finally, after the third reminder, Dr Moorthy forced himself to review the paper.

All the three stories, although fictional, are true in the current context, converging to one deep question: _What if there was an Artificial Intelligence (AI) support to the peer review system? An AI to support research evaluation?_

Desk rejection is a common phenomenon in academia, a woe faced by most early career, sometimes even by seasoned researchers. It implies that the journal editor sends back a prospective research article to the author without consulting its merit to the expert reviewers. Several reasons account for this activity: plagiarised content, article not falling within the scope of the journal, below quality article with respect to the competitive benchmark of the journal, template mismatch, spellings, language and grammar, etc.

The current peer review system is mostly human-centric and is biased sometimes. With the exponential rise of article submissions (better known as the ‘Publish or Perish’ bubble in academia), it is becoming increasingly difficult for the journal editors to keep up the pace with the latest research, go through each submission and respond to the authors in reasonable time. _What if there was an AI which could help the editors to take appropriate decisions by pointing out seemingly out-of-scope, below quality submissions? What if the AI could relieve the editors from this “burden of science” to some extent?_

Our current research is about investigating the role that AI could play in several aspects of the scholarly peer review process. We partnered with a reputed global scientific publishing house to pursue this very timely problem with the goal to ease the information overload on journal editors using Machine Learning and Natural Language Processing techniques. A system of this kind could also help the authors to choose the journals wisely and retrospect on the quality of his/her paper according to the journal standards. An ambitious vision of this project is to help the reviewers identify the novel aspects of a proposed research. It is now somewhat impossible for a human to
go through the massive volume of interdisciplinary research available. The need of the hour is to develop automated solutions for relevant literature discovery. We believe that the progress of this investigation at any stage could lower down the average turnaround response time of a journal, thus speeding up the overall process of peer review.

We begin with investigating the general causes of desk rejection from the author-editor-reviewer interactions made available to us by our industry partner. Upon in-depth analysis of rejection comments and rejected papers, we found that more than 50% of desk rejection accounts for the paper being “out of scope”. In spite of having merit, sometimes an editor is left with no other choice than to reject because the paper won’t find a reader among the audience of the particular journal. So, we took up this problem and viewed it as classifying a paper as “In Scope” or “Out of Scope” using Machine Learning techniques. Our seed idea was “information contained in the accepted and published papers of a journal are the benchmark of reference which defines the domain of operation of the journal”. We incorporate features extracted from almost all possible sections of a manuscript that may contribute to determining its belongingness to the journal concerned. We consider extracting keywords, topics from the full-text portions, clustering in-scope articles, author activity in the past five years, bibliographic information, etc. with respect to the published articles of the journal as our features. Our approach proved highly accurate and was able to outperform a popular state-of-the-art journal recommender by a relative margin of 37% for one journal. Thus, with our method, a system could be developed to assist the editors and authors to identify out-of-scope submissions effectively.

Our further analysis of desk-rejection comments revealed that editors are also concerned about the quality of research not matching to journal standards. We take a very simplistic approach here: ‘Good papers cite good papers’. We look into the bibliography section and see how many influential papers are cited and where are the cited references published (reputed venues generally publish significant contributions). We take the citation counts of the references, reputation of venues (Impact Factor, CORE Rankings), the temporal distance of the citations (too many old citations may indicate that the authors are not aware of current state-of-the-art), the presence of mathematical content, etc. as our quality features. We also identify which citations are influential to the current paper and which are just incidental and appropriately adjust the corresponding feature weights. We found that inclusion of quality features into our system greatly enhances its capability to identify desk rejections. Although there are other factors which are basic checklists at the editor’s desk like plagiarism, spellings, language and grammar, template mismatch, etc., we found proprietary state-of-the-art tools available to address them. However, these factors could make our proposed system more accurate.

Spending almost three years with the problem, we are now pretty convinced that this is an issue of epic proportions having many layers of investigation which requires significant collaborative efforts. It is more like doing science over science. Designing an AI-based peer review system is just the surface form of this investigation. Connecting the ever-expanding human scientific knowledge (which manifests in the form of research papers) and translating it to a machine-understandable form is the grand vision. However, there are several practical challenges: to get hold of knowledge (research papers) that are behind paywalls, enforcing a more knowledge discoverable format of
research papers rather than just PDFs, annotating scholarly artefacts, etc. With the rise of open access movements, significant technical efforts by AI companies like Chan Zuckerberg Initiative-Meta, Allen Institute of Artificial Intelligence, communities like FORCE11, we are hopeful that we are moving in the right direction.

Understanding novel scientific knowledge by an AI is a very far-stretched vision. However, with the ever-growing prowess of AI, in the near future, we could think of helping THE REVIEWER in identifying the NEW as well as to validate it. Maybe someday we can have an AI scientist as our peer, as a gatekeeper of scientific knowledge and wisdom.
Calm and persistent, rivers are truly physical marvels, the only way deep interiors of the continental landmass stay connected to the oceans. They have been an integral part of human civilization and continue to be one of the most important resources. But in the flowing waters and in the sediment shield is hidden a plethora of information related to earth’s landscape, geology, climate as well as the impact of ongoing human activities on the environment. Metal, plastic and organic pollution have deteriorated the health of most rivers across the world. In fact, the industrial civilization has brought many rivers to the tipping point and further changes would be unpredictable and irreparable, thus, quite alarming. Therefore, many governments have planned river restoration projects to address the challenges in river basin management.

In India, Ganga River is at the focal point of such restoration programs, as it is ranked in the top three most polluted rivers in the world for many years now. It is estimated that 85% (~95 m³/s) of waste generated from 222 towns is discharged untreated into Ganga River while the rest 15% is dumped onto land. Several missions to “Clean Ganga” over the last two decades and even “Zero liquid Discharge” policy have been implemented at few places. Though this policy would curb the entry of pollutants from point-sources such as industrial sewage and municipal effluents, non-point source contribution continues. Pollution via small seasonal tributaries and groundwater flux are such non-point source contributors and often go unnoticed in the bigger programs. Small catchment area and lower annual discharge seems to diminish the importance of such seasonal tributaries.

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Another emerging concern is the increased rate of fertilizer based agricultural activities in the Indo-Gangetic flood plains. Phosphates (P) and Nitrogen (N) compounds are primary nutrients and their deficiency could limit primary production. But in excess these nutrients cause eutrophication, acidification, algal blooms and hypoxia. Thus, nitrogen and phosphorus cycling is very well studied in oceans and also formany rivers in the world. In fact, long-term nitrogen and phosphorus concentrations in river water have proven how human activities have driven the riverine nitrogen and phosphorus loads. For example a study published in Biogeochemistry journal by Green et al., in 2004 showed that riverine contribution to global ocean increased by six times from preindustrial (N~ 2.1*10^6/yr) to contemporary times (N~ 14.5*10^6/yr). The decrease in fertilizer application has also shown to reduce the average nitrate concentration in some European rivers.

Currently, we lack holistic understanding about the fate of excess nitrogen and phosphorus from the fertilizers, their internal cycling and transport pathways to the Indo-Gangetic floodplains, groundwater and to the tributaries as surface runoff from cultivated lands. Here's where research from our group in the Department of Earth Science at Indian Institute of Technology Kanpur comes in. My research specially is using river and sediment on the different aspects of glacier-land-river-ocean pathways and processes. To address the above discussed problem, we monitored the Pandu River which is a right bank tributary of Ganga River. There are several small seasonal tributaries in the entire Indo-Gangetic flood plains. The hypothesis of the study was small tributaries in the Indo-Gangetic flood plains have higher nutrient loads and their collective contribution to Ganga would be influencing the river chemistry of this large river. Pandu River is 242km long with a catchment area of 1495km^2, of which 95% is agricultural land. It is mainly fed by rainwater during the Indian summer monsoon and surface runoff from surrounding irrigated lands. This river was monitored from February 2015 to April 2016. We measured dissolved silicate, phosphate, nitrate, nitrite and ammonium concentrations along with discharge. Nitrate, nitrite and ammonium are collectively called as the dissolved inorganic nitrogen (DIN). We found that, silicate, DIN and phosphate concentrations to vary between 6.99 -21.48, 0.6-7.23, and 0.08-4.58 mg/L respectively. Such concentrations are higher than most monsoonal rivers in India. The DIN, silicate and phosphate yields were 0.53, 1.08 and 0.118 t/km^2/yr, respectively. The only rivers having higher DIN than Pandu River, in India were rivers Haldia, Netravati and Zuari. In global comparison, Pandu River has higher phosphate yield than Amazon (0.009t/km^2/yr) and Yangtze (0.027 t/km^2/yr). Here it is important to note that differences in agricultural practices, waste management, effluent discharge policies, cropping intensities due to the socio-economic conditions of this river basin is unique and comparing these statistics with other river basins would be quite complex.

We estimated that Pandu River exports 177±29 t/yr of phosphate and 793±128 t/yr of DIN to Ganga River, which amounts to 0.42% and 0.1% of phosphate and DIN fluxes from Ganga River to the Bay of Bengal. Since Pandu River contributes only 0.03% of the total Ganga River water discharge to the Bay of Bengal, Pandu River carries relatively high phosphate and DIN loads. Since phosphate and DIN loads are dependent on human activities, we used fertilizer application rates per square area, irrigated land area and population density as metrics of estimating the representativeness of Pandu River and scale up the results for the entire Indo-Gangetic floodplains.
By comparing these data from Pandu basin with 118 districts in the Indo-Gangetic flood plains which cover 89% of Ganga Basin, we estimated the collective contribution from small tributaries. We estimated that small rivers collectively would annually export 1,15,903 and 25,706 t/yr of DIN and phosphates to Ganga River. This is 15% and 61% of the total DIN and phosphate fluxes from Ganga River to the Bay of Bengal.

Therefore, small floodplain tributaries do contribute significantly to the chemistry of large rivers and are an important source of non-point source pollution. Despite their importance these rivers were seldom studied and are now being recognized as potential contributors. Therefore, this work demonstrated the need for additional assessments of small streams with long-term monitoring policies and counting their contribution to the large rivers. This information would be critical in planning and implementing remediating efforts, and would help the water resource policy managers to better restore the river health and adapt to changes of land-use in the future.
Recently our Prime Minister received the ‘Champions of earth’ award from United Nations. International Solar Alliance was initiated by India around 2015. The Paris Agreement was signed on 12th April 2016. Have we ever thought why this hullaballoo over climate, environment and alternate fuel sources? Worldwide people are splitting their hairs to find the answer to one big problem, the mother of all problems. The problem of finding a viable, alternative, clean and renewable energy source to help us fight the menace of Global Warming.

Let’s have a look at the Mother of all problems:
   Fossil fuel reserves are exhausting very quickly.
   Years of fossil fuel burning has polluted the environment badly.
   Due to emission of greenhouse gases, Global Warming is increasing.
   Rapid deforestation is adding to our woes.
   Polar ice caps are melting, ecological balance is getting disturbed.
   And our energy demands are ever increasing.

Now, standing at such a point, looking at problems of such magnitude, we can conclude only one thing, the world is heading for destruction slowly. Now we as scientists have a scientific social responsibility to do something about it. At times of such need we can’t stay calm and play our violins like King Nero did, while his Rome was burning.
Thinking alternatively:

Carbon Dioxide (CO$_2$, a greenhouse gas) generation from fossil fuel burning is a big problem which leads to global warming. What if we can turn this problem into an advantage? What if we can turn CO$_2$ into some chemicals which can act as alternative sources of energy? Then with by one master stroke we can kill two birds global warming along with global energy crisis. We also have to find an alternate and environmentally benign source of energy, right? Nature has the solution, the lightest solution. Well, Hydrogen gas is the answer. We can use Hydrogen gas, the lightest gas in nature as an alternate source of energy.

Learn from Nature:

Whenever in problem, dial Nature for help. Mother Nature has all the solutions to our problems and we just need to take one good look at her to find inspiration. Plants and other organisms use photosynthesis to remove CO$_2$ from atmosphere and incorporate it into biomass. In our blood we have Myoglobin, Haemoglobin. These macromolecules have a common basic structural unit called Porphyrin. This Porphyrin contains iron metal in the core. Myoglobin and hemoglobin are known for oxygen storage and oxygen transport in the body respectively. Scientists have made synthetic mimics of those iron porphyrins and explored oxygen reactivity. Oxygen binds to the iron centre of the iron porphyrin at a state where Iron normally exists inside our body called Iron(II) state while CO$_2$ also binds with Iron but at a state called Iron(0) state where iron is saturated with more electrons. Nature has also created a class of enzymes (macromolecular biological catalyst, which acts upon some chemicals namely substrate and convert those chemicals into some other chemicals called product) called “Hydrogenases”. These enzymes are known for the inter conversion of protons (hydrogen atom sans electron) to hydrogen. Hydrogenases are classified into three different types based on active site (a portion of a macromolecule where the actual chemical reaction takes place) and metal content viz. nickel-iron, iron-iron and iron hydrogenase.

Our endeavour

Getting inspired by nature, we jumped at the first opportunity to find a solution to the Mother problems. In our laboratory we are working with several structural and functional mimic of nickel iron and iron-iron hydrogenases. These bimetallic catalysts (a substance that takes part in a chemical reaction and increases the rate of the reaction but at the end itself remains a spectator) can convert proton to hydrogen efficiently. In our laboratory we have prepared several iron-porphyrin catalysts which can reduce CO$_2$ to Carbon monoxide(CO) at a commendable rate. A mixture of CO and H$_2$ can be converted into hydrocarbons by an industrial process named “Fisher-Tropsch”. To look into more detail about these processes we need to take several snapshots of the systems during the course of the chemical reaction. These snapshots will tell us what is actually happening in the molecular level. This is called the investigation of the reaction mechanism. We all have our childhood memories captured digitally and also we have our recent remembrances in the
form of selfies in our smart phones. If we arrange those photographs chronologically then we can see our evolution from a child to a complete adult. Human evolution is a slow process. We can easily see it but those proton reduction and $\text{CO}_2$ reduction reactions are very fast. To visualize the advancement of the chemical reactions we need more sophisticated camera. Infrared spectrometer, cyclic voltameter, nuclear magnetic resonance (NMR) spectrometer, Raman spectrometer are the cameras for us. Light being an electromagnetic radiation interacts with the molecule and this leads to some changes in the molecules and that change is studied by the detector. For infrared spectroscopy infrared light source is used and for Raman spectroscopy we use LASER light. In NMR spectroscopy a strong magnetic field interacts with the molecule and gives the signature of the system. Cyclic voltammetry is a technique where electrical pulse which is equivalent to a burst of electrons is given to a molecule via the electrodes and the molecule takes up electrons and gets reduced. Finally the machine gives us a current vs potential diagram as output. From these experiments we can have some idea about the intermediate stages of a chemical conversion. Every person has a unique fingerprint and identity card. Similarly every molecule or species has its own distinct features. We have to identify them seeing those identification marks.

Now one can ask why do we need to see the progress of a chemical reaction at the molecular level? The answer lies within the human life. Many of us have regrets about the past. We think that if we had not made that mistake, life would have been different. So if we don’t look properly at the intermediate stages of a chemical reaction we can never improve on that. So far we have successfully converted proton to hydrogen and $\text{CO}_2$ to $\text{CO}$ with synthetic molecules. Our next goal is to convert $\text{CO}_2$ to methane (simplest hydrocarbon which can act as a fuel). To achieve this target we need to focus on the mechanism of the reaction and by the knowledge of the intermediate states involved in the reaction we can tune our catalytic system to make it much more efficient, cheaper and capable of producing hydrocarbon from $\text{CO}_2$ at industrial scale. Fortunately we got methane from $\text{CO}_2$ using bimetallic Nickel-iron catalyst in acidic medium in an aqueous environment. This is called heterogeneous catalysis where the catalyst is insoluble in the solvent phase and it is deposited on a surface of a material called edge plane graphite (EPG) surface. Without the presence of acid, $\text{CO}_2$ can’t be reduced so aqueous acid solution is used in the experiment. We have detected methane via gas chromatography analysis, a technique by which the presence of a gaseous species in the reaction mixture can be detected. But there occurs a competitive hydrogen evolution reaction which is predominant. Now like Sherlock Holmes, we have to solve the mystery behind this chemistry. We need to investigate the reaction mechanism of the methane and hydrogen formation using the above mentioned techniques and try to tune the catalytic system so that we can get methane as the major product of the reaction and also at an appreciable rate.

**The way forward:**

Following the natural stride we have found a pathway to fight the scarcity of global energy demand. But only scientists can’t do everything. Scientists, technocrats, government and above all the common people should come together in this journey to save the Environment. We all have to take
an oath murmuring the Bettie Wilson’s song “let’s work on the solutions So our children can play in pure clean water in blue sky above, it’s not a fantasy we’ll make it our reality, we’ve got to all come together and start planning the seeds, mother nature needs us”.
Khapla was a 23-year-old man residing in a small village of Manipur, India. Born in a poor family, Khapla's parents could not afford to send him to college for his graduation, though he had secured good grades in his 12th standard in the Science stream. Despite lacking higher education, there was no end to his inquisitiveness and thirst for gaining knowledge. He loved his hometown, folk culture and ethnicity. He was proud of the fact that he was born in the northeast (NE) of India, which was abundant in natural wealth and he spent his free time observing and studying the plants in the forests. He did a number of odd jobs during the day for his family’s sustenance because his father’s meagre wage (worked as a mason) was not sufficient.

One day while going for work, he decided to take a detour through the forest and enjoy nature for a while. There, Khapla saw a man, dressed in a suit (which immediately indicated that he was an outsider), carefully examining a plant which they used for cooking a delicacy called “eromba”. Because of his curiosity, Khapla went up to the man to enquire what he was doing. After some initial communication hitches (due to a language barrier), Khapla was able to communicate with him in his broken Hindi. The man, though initially hesitant, introduced himself as Dr Ranganathan, a scientist working on the medicinal properties of the local plants of NE India. He told Khapla that this particular plant was called *Alpinianigra* and it comes under the “ginger” family. Not much work had been done on this plant, so he wished to work on it, particularly on its anti-microbial potential. Hearing this, Khapla became very excited and he told Dr Ranganathan...
that the people in his village consume the juice or concoction from the shoot of this plant when they suspect they have “worm” in the stomach and they call it ‘pullei’. Dr Ranganathan, after finding out about his education, was overjoyed and offered Khapla to work in his lab in Guwahati, as a staff. He said, in addition to getting a good salary in the lab, Khapla would be able to see and learn many new things, thus, fulfilling this thirst for knowledge.

In Dr Ranganathan’s lab, Khapla met another boy, Sranto, also from Manipur, who was going to work on this “magic” plant brought from his village and all his inhibitions were gone. He observed in wonder, how Sranto toiled night and day with the different parts of this plant its flowers, leaves, seeds, fruit ‘covers’, stems, even the underground part (which Sranto called “rhizomes”) drying them, cooking them in different liquids, and then getting some sticky, aromatic, black colored oily and gummy substances. Sranto told Khapla that these were called “extracts” and they need to be studied to know whether they were heat stable, were they able to dissolve in water and if they formed “crystals” like sugar. These studies, Sranto told, were important for the industrial application of these extracts.

One morning (after around one and half years) in Dr Ranganathan’s lab, Khapla found Sranto jumping with joy. Seeing Khapla, he hugged him and exclaimed that he had isolated and identified a compound from the seeds of *A. nigra*. “It is a diterpene, I have solved its structure; see this” Sranto exclaimed in joy, and he drew a complex chemical structure with 2 6-carbon rings something Khapla recalled to have studied in organic chemistry in school! “Now I will proceed with antimicrobial studies and you will have to help me with it,” said Sranto. Khapla was thrilled because he always wanted to learn how these lab people worked with bacteria and fungus, something that can’t even be seen with the naked eye!! Thus, Khapla learnt to prepare different growth media for bacteria and fungus, to grow the micro-organisms and to subculture them, helping Sranto in his antimicrobial studies. Three years passed quickly as Khapla learnt about Gram positive and Gram negative bacteria, about *Candida albicans* the organism that was responsible for the skin infection his mother had some years back - and many other things. Had he known then, Khapla would have rubbed some ‘pullei’ on his mother’s wounds instead of making ‘eromba’ with it!!

One morning (after a series of overnight experiments with Sranto), Khapla found his friend, sitting with his laptop, teary faced. “What happened, maroop (friend in Manipuri)?” he asked. “I lostmaroop. This diterpene is not killing this notorious *Candida*; it is only stopping its growth for some time. Even though it is highly antibacterial, the compound is not candicidal. What am I supposed to do…time is running out,” replied Sranto. Having faced much worse in life, Khapla calmly replied, “So what? Didn’t Sir (Dr Ranganathan) say negative results can also be presented? And it is not like you don’t have any results. And if it is stopping the growth for some time, there also must be some reason. Didn’t you say it doesn’t dissolve in water? Maybe it is doing something on the ‘skin’ of *Candida*; the skin is also ‘water fearing’ (meaning hydrophobic) like your compound, isn’t it? You had told me that earlier. In my school, our chemistry teacher always said “like dissolves/mixes with like.” Come on, let’s find it out!” Sranto looked up at Khapla in astonishment. How could someone like Khapla give him research ideas!! He hugged his friend, wiped his tears and both began work in earnest. Together, they found that the compound was temporarily binding
on the fungus surface, due to which the fungus was not able to take up its “food” or scientifically called substrate, and thus, could not grow. Khapla was even more thrilled when his boss told him he would give Khapla’s name in acknowledgement of the publication of this work; for a small village boy like him this was equal to winning a Nobel Prize!

“Why don’t you do those industrial studies with this compound too? I am sure the ‘medicine’ industries would love to see these,” Khapla asked Sranto one day during dinner. They were in very high spirits because they had just got the news that Sranto’s work on the compound structure was going to be published and they were celebrating it with ‘pulleieromba.’ The same thoughts were also going through Sranto’s mind and with Dr Ranganathan’s approval, Khapla was allowed to accompany to the Centre where these studies were carried out and even work with them!

One day Khapla met Piyush, another boy from a different lab, who had come to help Sranto in his work. He came to know that since the compound did not dissolve in water, it cannot be used in large amounts to kill the microorganisms. So Piyush would give them some water soluble substances, which he called ‘nanoparticles.’ The mechanism of this work was a little mind-boggling for Khapla so Sranto tried to explain it with the help of an incident from Khapla’s life: “When Khapla was suffering from chickenpox, his mother used to forcibly feed him large amounts of ‘sebot’ or snake gourd, known for their anti-pox properties (which he detested) and he would end up vomiting. So what if his mother fed him a mixture of a small amount of drumsticks (which he loved) with a very small amount of ‘sebot’? He wouldn’t end up vomiting and his body would also get the benefits of this anti-pox vegetable!!” Khapla pondered over this parable all night to interpret and correlate it with Sranto’s work and “Nandakorewa!!” These particles would help to take Sranto’s compound in very small amounts into the bacteria (which alone were not killing the bacteria) and thus, would help in killing the microbes more efficiently!! This was indeed MAGICAL!

Working and learning with Sranto, Khapla did not realize that he was about to complete 5 years in Dr Ranganathan’s lab. His beloved maroop’s tenure in the lab was about to end; Sranto was now more engrossed in writing and reading.

Khapla had the experience to his lifetime in this lab. Looking back, Khapla realized that it was the master plan of THE ALMIGHTY that he met Dr Ranganathan on one of his daily forest trips and got a chance to realize his unfulfilled dream of gaining knowledge. He is still working in Dr Ranganathan’s lab and looks forward to more learning and lab research work!!!
Agriculture nowadays is gifted with many advanced technologies to facilitate the farmers in doing the cultivation-related tasks. Plant disease diagnosis is an essential agricultural task which the farmer needs to perform in an efficient way. Detection of diseases in the early stages enables the farmers to protect their plants for giving better yields. Many existing plant disease detection and diagnosis tools are image based. Most of the farmers are unable to use the technology due to their inability to type or because of unawareness. This inability can be overcome by speaking to the system. A cognitive application is one which provides necessary guidance to be taken based on the conditions to the users. The present paper focuses on developing a cognitive agricultural application that enables the farmer to easily communicate with the application even if he or she is an uneducated person and is unable to type. The major goal is to develop an agricultural application which interacts with the farmer to take the symptoms of the plant, and then process and provide the necessary solutions to the farmers in an efficient and a cost-effective manner.

Cognitive Science is an emerging field in multiple disciplines. The use of cognition allows a machine to take the decisions rationally. Human intelligence and machine intelligence are merged together to give the most effective results to the most complex situations. This is the motivation behind the usage of cognition in plant disease detection.

Agriculture is the major habituate of human beings which is the major source of food. A number of advanced technologies are used in agriculture to increase the productivity and decrease human labor. But, these technologies can be used only by those farmers who are educated or

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trained with the technology. Unfortunately, in most of the developing countries, those who rely on cultivation are far from education. They are unable to use the advanced technologies either due to their unawareness or because they are not trained. One major problem in plant cultivation is the detection and diagnosis of diseases. There are so many mobile applications available for the plant disease prediction and analysis. The major problem faced by the farmers in using these applications is the above-mentioned problem.

Many plant disease-detecting systems are available which are based on image processing techniques. These applications are faced with storage problems in reality due to the large computer storage requirements of the images. Many text processing applications need the user to type the information. There is a need to develop a text-based application where the user need not type but can simply give voice command to the system.

The present work focuses on development of an application which can listen to user’s voice inputs (plants symptoms), analyze user’s requirements (finding out the causes and solutions) and give possible outputs (reading out the findings). There are two ways to implement the system either with pure machine learning implementation or by just using voice analysis engine. Machine learning implementation would be quite complex and would take a long time to implement whereas voice analysis engine can be done in short time but would not be as effective as machine learning implementation.

The difference between machine learning implementation and voice analysis is quite subtle both require a pre-defined data samples. Machine learning would require such data samples in large quantity. The model has to be designed and trained with as many samples as possible (symptoms, causes, and solutions correlations). It would then automatically give possible causes and solutions when symptoms queried to the model. Voice analysis, on the other side, is plain and simple. All we need is to store the symptoms, causes and solutions relationships in the database and read the symptoms and query for the causes and solutions from the database.

The framework of the present system should support the farmer to interact with the system orally and get the results again by speech. The simple architecture contains three components as given in the figure. It gives the sequence in which the various operations will take place in the system.

| Voice Input Engine | → | Processing Engine | → | Voice Output |

The Voice Input Engine is the first module of the system which receives the human speech (the farmer giving the symptoms of the plant), recognizes the symptoms and sends it to the Processing Engine. It is the second module and it receives the symptoms and finds the related disease and measures to be taken. The Voice Output module conveys the information to the user.

The cloud engines such as Google Speech API or Amazon Alexa can be used as Voice Input Engine which can recognize the voice and perform speech analysis. The Processing Engine finds the disease that matches to the given symptoms and also finds the necessary actions to be taken.
The Voice Output module’s work is to convey the information to the user in voice by converting the text again to speech.

The system is coded with Java. The database has been taken from the Web for testing. Later, the real-time data will be taken and experimented. The questions format looks as follows:

What is the name of the plant?
What are the symptoms?
What is the frequency or intensity of disease?
How many days?
How old is the plant?

Most of the answers were recognized. Appropriate solutions were found. Individual parts were tested and found to be effective. The system needs to be integrated and tested.

A plant disease diagnosis system which can interact with the farmers would facilitate the farmers to feel free to express their feelings and get quick solutions. A Cognitive Plant Disease Detector thus provides an environment where the farmers can interact with the system orally. It also encourages the youth for cultivation.

The developed system is implemented in a generic way. The present system faces some problems with the ambiguity in speech and implemented in English. In future, it can be modified to support the regional languages also. At present, only a few plant diseases have been considered, but it can be enhanced with all the possibilities.
“Eat Healthy Think Better”

The above tagline is not just a slogan of the major food corporation, but is really an adage. Healthy eating habits result in a rejuvenated body and mind that can be more productive and deliver better results for the society at large. However, our fast-paced lifestyle in present times often leaves us with no choice than to skip healthy food. Even worse, we forget to include fruits in our diet. It should not be forgotten that fruits are truly the gifts of nature and are rich sources of essential nutrients like proteins, vitamins, minerals, etc.

Of late, an alarming rise in lifestyle diseases has led to increased health awareness. People have started to realize the benefits of consuming healthy food, including fruits on a regular basis. However, one cannot always carry a fresh fruit with him/her due to chances of degradation with time. Packaged fruit juices come to rescue in this regard, as they have a longer shelf life (time for which it remains fit for consumption) and thus, can be conveniently carried to places without any fear of degradation. But, these packaged juices have added preservatives, which are basically synthetic chemicals having severe and adverse health implications if consumed on a regular basis. Scientific studies have shown that regular consumption of synthetic food preservatives can lead to asthma, skin allergies, and even cancer. Thus, there is a dire need to perform research and develop some technology that will offer large scale production of natural fruit juices without the addition of harmful chemical preservatives.

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Research indicates that the main ‘culprit’ responsible for degradation of fruit is a polysaccharide called ‘pectin’. Polysaccharides are essentially carbohydrates, consisting of a large number of sugar molecules bonded to each other. Thus, if pectin can be removed from the fruit juice by some process, then the fruit juice can be preserved for a longer period without adding any synthetic preservatives. In other words, de-pectinisation (i.e., removal of pectin) of fruit juice needs to be carried out, if we want a long shelf life of the preservative-free natural juice.

Recently, a team of researchers led by Prof. Sirshendu De of the Department of Chemical Engineering, IIT Kharagpur has successfully carried out de-pectinisation of bael fruit (*aegle marmelos*) juice. Bael fruit is a rich source of vitamins such as A, B₁, and C. It is also rich in minerals like calcium, phosphorus, potassium, iron, etc. The researchers undertook enzymatic treatment (using pectinase enzyme) of the bael juice for the purpose of de-pectinisation. In other words, the bael juice was made free of pectins with the addition of an enzyme. They also successfully optimised the time and enzyme dosage of the process, which is very important in standardising the quality of the final packaged juice. The optimum time was found to be 60 minutes while the optimum enzyme concentration was obtained as 0.25 gram of enzyme per 100 gram of the bael juice.

For successful commercialisation of the fruit juice, large scale production is necessary. For that, the reactor where de-pectinisation is undertaken needs to be efficiently designed. In this context, the researchers have proposed a novel reactor designing scheme for de-pectinisation of bael juice in a continuous stirred tank reactor (CSTR) (a type of commercial reactor, used in industries). The scheme is generic in nature and thus can be suitably extended for processing of other fruit juices as well. This novel scheme ensures that the desirable product quality of the final processed juice is accurately maintained. The study combines both mathematical analysis and experimental validations to indicate that the residence time (time that the juice spends in the reactor) has to be greater than some threshold value, known as the ‘critical residence time’. This will make sure that the final juice is prepared perfectly with regards to the nutritional value and other desirable parameters like pH, sugar, etc.

It was also elaborately shown in the study that if the threshold value is not maintained, the product quality will get affected. The critical residence time was found to decrease with enzyme concentration at lower values of enzyme concentration. However, at high enzyme concentration of 0.2 % weight of enzyme/weight of juice and above, the change in critical residence time was not significant. Thus, at the optimum enzyme concentration of 0.25%, there is no further variation in critical residence time. This is a very important observation, beneficial for actual processing of the bael juice.

Although a CSTR (which is an ideal reactor) was initially used in the analysis, in order to make the study more relevant to a broader audience, a non-ideal reactor was also considered in the latter part. This was done so as to include maximum possible configurations of the reactor in the analysis. It provided novel insights into the requirement of critical residence time for various possible reactor configurations. It was found that as the reactor became non-ideal, the critical residence time increased.
Interestingly, the study also suggested that the maximum conversion (percentage of juice converted into pectin-free juice) that is achievable in the reactor is also dictated by a mathematical principle called “contraction mapping”. Any attempt to further increase the conversion will make the product quality unstable and unsteady. In other words, the product quality will no longer remain uniform. Maintaining the conversion within suggested limits will ensure smooth functioning of the large-scale process.

The treated juice was finally analysed, and found to be much less viscous than the original juice. This ensures that the end user buying the packaged juice has no difficulty in consuming it. Protein and polyphenol content of the treated juice was almost the same as that of the original juice, thus safeguarding the nutrient value of the juice.

The research team for the above study included Prof. Sirshendu De of the Chemical Engineering Department, along with research scholars Sourav Sengupta and Amit Jain. The results of their research have been published in the recent issue of the scientific journal *Reaction Chemistry & Engineering*.

Normally, we observe that scientists are often satisfied only in synthesising a product in the laboratory without thinking whether the product can be commercially made on a larger scale or not. But, that mentality is surely not sufficient in 21st century India. Taking the outcomes of scientific research from the laboratory to the outside society is definitely the need of the hour. It is our responsibility to serve the common citizens of this country who contribute for our expenditure in scientific research. The present study is definitely a positive attempt in that direction.
In November 1915, Albert Einstein published his theory of gravitation, the theory of general relativity (GR), which predicts that gravity arises as a consequence of the interaction between the geometry of space time and its matter-energy content. This dynamic relationship is perhaps best expressed through John Wheeler’s famous quote: “Space time tells matter how to move; matter tells space time how to curve”. A 100 years on, GR firmly stands (along with quantum mechanics) as one of the twin pillars of modern physics.

The theory and its predictions have been tested thoroughly and extensively in the last century, and have passed all experimental verifications with flying colours. Such tests include the classical solar system tests and subsequent precision tests in terrestrial laboratories and in space (using spacecrafts like Cassini and Gravity Probe B) which have helped test predictions of GR to unprecedented accuracies. However, almost all these tests of GR are “weak-field” tests, i.e., they test the predictions of the theory in regions where the effects of gravity is extremely weak, and spacetime can be assumed “almost” flat. In fact, before 2015, GR had never been tested in strong-field regimes of gravity and there was no reason to believe a priori that it indeed was the correct theory to describe highly curved spacetime.

Where in the Universe is one most likely to find such highly curved spacetime? The answer lies in one of the most interesting predictions of GR: black holes. Black holes are the predicted end-points of the life cycle of a star at least about 15 times as massive as our Sun. When such
a star exhausts all the fuel for nuclear fusion in them, it collapses under the force of its own gravity to produce a region of spacetime so dense and gravitationally strong, that not even light (or electromagnetic radiation) can escape from it (thus the name “black hole”). Some of the most dynamical spacetimes in the Universe can be found around black holes, specifically, black holes in a binary system, making them ideal environments to test the strong-field effects of gravity.

Another remarkable prediction of GR is the existence of gravitational waves (GWs). According to GR, a change in the matter-energy distribution in spacetime causes a change in the geometry/curvature of spacetime. GWs are these propagating changes, or ripples in the geometry of spacetime that carry energy and angular momentum away from the source. The resulting distortions of spacetime, as the wave passes by, can be measured using advanced Michelson interferometric setups, like the ones present in the Laser Interferometer Gravitational-Wave Observatory (LIGO) detectors in the United States. LIGO is a 4 km long Michelson interferometer that records relative changes in length between its two perpendicular arms produced by the passage of a GW. It is the most precise measuring device ever built, capable of detecting changes in length 1/1000th of the diameter of an atomic nucleus, roughly the displacements expected when the strongest GWs pass through Earth.

Among the various sources of GWs, mergers of black holes in a binary system (mentioned above), are the most promising for these detectors because, 1) such sources are extremely powerful, allowing us to observe them far out in the Universe, 2) they are expected to be quite frequent (about a few hundred per year when the detectors reach their maximum sensitivities) and 3) such sources are well described in GR. A binary black hole coalescence evolves over three phases: an
**inispirl**, where the two black holes move around each other and spiral in due to the emission of GWs, the **merger** when the two black holes coalesce into a single object, and **ringdown** when the recently merged object radiates away its asymmetries through a spectrum of exponentially damped sinusoidal GWs and settles down to a single stable rotating remnant black hole. While there are analytical descriptions for the inspiral and ring down stages of a binary black hole merger, an accurate description of the highly non-linear merger regime requires us to numerically solve Einstein's equations on a supercomputer. This also allows us to predict the final mass and spin of the remnant object accurately starting from an initial binary black hole system. Using the above information that a binary black hole merger is completely described in GR, the astrophysical relativity at the International Centre for Theoretical Sciences in Bangalore (which includes the author), formulated and implemented a strong-field test of GR called the “inspiral-merger-ringdown (IMR) consistency test”, and demonstrated it on actual GWs from binary black hole mergers observed by LIGO.

Given a GW signal observed by LIGO, it is possible to infer the properties of the source that produced it, for example, the masses and spins of the initial binary black hole system. The IMR consistency test is based on inferring the mass and spin of the remnant black hole from the initial part of the signal produced by the inspiral of the two black holes, and then comparing them to the same two quantities estimated independently from the final merger-ring down parts of the signal. If the underlying theory of gravity is different from GR, then a discrepancy from the predictions of GR is most likely to arise during the merger regime where gravity is the strongest and most non-linear. This would then show up as an inconsistency between the two independent estimates of the mass and spin of the final black hole. We demonstrated the robustness of the method by performing the test on a simulated population of binary black hole merger events across the Universe, and concluded that the test is most sensitive for some “golden events” where all three phases of evolution the inspiral, merger and ringdown, are observed with appreciable loudness; and that the strongest constraints on possible deviations from the predictions of GR can be obtained by combining information from multiple events. Finally we were able to show that the test is even able to distinguish cases where the energy and angular momentum emitted into GWs from a binary black hole merger is different from the predictions of GR, thus allowing for a theory-agnostic formalism to test deviations from GR from various theories of gravity.

**Real Gravitational Wave Observations:** On September 14, 2015, GWs produced by the inspiral and merger of two black holes (each around 30 times the mass of our Sun) passed through Earth and were observed by the twin detectors of the Advanced LIGO, opening the new window of GW astronomy onto the Universe, and allowing scientists to test GR in the strong-field regime for the first time. The IMR consistency test was among the handful of tests used for this purpose, and through the absence of any deviations from the predictions of GR, helped establish the consistency of the first LIGO event, GW150914, with a binary black hole merger described in GR. Since then, the test has been demonstrated on two subsequent detections: GW170104 and GW170814. We also showed that one can indeed obtain tighter bounds on possible deviations from GR by combining information from multiple events. As further proof of the robustness of the test on real
data, it was demonstrated on software injections, i.e., simulated GW signals injected in real LIGO instrumental noise as well as hardware injections, i.e., when the passage of a GW is mimicked by displacing the actual hardware of the interferometers!

**The future:** The IMR consistency will continue to be demonstrated on GW observations of binary black holes mergers by current as well as future GW detectors. The current second-generation of detectors are expected to be followed by a third-generation of ground-based interferometric detectors, like the Einstein Telescope and Cosmic Explorer (with almost 10 times more sensitivity), well as space-based detectors like the Laser Interferometer Space Antenna (LISA). With the detection of seven GW events by the current detectors so far, we have firmly begun an exciting era of GW astronomy. The upcoming years will be a period of active research which will help us address long-standing questions in theoretical physics, astrophysics and cosmology using information from GWs. It will also perhaps lead us into the unknown, revealing new mysteries about our Universe. The future of the field, in general, and the IMR consistency test, in particular, is truly exciting. Stay ‘gravitationally’ tuned!
The advent of easily affordable smartphones and Internet of Things (IoT) devices, coupled with Government initiatives such as the Digital India, has almost brought the whole world at our fingertips. However, while enjoying the luxuries of the digital world, we seldom spare a thought about the privacy of the vast amount of digital information we generate and transmit across the Internet every day. Perhaps we exercise utmost caution only during online payments or while sending some confidential emails. But then, the ‘https’ tag on the address bar assures us that our information is being securely transmitted across the web. But if security is already assured, why is there so much hype around online privacy? Doesn’t security implicitly guarantee privacy? Can the vast amount of internet traffic traveling around the globe leak some of our personal details? What can be the consequences of such information falling in the wrong hands? If these questions baffle you, then IIT Madras now has a solution that lets you evaluate your online privacy. The proposed solution, called CryptAnalytica, lets you discover all the information that leaks when you browse through websites even while using a secure communication protocol. It further lets you understand if the leaked information can pose a threat to your online privacy and also gives an insight into how you can prevent a potential privacy breach on the Internet.

Although ‘security’ and ‘privacy’ conceptually sound very similar, there is a fine line that distinguishes the two. For those of you who are not familiar with this subtlety, here is a simple illustration that will help you understand the difference. Imagine that on a fine morning, you get a call from a courier waiting at your office entrance while you are at your desk. Upon meeting, he

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delivers you a gift that your friend has sent you for your birthday, parcelled up in a pretty wrapper. However, you do not want to open the parcel in front of your colleagues, so you put the parcel in your drawer and lock it up once you walk back to your desk. Now, your colleagues who have been observing all your activities can easily infer that you have received a parcel by courier. The wrapper of the parcel further indicates that it is a gift. Some of your colleagues might ask you if it is your birthday. Finally, the secrecy you maintain about it makes some people believe that the parcel might contain something expensive. As a result, although you have now successfully hidden the contents of the parcel from your colleagues, by merely observing your actions they come to know of some information about you, which you explicitly did not share with them. Some of this information may be correct and some may be wrong. Hence the inferences made by your colleagues are definitely probabilistic. However, the consequences of such information being leaked can be either pleasant or painful for you, depending on who observes what. A friendly colleague may organize a birthday party for you, while a jealous one may plan to steal the parcel. In the world of Internet communications, the act of locking up your parcel in the drawer ensures ‘security’, and the inferences made by your colleagues from your behavior and the appearance of the parcel constitute the ‘leaked information’ that may violate your ‘privacy’. All the attributes of the parcel and your activities constitute the ‘metadata’, and the metadata that helped your colleagues draw inferences about you are called ‘side-channels’. Your colleagues are the ‘surveillants’ here.

The concept of mass-scale digital surveillance garnered worldwide attention when thousands of classified documents belonging to the National Security Agency (NSA) of the USA were leaked by its ex-employee Edward Snowden in 2013. These documents revealed that post the 9/11 attacks, the US Government has been spending heavily on well-organized mass surveillance programs such as the PRISM, XKeyscore, and Tempora. Through these programs, the NSA collects and analyzes Internet communication traffic generated by people across the globe with the help of companies like Google and by intercepting fiber-optic cables around the world. When confronted with charges of unauthorized information access, the NSA attempted to defend themselves by stating that they only collect metadata about Internet communications for national interests, and do not break the security of the actual data being communicated. However, this sparked a debate regarding the role of metadata in breaching the online privacy of an individual, an institution or a nation.

Internet measurement studies suggest that as of August 2018, 90.4% of all Internet traffic consist of web browsing traffic, and it is also the most sought-after source of information for mass surveillants. CryptAnalytica focuses on identifying side-channels in secure web browsing traffic that may leak information about which web pages in a website are popular among the masses. Such information, when leaked, can help cyber attackers identify their sweetest target points for circulating malwares or other malicious activities. Identification of such side-channels before making a website publicly available will help a website designer devise ways to protect web browsing privacy. Existing mechanisms for evaluating privacy vulnerability of Internet communication assume targeted surveillance on specific people, where the attacker is believed to possess a lot of background information about the victims. Such information includes personal details such as preference of food, possible medical conditions, etc. Possessing such detailed knowledge about a
large number of people is not practically feasible. To the best of our knowledge, CryptAnalytica is the first framework that evaluates the vulnerability of web traffic in the face of mass surveillance, assuming no prior knowledge about the targets.

CryptAnalytica operates in two phases *profiling* and *prediction*. In the profiling phase, it first observes the metadata of Internet traffic generated when a user accesses different web pages of a website. By metadata, we refer to those attributes of Internet traffic which are visible to anyone who can intercept it. Such metadata include the volume of network traffic, the time required to transmit a file, IP address of the web server, IP address of the user, etc. From the metadata, CryptAnalytica identifies the side-channels which might reveal which web resource (image, video, etc.) has been communicated over a secure channel. As we know, web pages are composed of multiple such web resources. So, if a surveillant can infer which web resource has been accessed, he can further infer the webpage accessed. CryptAnalytica then selects those side-channels which have a steady value across different network conditions. This is important since side-channels having different values for different scenarios are not suitable for mass-scale analysis. For instance, the time required to download a video from a website is not a good side-channel for identifying which video has been downloaded, since the download time depends on the network speed, which varies from time to time. Hence, by observing the download time, a surveillant cannot infer which video has been downloaded by a user. However, it has been observed that even when communicated securely, the sizes of the web resources cannot be hidden from a surveillant. Furthermore, these sizes remain constant across various network conditions and user behaviors. So, this forms a stable side-channel. Once such stable side-channels have been identified, CryptAnalytica stores the side-channel values (in our case, the resource sizes) in a database. Thereafter, in the prediction phase, CryptAnalytica uses this information to check if the different resources can be identified uniquely from their side-channel values. Also, from the resource identified, it checks if it is possible to predict the webpage accessed. This analysis is important because in practical cases, a website often hosts different resources having similar sizes. Also, the same resource can be shared by multiple web pages. Owing to such factors, the inferences made from side-channel values are always probabilistic. We evaluated CryptAnalytica on a real website and it was found that the side-channel leakage of the website can allow surveillants to correctly predict web pages browsed by its users in 78% cases.

Apart from the cyber attack point of view, unauthorized inference of web page access statistics can have several other consequences. There has been evidence of dishonest Internet Service Providers, VPN and cloud service providers who sell information about their clients to unauthorized people. If such entities can discover stable side-channels in business websites, they may sell off the web page access statistics to data analysts who can infer further information about the business organizations, such as their consumer bases, popular products, and other confidential business-specific information. On the other hand, if used by authorized personnel, CryptAnalytica can be used to identify malicious contents such as malwares on live web traffic and that may help in controlling the proliferation of such harmful objects.

The research team at IIT Madras that has been working on CryptAnalytica includes - Gargi Mitra, Prasanna Karthik Vairam, Prof. V Kamakoti and Dr Nitin Chandrachoodan.
A Novel Approach for Solar Potential Assessment using Geoinformatics for Rural India

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Nearly 30 crores of people in rural India lack access to electricity, promoting the use of non-renewable sources of energy such as kerosene, chulhas (wood fired), petrol, diesel, etc, which not only results in massive environmental damages but also significant health and serious hazards. Solar energy offers an opportunity to channel this huge infrastructure gap and advance the social, economic, environment and health indicators of 30 percent of India's population. Non-renewable sources of energy are depleting fast. It is recommended to use renewable energy since non-renewable energy sources are limited in nature. Climate change, increase in the cost of the non-renewable energy sources are the factors that are warning us to use renewable energy sources. Solar energy is the cleanest form of energy available on Earth's surface. A lot of research is going on to use renewable sources of energy. The government is also focusing on maximum utilization of solar energy and methanol with diesel/petrol. There are subsidy schemes for the people/institutions in different states to install solar panels on their rooftops. In the upcoming five years, India aims to mount 10,000 small-scale solar power grids across the country to provide basic electricity to households. But providing access to a nominal supply of clean power for two LED lights for few hours and charge a cell phone is perhaps not enough to meaningfully improve people's lives, new research suggests. In a recent study in Uttar Pradesh, thousand plus houses have received clean electricity for the first time. This has resulted in the decrease in their spending on costly kerosene for lighting purpose.

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Solar Photovoltaic (SPV) uses solar energy to generate electricity. SPV absorbs solar irradiances to produce electricity. The SPV is made of a semiconductor which has four electrons in the outer shell. So when the sunlight falls on the SPV the electrons get charged by this energy. To accommodate this extra energy, electrons travel from one place to another place inside the semiconductor. This extra energy has been used to generate electricity using SPV. The solar cell has been developed using dyes naturally found fruits/juices (viz., Indian jamun, plum, black currant, and berries) by researchers at IIT Roorkee. IIT Roorkee has adopted five villages for rural development under the scheme of Unnat Bharat Abhiyan (UBA). The five villages under this UBA scheme are Meerpur, Chandpur, Chharba, Beladi Salhapur, and Puranpur located in Uttarakhand. This research focuses on these villages in providing electricity by utilizing the solar energy. Different types of installation places such as land, canal-top, rooftops have been analyzed for SPV installation in this research. This research also focuses on the optimum tilt angle required to install the SPV panels. Studies on Salhapur and Meerpur have been performed to estimate the energy requirement and solar potential assessment. The energy requirements and solar potential assessment have been carried out for these two villages.

A geodatabase of these two villages has been created to assess the solar potential and energy requirements. Satellite images have been downloaded to create the land use land cover (LULC) map of the villages. The important parameters such as area, perimeter, population, agricultural land, and well pumps have been taken into consideration for the assessment.
The energy requirements of Salhapur and Meerpur villages are 8.5 MWh and 10.5 MWh. The annual solar potential assessed over rooftops of the Salhapur and Meerpur are 84.95 MWh/day and 47.5 MWh/day. The survey has been performed to assess the length of the Ganga canal need to install the solar panels to feed the electricity requirements of the nearby village and towns. The population and socio-economic data have been obtained from the online website of India Census 2011. It has been found from the studies that solar energy is capable of fulfilling the requirements of these villages.

The energy requirements of the villages are of great importance. Energy demands are increasing to cater to the needs created by new techniques/technologies available in the market. Some of the techniques such as drip irrigation, well pump, etc. are forcing the farmers to use electricity. This UBA scheme is a very innovative scheme started by the Government of India for rural development of the villages and towns located nationwide. A software tool has been developed by Geomatics Engineering, IIT Roorkee, and published in the Springer Spatial Information Research journal (http://www.solarcloudgis.appspot.com/). This tool has two modules. In the first module, it has the capability of estimating the energy requirements of the household, institute, village or town. The parameters used by this software for estimating the energy requirements include type and number of electric equipment, wattage, and hours of usage. Based on these inputs it calculates the energy requirements on the daily, monthly, and yearly basis. The second module is capable of predicting the solar potential available at the specific location.

The inputs for this module are tilted monthly/annual GHI, latitude, longitude, number of rainy and cloudy days. This software tool is designed to work efficiently in the Indian context. It has been tested and modeled with the live solar plant data to work accurately. The decentralized and modular nature of solar panels makes it easily approachable and installable at different locations. The intensity of solar radiations available on the hills is more in comparison to the ground. This is because of the aerosols, dust particles and pollution on the ground. Therefore, installation of solar panels at the hills produces more electricity than on the ground. It has also been validated with the Pyranometer survey conducted by us. We have got the solar irradiance of 865 W/m² at Roorkee and 921 W/m² at Pauri Garhwal. This clearly states that solar irradiance at hills is more intense than on the ground. Our approach has also stated the best optimum tilt angle required to install the SPV panels based on specific latitude of the location and other important parameters. In Uttarakhand, Uttarakhand Renewable Energy Development Agency (UREDA) is also providing subsidies to the people living on hill terrain to install solar panels and sell the excess power to the state government in exchange for units. This research is helping local people and government in providing subsidies and policy-making for people’s benefit.
Delving into the world of miniature wide opens a new vision to the existing research. Identifying potential of the minuscule encourages the development of current research. It becomes a massive power when such a miniature mimics the entire system of mammals. One such wonderful wicked weapon among the model systems is a nematode which is the title hero of the current story, Caenorhabditis elegans.

It is a microscopic model with the adult having 3 mm in length. One can manifestly witness its elegance by the transparency of the worm through the microscopic eyes. The miniature model is being used by the researchers all over the world for more than decades in various fields of Science. Our group, led by Prof. K Balamurugan, Department of Biotechnology, Alagappa University, Karaikudi, Tamil Nadu primarily focuses on the research based on host-pathogen interactions and have published quality of research findings on a number of human pathogens. The former

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research scholars of the group have given a special attention to understand how a eukaryotic host system elucidates the innate immune responses against bacterial pathogens by targeting the effector systems involved. Each research finding attests the role of physiological/biochemical/neuronal cells in innate immune response of the host system during infection with various human pathogens.

In common, all of the tested pathogens were found to reduce the survival of the host, however, the interaction with the host varied for each of the pathogen tested. As a notable concern, the host system was found to exhibit biphasic and triphasic expression pattern of regulatory players during infection. Recently, the key proteins involved in regulatory events during bacterial infection were uncovered through 2D-based proteomic approach. Excluding the host pathogen interactions, our research group fascinated their research towards ageing, obesity, reproductive defects and post-translational modifications. The writer of the present story is a member of this research group who is engaged in exploring the potential of the model nematode for utilised in wound research.

Wound is a common threat worldwide. The term 'wound' comprises all kinds of injuries from scratch to laceration. Briefly, it is a damage or disruption of the normal anatomy of the biological system. The damage instigates a process of restoration named healing, which is customary for all biological systems. Due to the environmental factors and deterioration of the individual’s immune, the biological system is unable to accomplish the processes of healing. Hence, external inducer(s) in the form of therapeutic agents are required to endorse the system to promote healing. In the era of wound research, lot of therapeutics are being investigated to address the wound-healing process through antibacterial therapy. However, there is not much attention given for wound closure-related therapeutics. Hence, a simple model system is needed to take the research forward to delineate healing and closure-related therapeutics.

The process of healing may vary from one organism to another, depending on the skin architecture, although the basic ideology behind the healing is common over eukaryotes. Hence, an outcome, from the wound research in a simple model will pave way for a new window of knowledge to demote the wound complexities over the horizon. One of the major complexities of injury, which is contemplated over here, is infection at the site of injury. The process of healing is interrupted and delayed by the incidence of infection and it deliberately escort to a chronic state of the wound. Hence, fortifying the immune system against wound infection becomes obligatory. In this context, the research work of the writer endeavours to provide new insights from the wound infection studies using the model nematode, C. elegans.

The incidence of injury in C. elegans was first reported in 2008 by Pujol and subsequently the simple nematode was being employed for understanding the wound-healing process. Based on functionality, the simple epithelial epidermis and overlaying collagen cuticle of the nematode is comparable with mammalian hypodermis and the outer dermis, which becomes a massive advantage of using this model in wound research. Earlier, wounding of C. elegans was done individually using femtosecond laser and microinjection needle. In my study, a novel wounding protocol was discussed to provide voluminous wound population in a single venture. The protocol requires truncated glass wool pieces to wound C. elegans. The occurrence of injury was confirmed by morphological changes as well as other parameters of wounding such as reactive oxygen species,
calcium signalling, F-actin dynamics and collagen content. By evaluating the different parameters of healing, the active principles from plant sources accountable for healing and closure were assessed. Briefly, the wounded C. elegans were subjected to preliminary screening with phytocompound(s) for their wound-healing abilities. Furthermore, the mode of action of selective active principles was investigated through analysing the global transcriptomics and proteomics alterations during the course of healing/closure and this part of research is communicated to an International Journal.

To extend the research on wound-healing process, a wound-infection model was developed using C. elegans. Briefly, the wound-infection model was established by exposing the wounded C. elegans with a pathogen, Staphylococcus aureus, which is commonly noted in most of the wound infections. The impact of the pathogen on wounded worm was assessed through their lifespan. It is known that the survival of the host was invariably reduced upon exposure to any virulent pathogen(s), and hence, it was anticipated that the exposure with S. aureus could diminish the survival of the wounded worms. As anticipated, the survival of wounded worms was found to be decreased than the unwounded worms. To our surprise, the study observed that the wound-infection model showed better survival ability than the wound model. The rationale behind the improved survival of wound-infection model is being investigated through molecular and proteomic approaches.

This new study outlined the potential of the model nematode, C. elegans for wound research, including wound healing as well as wound infection. Our findings will attest the contribution of the tiny model in screening of phytocompounds specific for healing and closure. However, further research is required on wound-infection studies using C. elegans to uncover the key regulatory player(s) involved in longevity of wounded worms during the course of infection.

Have you heard the story of ‘Jack and the Beanstalk?’

It is a pretty charming tale. Jack, a poor little boy, exchanges his cow for a few magic beans that grow all the way up to the sky overnight. Jack climbs up and after the adventure on top of the massive beanstalk, he cuts the plant and kills the giant pursuing him. And discovers a bag of gold, golden egg-laying hen and a magical harp. ‘Poor’ Jack does not remain poor anymore, thanks to the magic beans. How wonderful it would be to have a bean that makes you rich like that! Well, you may not be rich, but at least hunger-free could be the wish.

Practically speaking, beans can never grow overnight, or enormously limitless. It is just a plain Old English fairy tale. Much of the literary works from the bygone era describe beans as cheap food, fit only for the poor.

‘They eat beans mostly, this old yellow pair
Dinner is a casual affair.’
Gwendolyn Brooks, The Bean Eaters (1960)

From these lines from Gwendolyn Brooks poem, ‘The Bean Eaters’, one finds what beans have always meant to the world. In the world where everyone cannot afford animal products, people surrender to beans. Since time immemorial, beans, and other legumes in the family are known as ‘poor man’s meat’. Like beans, all other legume foods are low-cost and yet they are not

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in the mainstream. They are at best, alternative sources of vegetable proteins, calories, vitamins and minerals. No wonder they are highly popular in numerous under-developed and developing nations.

Food legumes are those having two or more seeds enclosed in a pod, like in the green peas. The word ‘legumes’ and ‘beans’ are often used interchangeably. Legumes growing on trees are commonly called ‘Tree Beans’ or ‘Tree Legumes’. Recently, food legumes are a major crop group in the Asia-Pacific region. Several legumes like soybean and groundnut have changed the face of modern agriculture amidst the dominion of cereals, becoming leading crops in conventional farming. Could there be a new prince in the story? A new savior?

**The Way Forward**

Asia needs one such princely savior. Asian continent ranks the topmost regarding population density; it is also the continent with the hungriest people, accounting two-thirds of the total. India peaks with almost 200 million inhabitants going to bed hungry every night. On the plus side, India has emerged as the fastest growing major economy in the world, but on the minus side, it is home to the largest number of undernourished population. The hunger situation in India is an extremely critical issue. Food grain production in India is finally improving. The land is the world’s largest producer for milk and second largest producer of fruits and vegetables. Digital India prides itself as the progressive nation but fails to keep pace with the matters of food and nutrition. Imagine the irony of not having the ability to reach out to the hunger population even as the country has reached self-sufficiency in food production. Despite all the green revolution, providing for the hungry stomachs in the future is still a dream, a dream aiming at ‘Zero Hunger’ by 2030. For achieving ‘Zero Hunger’, nutrition and food security are vital. But there are a growing number of people and a significant burden on conventional food resources. In spite of this, the land where there is a struggle, nature hides the key to success as well. Scientists have identified several under-exploited food legumes that could be the saviors in food and nutrition insecurity crisis. Legumes are indispensable and some of which are regionally highly valuable food for men and beasts.

**The Long Journey: Spilling the Beans**

One of the legumes could be just lying, literally, on our walking paths. During the British Raj, the elite introduced park culture in cities like Bangalore. This culture gradually integrated among Indians leading to the beautification of cities with parks and gardens focusing on planting multipurpose trees among ornamental and flowering plants.

Thanks to the people of yore under urban vegetation cover, many native and exotic species diversity still exists today. Among them, one can find plenty of ‘Parkia Tree’ or ‘Badminton Ball Tree’ (*Parkiabiglandulosa* Wt. & Arn.) gracing the street lanes and adding aesthetic value to the park spaces in Andhra Pradesh, Maharashtra, and Karnataka. For locals, the tree is just another one giving shade in the Sun or plain beauty.
But Parkia is more than just a beauty. Its pods could be sources of future protein. The tree with its flowers and fruits bears a close resemblance with another tree *Parkiatimoriana* DC. Merr., which is seen only in North-East India. In Manipuri language, it is famously known as ‘Yongchak’. Unlike the pods of Badminton Ball Tree, which are the length of a 15cm scale, containing 5-8 seeds in every pod, the Yongchak is 35-40 cm long and includes 18-20 seeds per pod. It is highly valued in Manipur for its ecological and economic importance, and is a huge part of traditional food preparations like fresh salad, singju and boiled curry, eromba. In the beans, one finds an appealing palate taste which makes the bean so popular and high in demand during its peak season.

On the other hand, *Parkiabiglandulosa* Wt. & Arn., is the native of Malaysia, introduced in India through cultivation. It is often mistaken for the Gulmohar tree during the non-flowering and non-fruiting season. But on any wintry day from December till early March, one can see the inflorescence in full bloom. The myriad cream color flowers, with yellow hints, cluster in a spherical shape and look like badminton balls, hanging on long stalks. It is a beautiful sight to observe parrots and other small birds bite into the fruit clutching the long stalk and swing. Walking under the shades of these trees during hot summers, one may never ponder on the food potential of the short and twisted pods that grow out from these flowers in bunches of 10-20 in numbers.

Luckily, the distribution of these trees in and around Mysuru district of Karnataka has opened new ground for the food scientists and researchers at CSIR-Central Food Technological Research Institute. Credit goes to one of the CFTRI Food Scientists. Dr Ngaseppam Iboyaima Singh hailing from Manipur finds these tree legumes of Mysuru as an alternative substitute for the highly popular beans from Manipur for the local consumption of Manipuri population in Mysuru city. Having consumed both the tree beans during his 25 years long career life, he does not find any difference in the taste, except the observable physical characteristics of the tree, flowers, and pods.

But appearances apart, the food value of a plant depends upon many other factors. Though its use in food, medicine, and fodder is little known, the preliminary probing reveals the promising food and nutrition potential of these seasonal tree beans. The resource-rich beans packed with protein (25-35%), fat (11-20%), vitamins and minerals can meet the needs of basic and wholesome nutrition. But there is a catch. Processing is a major factor for such legumes, as they many times contain anti-nutritive substances which do not allow nutrition gain in the body. Science can help here. While carrying out nutritional profiling, processing, and development of traditionally valued legume-based products are underway. These are ready-to-prepare and ready-to-eat, attractive and convenient. With the touch of science, the utilization of the strange yet familiar Parkia tree beans is now possible for the first time, to its full potential.

Today’s research can drive the future of food, and every progress made with science, technology, and hopes, will be a step ahead to win the battle against hunger.
Coastal ecosystem is a meeting zone of terrestrial and marine ecosystems. This transition region creates a unique environment which harbours a great biodiversity. Salt marshes, wetlands, bays and estuaries comprise some of the coastal areas. India has 7516.6 km of coastline area, while Gujarat alone has 1600 km which is the longest coast line and covers around 24% of India sea coast.

Coastal areas are saline in nature with higher pH (alkaline). It is observed that soil’s chemical, physical and biological properties are severely affected by high salt concentration, which leads to destruction of vegetation and, finally, soil desertification. These areas are not suitable for growth and reproduction of normal living forms because of harsh saline condition, but it is said that god hasn’t created anything in this world without any reason. If a place on this earth, is not suitable for someone, it doesn’t mean that the place is not for others. These harsh conditions are optimum for creatures who not only tolerate but also require severe environmental conditions for their proper growth and survival. The organisms that can tolerate and grow in saline conditions are called halophiles (salt-loving organisms). These creatures have adapted themselves to salty environment through mechanisms like regulating the expression of stress responsive genes, and production of osmoprotective molecules, etc.

Coastal vegetation (halophytes) protects us from heavy storms and waves and plays an important role in increasing soil quality by reducing soil salinity and addition of important

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nutrients. Plant influences soil characteristics, microbial community structure and enzyme activity by the release of root exudates, lysates, sloughed-off cells and exogenous enzymes into the rhizospheric soil. Root exudes of halophyte provide carbon and energy source to microbes and the concentration of these exudates change with different plant species, metabolism type, plant growth stage and season and, simultaneously, microbial community structure also changes. These microbial communities involve in decomposition of complex substrates by the use of hydrolysing enzymes and cycling of nutrients. This way, coastal vegetation significantly requires nutrient cycling and maintaining huge biodiversity, which differentiates barren soil (without vegetation) from vegetation covered soil.

So, the study of this special ecosystem will definitely enhance our knowledge about halophyte soil-microbe interaction and how salty environment influences ecosystem function. Most of the previous studies were conducted on agricultural fields but scarce information is available about coastal ecosystem. To address this, we did a comparative study of soil characteristics, microbial community structure and enzyme activities of halophytes covered soil vs barren (control) soil during three seasons (rainy, winter and summer).

For this interesting research work we have selected Dharabandar site (20°49.04’N, 71°13.47’E) which is in Amreli District of Gujarat, India. This site is unique in term of vegetation types because many perennial and annual halophytes grow luxuriantly and complete their life cycle. For this study, we have chosen four perennial halophytes (Aeluropus lagopoides, Arthrocnemum indicum, Heliochloa setulosa and Suaeda nudiflora) because perennial plants are one of the most influential factors in coastal areas which affect ecosystem processes.

At Dharabandar site, we randomly selected 5 m x 5 m plots (3 replicates) for vegetation covered soil and control soil collection. The soil samples were collected in rainy, winter and summer seasons. After collection of soil samples, they were immediately transported to laboratory and sieved with 2 mm sieve. Soil samples were then stored at room temperature for chemical analysis and at -20°C for enzyme activities and PLFA analysis.

The air-dried soils were used for the analysis of electrical conductivity (EC), pH, organic carbon, soil mineral nitrogen (nitrate and ammonium), available phosphorus, soil potassium and sodium contents. The -20°C stored soils were used for PLFA analysis and enzyme activity estimation of three important enzymes like β-glucosidase, urease and alkaline phosphatase which involve in carbon, nitrogen and phosphorus cycling, respectively.

Soil salinity is measured in terms of electrical conductivity while pH tells us about the acidity or alkalinity of soil. Organic carbon works as a source of food for microbes because they
utilize organic carbon and degrade complex compounds into simpler one and finally increase the concentration of soil nutrients such as nitrate, ammonium and phosphorus. So, the study of enzyme activities, works as a useful indicator of soil quality. Potassium is very useful ion which plays an important role in normal functioning of cells while halophytes accumulate sodium ion for osmotic adjustment so, the availability of these ions is essential in soil. PLFAs (Phospholipid fatty acids) are vital components of living microbial cell membrane which are produced by microorganisms through different pathways and can be used as biomarkers to examine the soil microbial community structure.

We observed that pH, EC, soil nutrients, enzyme activities and microbial community structure were significantly influenced by vegetation type and seasons. The activities of all three enzymes urease, β-glucosidase, and alkaline phosphatase and total PLFA content (microbial content) were significantly higher in halophyte's root zone soils than in control soil. The highest β-glucosidase activity was observed in *Suaeda* covered soil during rainy season, *Helechohra* in winter season and *Arthrocnemum* during summer. The alkaline phosphatase activity was higher in rainy and summer seasons than in winter season. In all seasons, halophytes showed more or less similar alkaline phosphatase activities while control soil showed the lowest activity. In all seasons, similar urease activity was observed. The highest urease activity was in *Helechohra* and *Suaeda* covered soils and the lowest in control soil.

In winter and summer seasons, significantly higher concentrations of total, GM-ve, GM+ve, total bacterial, actinomycetes and fungal PLFAs were observed than during rainy season. *Arthrocnemum* and *Helechohra* halophytes showed higher concentrations of total, GM-ve, GM+ve, total bacteria and actinomycetes PLFAs followed by *Suaeda* and *Aeluropus* while the lowest content in control soil. The amount of fungal biomarker PLFA was higher in *Arthrocnemum* and *Suaeda* followed by *Aeluropus*. Similar to enzyme activities different halophytes showed variation in higher concentration of PLFA biomarkers in different seasons. The NMS (nonmetric multidimensional scaling) study also suggested that the microbial community structure varied significantly in control and halophyte-covered soils as well as in all seasons.

Our study has proved that the ecophysiological approaches developed by halophytic plants alters soil’s chemical and biological structures in positive manner than that of barren soil. The root zone processes like release of root exudates were strongly linked with halophyte species and seasons in saline soils. We found amazing differences in the soil chemical and microbial properties in different seasons and between vegetation covered soils vs control soil. Halophyte root zone soils were higher in enzyme activities and microbial content compared with control soil because of the availability of carbon and energy sources and less salinity. Halophytes reduce soil salinity for maintaining their own osmotic balance and through this mechanism; they not only reduce salinity stress on microorganisms and enzyme activities but also play an important role in restoration of coastal ecosystem.

Our results also suggest that not a single halophyte species enough for healthy functioning of coastal ecosystem because different species of halophyte showed higher microbial content in different periods of time likewise enzyme activities also were higher in different halophyte covered
soil at different seasons. So, it can be suggested that all halophytes at community level are very important for maintenance of coastal ecosystem.

Our serious concern is that this unique ecosystem is in danger because humans are continuously degrading it to fulfil their greed. So, it is our moral duty to protect this because these halophytes being a plant also absorb large amounts of CO$_2$ from the atmosphere and help us in reducing a potent greenhouse gas. However, coastal ecosystems are also sensitive to changes in the environment, and it already been studied that some coastal areas are now struggling to maintain their biodiversity due to anthropogenic effect.
Did you know that a tree stopped reproducing in Mauritius since after the 1600s? The reason is extinction of “Dodo” bird which helped in the reproduction of this tree. The little-known “Dodo” bird used to eat the fruits of this tree. It helped to remove the external seed coat which helped in the germination process. But, how did it become extinct? The bird used to live in the island of Mauritius and eat fruits which fell from the tree. But, when in 1505 the hungry Portuguese came to this island first, they saw Dodo as a source of meat. Within 100 years, the Dodo bird became extinct and the last Dodo was killed in 1681! To make matters worse, only 21 out of the 45 bird species originally found in Mauritius managed to survive.

Another alarming statistic reported by 2018 state of the world’s report is that around 40% of the world’s 11,000 species are in decline!! We still do not know what the possible consequences of this extinction could be. Sylvia Dolson, a naturalist and author rightly said, “Like us, animals feel love, joy, fear and pain, but they cannot grasp the spoken word. It is our obligation to speak on their behalf ensuring their well-being and lives are respected and protected”. Hence, at least now we need to conserve our birds. This can be done by continuously monitoring the number of birds in a locality. Since birdwatching for a long time is a laborious task, automatic monitoring is needed. Researchers at the Indian Institute of Technology, Mandi have already started to work towards achieving this goal. The team led by Dr Padmanabhan Rajan, Dr Dileep A D, and Dr Arnav Bhavsar at Multimedia Analytics and Systems Lab started to analyse the bird data and monitor the bird species.
In birdwatching, the watchers keep their eyes and ears alert so that they can spot birds at the right time without missing out any of them. Following the same strategy, the researchers captured both the audio and image data. The audio data was captured using microphones and the images of the birds were captured using the camera. For a computer engineer, the task of classification may sound straightforward. “The task of classification isn’t straightforward. The data contains a lot of other sounds such as the sound of the rain, wind and animals” said Dr Padmanabhan Rajan, one of the lead researchers of the project. Also, the images of the birds obtained could be blurred or blocked by leaves or, even worse, only a part of it is captured. Expert birdwatchers could identify the birds from these corrupt images or sounds. Hence, the task is to make the machine as good as this expert.

The only possible way to make the machine as good as humans is to train the machine to think and process information like humans. The name for this process in the science world is “Machine Learning”. How do humans learn to identify an object? Humans first “train” themselves to identify objects by registering some of the important “features” and, later based on the training, we recognise the object. Similarly, to build an algorithm which can classify the species automatically there are two stages training and testing. To train the algorithm, image and audio data of various species is fed into the system. Then, using audio and image processing tools, the algorithm learns to classify the species. In the testing stage, the algorithm automatically differentiates the species given the audio or image data.

However, before classifying the species, it is important to find out that in the given audio recording, bird sound is present or not. Otherwise, we simply waste our resources by running the algorithm even for the non-bird recordings. Indian Institute of Technology, Mandi has developed the Bird Activity Detection (BAD) framework to achieve this goal. They developed a simple and powerful algorithm using Support Vector Machines (SVM) with Mel Frequency cepstral coefficients (MFCC) as features. But, what is the specialty of MFCC? Or why MFCC? It is said that the human ears act as filters. They are more sensitive to sounds which have low frequency. MFCC mimics this human ear behavior and hence is the favorite choice of speech/audio signal researchers. They used SVM with Probability Sequence Kernel which basically gives a value on how well the given feature vector matches the bird and non-bird class. They were able to get an accuracy of 77% and 85% on the online dataset Warblr and Free field respectively.

The next step is to classify the sounds, given that the audio recording is having bird sounds. Similar to the previous algorithm, Mel Frequency cepstral coefficients were used as feature vectors. These features were fed to Deep Neural Networks to classify the bird species. I am sure the name “Deep Neural Network” will ring a bell for biologists especially the second word. Yes, it has something to do with the human brain. Neural networks were built by taking inspiration the way how human brain processes the information. Similar to the human brain, the neural network has neurons which process the input and gives an output. Since it mimics the way human process information it is quite popular in the machine learning world. But it became very popular only after the invention of Graphical Processing Units (GPUs). The application of GPU for Deep Neural Network happened in the year 2009. Before this, Deep Neural Networks were trained using
multi-core CPU’s. It was found that training with GPUs was 70 times faster when compared to multi-core CPU’s. To test how well the Deep Neural Network classifies the birds, researchers at Indian Institute of Technology, Mandi classified the 26 bird species found in the lower Himalayan region. They were able to obtain 95% accuracy which shows that MFCC Deep Neural Network framework could be used for the bird classification task.

To classify birds from images, the first step is to mask out the regions which do not contain birds. Hence, one obtains images which have only birds. Then from these images, certain important features such as beak shape, wings, tail etc. are obtained. Deep Neural Network was used to classify the birds using these features.

The research team has won the Judge’s award at the recently held Bird Activity Detection (BAD) challenge conducted by the Machine Learning Lab of Queen Mary University, London. Also, the research team has published papers on Bird Activity Detection and classification.
Glaucoma, a second major cause of blindness, is an eye disorder caused by an increase in the intraocular pressure (IOP) that leads to damage of the optic nerve and, ultimately, blindness. The disease affects more than 6.5 crore people, leaving around 85 lakhs with blindness. For its treatment, majority of the dosage available in the market is in the form of eyedrop solutions. Eye drops are easily washed off either by tear drainage or by blinking when instilled in the eye; this decreases their presence on to the site of action leaving only 1–5% drugs. To overcome this issue, eye drops are generally prescribed with a high dosing frequency; this encourages the drug-associated side effects and also reduces patient acceptance. Therefore, an innovative approach was required to treat long-standing eye diseases such as glaucoma, by improving the drug residence time on the eye surface.

Our team at Maliba Pharmacy College, which is a constituent college of Uka Tarsadia University, Surat, is working to develop an innovative method to bypass all the issues associated with eye drops and other currently utilised methods giving a more comfortable medical device to the patients suffering from eye disorder like glaucoma.

For the last five years, we have been trying to understand the issues faced by the patients with eye diseases. This has led us to experiment with different established techniques to address the problem. From in-situ gels, that is originally in the form of eye-drops solution, but when instilled in the eyes’ changes to gel form and then the drug is released. It has given success at the laboratory scale, unfortunately during animal studies it failed to deliver for a long time and our target remained unmet. Results were scary as hard work of several months went in vain.
The turning point for my team was an idea of delivering drug through contact lenses surfaced in our laboratory and we started searching available data and methods. We have found several loopholes in the current available data and decided to diverge the energy to solve the problem. The available, widely used, method includes soaking the contact lenses in the drug solution and then delivering it to the patients, but that did not yield any commendable results. In another method of preparation, where the drug is mixed with the contact lens material and then the contact lenses are fabricated, even that did not reach the destination as it barred vision due to the presence of drug in the entire region of the contact lens.

Then, we have come up with an idea of fabricating a chip-implanted contact lens. We have formulated a chip made up of contact lens material and drugs loaded into it. This drug-chip was then stabilised inside the contact lens. The chip resembled a complete ring cut into two halves, each containing two different molecules for increasing its effect. This chip/ring was placed such that they left 6 mm from the centre of the contact lens, so that they do not place any difficulty in vision. Initial results were encouraging and demanded more time to be hundred percent perfect.

We did not want to take chances and did every study possible to find out the loopholes of our proposed method. It brought several challenges and gave rise to many new problems. Some of them are the drug loss during extraction, wet sterilisation and storage in the final packaging solution. Each of them were addressed separately and successfully. Drug loss during the extraction was overcome by placing the drug inside water, which was utilised to remove the excess unreacted contact lens material that remained on the surface after fabrication. This has saved approximately 10% of the total drug loaded in the contact lens.

Another issue was drug loss during wet sterilization (heating with water in a cooker like system for 30 minutes) of the contact lenses. This method involves exposure of the material to such an environment that no microbes remain in it, however, the presence of water leads to drug loss in sterilisation solution. To overcome this, dry radiation sterilisation technique was used which does not involve water and thus bypassed drug loss due to water presence. Both this changes prevent 40% drug loss from the contact lenses.

Laboratory study of the drug-chips implanted contact lenses showed drug release up to 7 days that means, a single contact lens can free the patient for 7 days from the eye-drop therapy. Utilising the instruments at Shah-Schulman Center for Surface Science and Nanotechnology, Dharmsinh Desai University (Nadiad, Gujarat), the surface structure of the contact lenses was found to be 400 times smoother and elegant than those available in the market. The product is being developed as a platform, so that very conveniently the drugs can be changed according to the need of the disease or disorder. We have kept hyaluronic acid fixed in one ring/chip as it gives the comfort to the contact lens wearer for more than a week.

Initially, we got success with timolol, which is gold standard for the treatment of glaucoma. Animal studies has shown the effect of contact lenses and glaucoma was treated in the initial batches. Further studies are being carried out to make the product reach clinical trials and the team is expecting the final product to launch in the market by 2024.
Dr Maulvi’s lab (A: Please give context) is engaged in constant development of new technologies utilising contact lenses for the delivery of drugs to various parts of the eye. It is the motto of the principal investigator and team to eradicate preventable.
Musa “Pisang Awak” (Banana Peel) – A Novel Renewable Heterogeneous Catalyst for Biodiesel Production

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Energy becomes an inevitable part of a nation’s development and its requirement is increasing at a faster rate due to the urbanisation, industrialisation and transportation sectors. Till date, this huge energy demand in India is predominantly met by utilising fossil-derived fuel resources such as coal, crude oil, and natural oil, which are non-renewable in nature. Extreme utilisation of these fossil reserves results in the emission of harmful greenhouse gases and hence, India stands third in the liberation of CO$_2$ in 2016 (2431 Mt CO$_2$) preceded by China (First, 10151 Mt CO$_2$) followed by USA (Second, 5312 Mt CO$_2$) (Source: Global Carbon Atlas [http://globalcarbonatlas.org/en/CO2-emissions]). A huge share of transportation fuel demand in India was met by employing diesel (72%), petrol (23%) while the CNG and LPG account for the rest (National Policy on Biofuels, 2018). Presently, 210MMT of crude oil is needed for petroleum products based consumption. However, the domestic production entails only 17.9% while the rest is met through imports. This heavy exploitation of imported non-renewable oil sources will tremble nation’s energy security and therefore, it forced the researchers, industrialists, and government to search and to develop different alternative renewable fuels in order to minimise the exploitation of fossil fuel reserves.

Biofuels are renewable fuels, which are derived from lignocellulosic biomass, municipal and industrial waste materials. Biodiesel is a biofuel, which is chemically mono-alkyl esters of long chain fatty acids developed from renewable lipid based feed stocks, has commanded immense attention in the field of renewable fuel research due to its characteristics such as biodegradability, renewability,

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non-explosive, non-toxicity, no or less emissions, nonflammable, and its direct application in diesel engines without any major alterations. The physico-chemical properties of biodiesel are analogous to conventional petro-diesel and making it appropriate for commercialisation.

The four main methods applied for biodiesel production are (i) pyrolysis process, (ii) micro-emulsification, (iii) blending of oil with diesel fuels, and (iv) transesterification process. Among these methods, the most widely employed method was transesterification, which is basically the chemical reaction between oil and short chain alcohol in the presence of an acid or alkali catalyst to produce fatty acid methyl esters (biodiesel) and glycerol.

Additionally, a major problem associated with biodiesel production is the availability of feedstock. The lipid feedstock utilised for biodiesel production can be majorly categorised as vegetable oil (edible oil and non-edible), animal wastes and recycled oil. During the past few decades, non-edible oils were utilised as an alternative low-cost renewable feedstock to decrease the biodiesel production cost and to overcome the conflicts possessed by edible oils. *Ceiba pentandra*, a non-edible plant which is native to India, Sri Lanka and Southeast Asia, belongs to the Malvaceae family. Kapok tree bears pendulous, oblong-ellipsoid shaped capsules containing numerous brown seeds entrenched in silky hair. The seeds of *C. pentandra* contain 25-28% of oil in each fruit and is used for fuel and in the manufacture of ointments, paints, soaps, and as a substitute or adulterant for several edible oils such as olive oil and cotton seed oil. Several researchers have reported that it exhibits huge potential as a feedstock for biodiesel production.

The catalyst used for biodiesel production can majorly be classified as homogeneous and heterogeneous catalyst. The choice of catalyst depends on the amount of free fatty acid (FFA) present in the raw material. The conventional catalyst utilised for biodiesel production is homogeneous catalyst (includes acid and alkali). Homogeneous alkali catalysts such as potassium hydroxide, sodium hydroxide are widely used for large-scale production of biodiesel owing to its advantages such as shorter reaction time, high catalytic activity, modest operating conditions, abundant availability and low cost. Besides several advantages in using homogeneous catalyst, the major limitation relies on the purification of biodiesel, which requires an enormous amount of water invariably leading to the generation of a large amount of waste water. Moreover, the catalyst cannot be recovered and reused.

To overcome the above-mentioned problems, our research group has developed an eco-friendly, highly active heterogeneous catalyst derived from the banana peel (*Musa* “Pisang Awak”) for biodiesel production.

Banana has been widely cultivated in more than 26 states of India which includes Gujarat, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Maharashtra, Karnataka, Madhya Pradesh, Bihar, Kerala, West Bengal, Assam, Chhattisgarh, Odisha, Tripura, Telangana, Mizoram, Nagaland, Meghalaya, Manipur, Arunachal Pradesh, Jharkhand, Punjab, Sikkim, Rajasthan, Himachal Pradesh, and other few states. Among these states, Gujarat, Andhra Pradesh, and Tamil Nadu occupy the top three places in banana production (Source: Horticulture Statistics at a glance 2017, Government of India). The banana *Musa* “Pisang Awak” (Cultivar Name: Karpooravalli or Karpuravalli, Cultivar Group: ABB) is a popular banana variety cultivated widespread in Southern
and Central parts of Tamil Nadu and Kerala. In Bihar, it is cultivated under the name “Kanthali”. This banana variety is the sweetest banana in India and is suited for marginal lands with low input conditions (Source: http://nhb.gov.in/pdf/fruits/banana/ban013.pdf). The ash coated golden yellowish coloured peel which comprises 18-33% of the whole fruit has been regarded as waste and thrown to garbage in several places after using the banana pulp. Furthermore, the peel is rich in minerals such as sodium, potassium, calcium, magnesium and other trace elements. This peel upon calcination at a particular temperature over a particular time period yielded a highly efficient catalyst.

To test the effectiveness of the developed catalyst, M. Balaji and S. Niju performed a number of experiments in the laboratory to determine the maximum conversion of biodiesel. Non-edible Ceibapentandra oil was utilised as a feedstock and a biodiesel conversion of above 90% was observed by the authors. Biodiesel produced from non-edible Ceibapentandra oil using the banana peel ash derived catalyst was shown in Fig.1.

We found the purity of biodiesel and quality of glycerol to be good while using banana peel ash as a catalyst and the reaction conditions used in transesterification process was in comparable with the commonly used heterogeneous catalyst and possesses better catalytic activity. This catalyst is recyclable and can provide a sustainable solution to the waste water disposal problemised by homogeneous catalyst in biodiesel process industries.

![Figure 1: Separated biodiesel and glycerol layers](image-url)
Maternal Responses to Offspring Death: Insights from Studies on Anthropoids

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Om tryambakam yajāmahe sugandhim pushtivardhanam Urvārukamiva bandhanān mṛtyor muksiya mā 'mrtāt -Rigveda (7.59.12) and Yajurveda (TS 1.8.6.i; VS 3.60)

The maha mṛtyuñjaya mantra or Mrita-Sanjivni mantra invokes Tryambaka (the 3-eyed one; in the image above) or Shiva as part of a life-restoring practice that the great sage, Shukracharya was endowed with. In Greek mythology too, similar power of bringing the dead back to life laid with Asclepius, son of Apollo and Coronis. Anthropological literature covering animalistic tribal societies propounds shamans being capable of rejuvenating the dead and sometimes sealing the soul in a subverted human state such that the body was neither dead nor alive, termed zombie.

In effect, death has always fascinated us since our very beginning. Sages, philosophers, poets and scientists have equally pondered over the mysteries of death in an attempt to comprehend and conquer it. In modern times, advances in anatomy, physiology and cellular

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and molecular biology have triumphed in providing intriguing insights into the mechanisms of ageing and death. A branch of psychology even investigates near-death experiences, which records and analyzes personal accounts associated with death and impending death. It encompasses a variety of sensations including detachment from the body, mid-air levitation, being pulled into vacuum, dissolving into a void, etc. Regardless, the psychosocial manifests and consequences of death continue to elude us. The discipline of human thanatology has been instrumental in this regard by describing emotional antecedents of death and mechanisms of coping post mortem.

Findings from human thanatology are increasingly being applied in nursing for management of bereavement-induced grief. A crucial factor however, missing from our understanding of our own emotional responses to disruption of attachment to the deceased, and attachment in general is its evolutionary origin. And, that is where such complex, unmanageable and acute emotions emerge from.

In his book, *The Expression of the Emotions in Man and Animals* (1872), Charles Darwin wondered about the possibility of an emotional continuity from animals to man, similar to an evolutionary one. Despite such early advances and propositions, scientists have always kept human expression of emotions, especially compound emotions (like anger, jealousy) separate from that of animals, coining analogies even if similar behavioral manifestations to a stimulus is observed. Although animal models became popular for studying human diseases, human physiology and even human behavior, a scientific comparison of emotions between the two was never embarked on. Very recently, this Pandora’s box was opened to explore probable commonality in the emotional make-up of human and animals. Based on a flurry of reports on animal responses to dead and dying conspecifics, researchers have emphasized the study of animal responses to death for a better understanding of our own psychologies surrounding grief, mourning and bereavement.

The quintessential relationship that depicts emotional attachment in its strongest form is the one between mothers and their offspring. As a consequence, we expected mother-offspring pairs to display the most intense responses to premature disruption of attachment by means of transient or permanent separation. In the context of the most extreme form of cessation of this bond, primate mothers were observed to stay close and transport the dead bodies of their offspring for days and sometimes, months. Moreover, what was odd was that the cases even within the same species varied widely. For
example, one chimpanzee mother carried her deceased baby for 2 days whereas another carried hers for over 127 days despite the corpse morphing into an unrecognizable inanimate object. We were firstly interested in unearthing the reasons for this variety of responses within and between various species of non-human anthropoids, which include species of macaques, langurs and apes and secondly, wished to examine how behavior of the bereaved mother differed from that of other mothers. To decipher diversity in deceased infant portage, we amassed detailed information on every available case which included details about the nature of the death, like due to sickness, human or animal-induced death called unnatural, etc., offspring, like age and sex, about the mother, like age, how many times she has had babies previously, etc. and characteristics of the troop and the species, like whether the troop lives in the wild or is held captive, their degree of arboreality, etc.

Since, few researchers had previously suggested that the duration of a deceased infant portage could be influenced by temperature conditions; we also found temperature to be a contributing factor in every instance. The second portion of the study was relatively challenging since it involved building a network of informants who lived close to troops of monkeys and could notify us immediately as soon as the behavior of the interest occurred. After days of patient waiting, we received our first call and we successfully managed to document the entire incident in as much detail as possible. Within the next 4 months, we encountered our second case quite accidentally while conducting our regular observations of monkeys. By contacting primatologists closely associated with us, we were able to document several cases in the Bonnet monkey and in the Lion-tailed monkey. Through analyses of the behavior, we compared time allotted to feeding, looking for food, movements, socialization with group mates, etc.

In the first phase of the study, we found that anthropoid species that showed deceased infant portage were evolutionarily related to each other, which meant species that are genetically related to each other showed similar levels of behavior. As expected, we quantified the diversity in the responses within each species. Unexpectedly, our results showed that duration of infant portage was strongly determined by mother’s age, context of offspring death, living condition and degree of arboreality. In the second phase, we found that Bonnet mothers carried their deceased offspring for 3.56 days (averaged over 7 cases), showed reduced feeding, long period of inactivity and solitude though they intriguingly continued to care for their dead offspring similar to other mothers with live offspring.

To interpret the behavior of the bereaved mother directed towards her deceased offspring, we used the conceptual layout of ‘death perception’ described by Anderson et al. (2016). As a consequence, we interpreted repeated investigation of offspring body by mothers and group members as collating physiological information following death (‘causality’ of death), peculiar support of dead offspring by mother and communal defending of infant bodies as comprehension of ‘non-functionality’, the dead cannot feel, think or see. And lastly, the mother allowing intrusive exploration of her offspring corpse followed by a progressive disinterest in it as perceiving ‘irreversibility’ of death, i.e., the dead cannot come back to life.
By comparing studies on bereavement-induced grief caused in similar scenarios (death of an infant) in humans, we demonstrate that reduced feeding and passivity are hallmarks of grief. We surmised that deceased infant portage can be integrated into existing models of attachment if it is recognized as post-death attachment mediated by ‘bereavement-induced maternal grief’ whose strength is incumbent on the quality of mother-infant attachment history.

Finally, to describe the maternal portage of corpse comprehensively, we proposed a system-inspired conceptual model along with its causal factors. We divided the behavior into three phases: ‘onset’ of deceased infant portage governed by hormonal and non-hormonal condition (like...
physiological state) of the mother, recognition of absence of agency in offspring corpse resulting in either continuation or abandonment of body (termination); ‘maintenance’ if a mother continues to carry her dead offspring followed by voluntary ‘termination’ as a result of extinction of grief, avoidance by group members and/or constraints due to living conditions.

Most importantly, our study took a plunge into the deep unexplored space of the Pandora’s box and helped initiate an international dialogue among researchers interested in studies on animal sentience, animal emotions and specifically, animal and evolutionary thanatology. The study further demonstrated how our emotional capacities are not unique and are shared with other species. If not anything, it ought to at least help us co-exist peacefully and accord animals their right to the planet.
The disaster that occurred more than five years ago in Kedarnath (Uttarakhand) is known to all. Thousands were rendered homeless, wounded and killed when prolonged and heavy rains together with the bursting of a glacial lake known as Chorabari Lake caused the flooding of rivers Saraswati and Mandakini in the Rudraprayag district of Uttarakhand. This disaster washed away the Gaurikund, Rambara and Kedarnath towns and the Char Dham Yatra was hit badly [1].

The outburst of glacial lakes such as Chorabari Lake is a major cause of concern in the context of loss of life and property. The outburst of glacial lakes refers to the rapid discharge of huge amount of water and debris. One of the reasons behind the occurrence of such catastrophic events is when glaciers melt and forms lakes.

Therefore, precise and detailed mapping of glacial lakes is important. But, the conventional field methods to map the glaciers in high mountain regions is time consuming, costly, dangerous and do not provide synopticspatial measurements.

So is there any alternative? Yes, remote sensing images and associated digital image processing. Remote sensing gathers information about an object or phenomenon without making physical contact with it. The details that can be extracted from a satellite data depends upon its spatial resolution. Spatial resolution refers to the smallest ground object that can be resolved on the ground; thus, the higher the spatial resolution, the finer the details that could be extracted. Although plenty of high spatial resolution (HSR) satellite data is available, the existing remote

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sensing-based methods cannot completely utilize the spatial properties such as shape, texture, context, etc., of the HSR satellite data to extract the ground objects.

What makes the HSR satellite data special? In recent times, the object-based image analysis (OBIA) is being seen as an alternative framework for analyzing the HSR remote sensing data due to its ability to utilize spatial properties including the spectral information of the ground objects. It also provides a means to consider the data from different sources at one go, weigh them based on their importance and classify them based on different mathematical and semantic criteria. Therefore, OBIA has been used in numerous applications related to urban, forest, military, landslides, etc. However, it has received little or no attention within the glaciological community.

A study focused on this issue led by this author under the guidance of Prof. Manoj K. Arora, Punjab Engineering College (Deemed to be University), Chandigarh and IIT Roorkee (on lien); Prof. Sanjeev Sofat, Punjab Engineering College (Deemed to be University), Chandigarh and Dr Reet K. Tiwari, IIT Ropar, has developed a new method to map glacial lakes from HSR data of Resourcesat-2 satellite of Indian Space Research Organisation (ISRO) using OBIA. A new index has been developed in this method to map particular type of lakes called “supraglacial lakes.” Supra means “on the surface”-so these lakes are found on the surface of the glacier. The new index utilizes ancillary data as well such as temperature and slope to distinguish between shadows and supraglacial lakes. Shadows exhibit lower temperature than supraglacial lakes and are usually found at higher elevation than supraglacial lakes. This research is an innovative and a novel contribution in the context of high altitude Himalayan glaciers.

As a case study, the research team tested the new method to map supraglacial lakes of Gangotri glacier in the state of Uttarakhand. Gangotri glacier is one of the longest glaciers in the Indian Himalayas. It covers an area of around 143 sq. km. and has a length of ~ 30 km. The Gangotri glacier contributes a major portion of the freshwater to the river Ganges, which has a
high sentimental and economic importance in India. The Ganges along with the rivers Indus and Brahamputra provide close to 50% of the country’s total utilizable surface water resources [2]. The Gangotri glacier has a series of supraglacial lakes in its ablation zone (low altitude glacier area with a net loss in ice mass due to melting).

The method developed by the use of HSR data has provided large-scale maps (maps with fine details) of the supraglacial lakes. The results of this method have been validated with the reference dataset created using on-screen digitization and a 90% match has been observed through visual interpretation. The accuracy of the results has also been assessed using statistical measures such as overall accuracy. The significance of this method is that it can map even a supraglacial pond as small as 0.0001 sq. km. with a high overall accuracy of 94.83%. This is important because the glacial lake outbursts usually occur from some specific type of glacial lakes which are popularly known as “moraine dammed lakes.” Quite often these types of glacial lakes originate from the supraglacial lakes. The supraglacial lakes form in the hollows on the glacier surface.

The authors compared the new method with other existing traditional methods. The comparison showed that the other methods require manual corrections for shadows whereas the method developed in this study, is able to extract supraglacial lakes without any manual correction providing a substantial advantage to this method. Comparison of this study with other published noteworthy studies shows that, previous studies have used the medium to coarse spatial resolution satellite data to map supraglacial lakes and, therefore, the small supraglacial ponds have not been mapped.

This study has great socio-economic importance as it will help stakeholders such as government organizations related to natural disaster management, etc, to make the masses aware of potential threats that may arise from the glacial lake outbursts and will also help them make adequate arrangements to ensure the safety of lives and property.

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It Is Time to Know Your Gut Microbe: Bifidobacteria

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Feeling lonely? Maybe you are not aware of it but you are always accompanied. Yes, it’s true you are not alone in the absence of someone because we are accompanying you all the time since the day you are born.

Confused? Ok please don’t be, we are always with you, and we are microorganisms.

Of course, you may have heard a lot about us; it is always being advertised (use hand wash, toothpaste, sanitizer to get rid of bacteria, germs, etc. etc.). Do you believe if I say that more than 5 kg of your body weight is because of microbes residing in your gut? And it includes both helpful and harmful organisms. That’s the reason you are not alone, and microbes are part of you.

Oh! Wait a second! Let me introduce myself. I am *Bifidobacterium adolescentis* and I belong to the type of bacterial family called Bifidobacterium. All my family members carry the first name as bifidobacterium. It’s just like your surname. Our ancient history was spotted long back in 1899 by physician Tissier in breastfed babies stool. According to him it precisely looked like alphabet ‘Y’. So based on its shape he named it as bifidobacteria. The area of research on beneficial organisms in the gut was reported by then and was known as probiotics. According to World Health Organization (WHO) probiotics are the live microorganisms which will be helpful if consumed in adequate quantities. We the bifidobacteria are now considered important probiotics but then in the beginning we were mistaken to be one among the Lactobacillus family. Luckily, later in 1924 Orla Janson recognised us and separated our family as bifidobacterium.

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We are the warriors raised to protect you from destroyers or invaders like harmful bacteria, and we will be taking care of your system by contributing to the resistance. That means my family members are the ones who enter your body first through your mother’s breast milk and assure your safety. Once people understood our importance, they were after us for two decades to know more. Foremost curiosity was about our morphology, and it’s been concluded that some particular components in the media, or the food scientists feed us with, plays an important role in keeping us in this unique bifid shape.

During those days researchers focus was on understanding morphology of the 2-3 members who were then known. Although one of my family members was identified and designated as bifidobacteria based on its shape, the era of research is advanced, and scientists are after us to find more about us. Now they are aware that more than 69 different members are in my family and analysing and understanding us will be more ideal. Out of curiosity and with interest recently in 2013, a team in CFTRI started research on our shape. Not all of us look alike, and definitely not all of us have the bifid shape that Tisser found. Obviously, there were questions to be answered like why we are all not in bifid shape? What is determining our shape? Is the name bifid a misnomer? Earlier why did they decide that media composition contributed to the morphology?

Well, the questions seem to bog down many scientists. To find out the answer the CFTRI team selected a few of my family members and took their SEM portfolio. As you aware, SEM is the closest view of any surface possible and is taken with an electron microscope. Understanding whether media composition plays an essential role with selected members was necessary. Irrespective of the media composition or external condition most of us still remained rod-shaped and only me (B. adolescentis) was in Y shape.

For your understanding I can simplify it. The structure of bacteria varies at different conditions just like human emotions vary based on the situation. So it is confirmed that you are not being named based on your character. Here also the team found that it’s an intrinsic property of the bacteria to be in particular shape irrespective of the condition, and most of the bacteria are in rod-shape and only few will be in bifid shape. Accordingly, I’m the only one among the family of eight that has Y shape irrespective of the condition. Also, the name bifidobacteria for others is a misnomer. Hey! I’m happy because I’m Bifid, as my family name goes.

But that is not all; the team also found out accidentally how tough I am with drugs. For the first time, they found out that I can survive even in the highest concentration of drugs. This changes their impression of me a lot because, till now it was thought that probiotics are susceptible to drugs. I mean if you have ever noticed that your physician prescribes probiotic tablet along with antibiotic it is to replenish gut flora in your system. Usually, the gut microbes will be sensitive to the antibiotics, and will be killed or washed out by the system. As you are aware, TB disease is the most dangerous, and for treating it highly effective drugs like Rifampicin, Isoniazid and Streptomycin sulphate are needed. Since it’s proven that I could resist even these drugs despite the dosage, there is less to worry about. I am very sure I’ll be the VVIP soon in the market as I can be useful for developing the probiotic antibiotic therapy. And I can resist not one but many drugs I’m a multidrug resistant.
Oh! It’s time to end, and I don’t think that I have shared all my secrets. There are many more. Be in touch to know more.

Your brain can be fooled, and your heart is an idiot, but your gut doesn’t know how to lie. So dear, “Know your gut, and always trust your gut feeling.” It will never misguide you.

Reference:

Dhanashreee Lokesh, Raman Parkesh, Rajagopal Kammara. (2018). Bifidobacterium aolescentis is intrinsically resistant to antitubercular drugs. Scientific reports,8(1),11897.
Hello, my name is Sumit Bawari, and what follows is the story of my encounter with a rather tedious assemblage of materials and their catalytic property. Dear reader, what I am writing may not be exactly in the scientific frame of mind. But I shall try to convey my experience during this study. Since people at AWSAR have been rather liberal with the maximum word count, I shall provide a background as well.

My host institution is the newly operational campus of the Tata Institute of Fundamental Research (TIFR), located in the outskirts of the city of Hyderabad. In the year 2015, I joined the integrated PhD course here in chemistry. Mingled with the fear of being so far away from home, and the excitement of trying out new things, I braced for the journey that would be my PhD. But before actually registering for PhD, one has to complete coursework. As opposed to traditional MSc courses, the I-PhD course gives more weightage to one’s research projects rather than coursework.

While I barely skimmed by in courses, the projects were something I had never encountered before. Me, a mediocre BSc student from the University of Delhi, who had never experienced the gentle touch of a micropipette, had never plotted my own data, and never known what research papers were. And while fellow students went for summer projects, I went home to relax in the hills of my homeland Uttarakhand. Please do not mind the digression dear reader, but one has to sidestep once in a while, to grasp the whole story.

Anyway, finally in the fourth paragraph, I will talk to you about my project. I chose Dr T. N. Narayanan (TNN), who is a material scientist as my project guide. Joining his team reminds me

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of a funny thing he said, when I was leaving for home on vacation before the project. I had asked him to give me material to read while at home. He just smiled and said, “We will discuss when you come back, it’s not like you’re going to read it anyway.” I just nodded, smiled and walked away; thinking he probably remembers being a student himself.

When I came back, I started work on chemically coupling graphene sheets. I’m certain the reader must be familiar with the structure of graphite (if not there’s always Google). Graphene is a single sheet of hexagons of carbon forming large sturdy sheets. For perspective, if you draw a faint line with your graphite pencil, you will form layers that have 100-1000s of layers of graphene. Graphene has often been called the “wonder material” by many, as has the potential to replace and improve most modern technologies. In our case, we focus on graphene for catalysis, due to it’s overwhelming surface area.

Shubhadeep had already found the method promising in coupling carbon nanotubes, which are just rolled up graphene sheets. Predicting enhanced catalytic properties, we started the tiresome coupling process. The coupled sheets came out completely different from the initial dispersed oxidized graphene sheets. They had formed clumps where some were floating to the top, while some were settling on the bottom. Intrigued by their weird behaviour, we made inks of the same and began catalysis experiments.

Electrocatalysis is the conversion of electrical energy into chemical energy. Specifically, our reaction of study is abbreviated as HER (Hydrogen Evolution Reaction). This particular reaction can, in simple terms, break water to form hydrogen. Hydrogen, believed to be the fuel of the future, requires a way of efficient hydrogen production. Till now, only a handful of hydrogen powered cars and trains are operational. And to make this hydrogen powered future a reality, scientists have to
develop cheaper and efficient catalysts. The reader should realize the benefit of powering their cars just by using their pencils.

Anyway, it turned out that even though the same coupling for CNTs gave promising hydrogen production activity, our graphene based sheets did not. This result was more intriguing than disappointing, and reflected on our lack of knowledge of the system. After this initial failure, we tried something planned yet outrageous. This time, during the coupling reaction we added, along with everything else, small amounts of hexagonal Boron Nitride (hBN). Hexagonal Boron Nitride can be thought of as analogous to graphene where instead of carbons everywhere, one finds alternating borons and nitrogens. The interaction of graphene with hBN is well known and our advisor was probably playing at that. Surprisingly, graphene-hBN composites had tremendous hydrogen production activity. Slightly better than coupled CNTs, but lagging behind platinum. This promising result came with its own questions, as to what was the cause of this activity.

This marked the end of my first project. For my second project, I aimed at learning computational simulations. And the only person, at that time, whose work involved computation in chemistry was Dr Jagannath Mondal (JM). And it so seemed that TNN and JM had already conspired behind my back, and I was to continue studying the graphene-hBN hydrogen evolution activity, now from the simulation point of view. For better or worse, JM worked on biomolecules and had never actually worked on materials. And while most of the catalytic materials community relied on DFT (Density Functional Theory) calculations, JM did molecular dynamics (MD). Due to this, we were forced to look at the bond breaking problem in a form where bonds cannot break.

After some literature and soul searching, we decided on studying specific steps in the reaction, for a reaction to occur the reactant has to get there first. And the product also needs to get away, so that it doesn't overcrowd the place. We studied water ion adsorption and hydrogen desorption on our graphene-hBN picture, and found that the hBN edge can selectively adsorb water ions and also desorb hydrogen, when the hBN is stacked on graphene. This phenomenon provided some explanation for the unexpected improvement of catalytic activity, but JM and TNN were not still not satisfied.

Then came the time for my third and final project before I could register for a PhD. This turned out to be another collaboration between JM and TNN, where I had to helplessly shuffle between computation and experiments. Since we had some background proof regarding the hBN effect on graphene, the same had to be tested on a non-coupled environment. Almost pure and slightly oxidized graphene both were studied, and both gave enhanced catalytic hydrogen production when mixed with hBN. For a complete view of the reaction process, JM removed his MD shackles and delved into the DFT realm. This also marks the entry of Nisheal Kaley into the picture, a project student who had some previous DFT knowledge. Together, Nisheal and I, uncovered that the hBN has a polarizing effect on the graphene. And this makes the carbons in graphene active for hydrogen evolution.

Now, after two published and one report in compilation, we know that hBN can adsorb the water ion, make the graphene lattice polarized for bonding steps, and also desorb the product hydrogen, while just sitting on top of graphene. I hope the reader has not been too caught up in jargon, and can appreciate the elegance of stacked heterostructures for catalytic applications.
Publications on the topic:


Magnetic Nanoparticles Hyperthermia: An Emerging Cancer Therapy Sans Side Effects

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Cancer, a real threat to human race, is spreading its roots in every organ of the human body. The probability of occurring cancer in different organ varies: in some organs it’s quite evident whereas it's rare for some other parts of the human body. With time, scientists and doctors worked together and managed to discover various means for damage control, but still curing cancer remains one of the biggest challenges for mankind. The most effective and popular techniques like chemotherapy, radio therapy, hormonal therapy, have permanent side effects which may be severe for certain cases. In chemotherapy the drug is designed to destroy fast growing cancer cells which besides doing its job, also gets involved in damaging fast growing blood forming cells in the bone marrow, hair follicles, cells in the mouth and digestive tract, etc. leading to anaemia, hair loss, infection and various other side effects. Similarly radio therapy causes permanent skin problems. So the need of the hour is an efficient cancer therapy with minimum side effects.

In cancer treatment the primary goal is to kill the cancer cells. Our human body uses a mechanism to get rid of germs by simply increasing our body temperature which manifests as fever. Why not use the same defensive mechanism to kill cancer cells also in a controlled manner? Yes, it can be done. Cancer cells, like other cells, are susceptible to temperature rise. Research shows that beyond certain temperature regime (>42°C), the growth rates of cancer cells reduce significantly. Further increase in temperature, leads to necrosis of cancer cells. Such temperature sensitive growth rate of cancer cells is tried to exploit in hyperthermia-based cancer treatment, where, initially, hot water circulation was used to cure cancer. But its success rate highly depends on the position of the

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tumour and tolerance of the patient. If the tumour is well within the body it’s extremely difficult to use this technique.

The path breaking developments in the field of nanotechnology, in the last decade, showered new light on the hyperthermia technique. It’s well known that ferro/ferri magnetic material can dissipate heat energy through magnetic hysteresis loss when subjected to an alternating magnetic field. Nano sized magnetic particles (1nm = 10^{-9}m) can easily travel through the blood vessels and reach the cancer affected organs. Once it reaches the desired organ, an alternating magnetic field can be applied around that region externally. In the AC magnetic field, the magnetic nanoparticles (MNP) start dissipating heat energy owing to their inherent loss mechanisms (like hysteresis and relaxation losses). Here, the tiny magnetic nanoparticles act as transducers that converts the externally supplied magnetic energy into heat energy. Magnetic nanoparticles mediated hyperthermia therapy is called magnetic fluid hyperthermia. The major advantage of magnetic fluid hyperthermia is its ability to act as focal therapy due to the smaller sizes of the magnetic nanoparticles. The MNPs can be distally controlled using an external magnetic field and tissue specific targeting can be achieved by selectively coating the MNPs with various bio-compatible moieties. As the entire body is not exposed to the AC magnetic field and a very low amount of MNPs is sufficient to provide a therapeutic dose to the cancer cells, the side effects are substantially lower in the case of magnetic fluid hyperthermia based cancer treatment. Though originally proposed by Dr. R. K. Gilchrist and his group, in the year 1957, recent advances in nanotechnology resulted in the continued and active research and development in this field.

Out of so many magnetic materials available, iron oxide has been approved by FDA for in vivo clinical trials owing to its low level of toxicity in the human body. These MNPs can be directly injected into tumours or it can be guided through the body fluid. For guiding through the body fluid, these MNPs should be coated with biocompatible molecules which ensure less side effects and stable dispersion behaviour in body fluid. However, questions have been raised by several biotechnologists about the side effects arising from the interaction of the magnetic field of MNP with the body’s own magnetic field. Upon reducing from bulk to nano size, the property of ferro/ferri magnetic material changes mysteriously and they exhibit superparamagnetic behaviour. In room temperature (~30°C), they behave as paramagnetic material, i.e., no magnetization unless a magnetic field is applied externally. However, their magnetic response to external magnetic field is ~5000 times more than that of a paramagnetic material.

Here in the Indira Gandhi Center for Atomic Research (IGCAR), we are working on the development of superior MNPs for efficient biomedical and sensing applications. We have, in-house, developed a radio frequency induction heating facility for testing the magneto-thermal conversion efficiency of MNPs dispersed in a suitable base fluid. The efficiency of the dissociated heat energy is described in terms of a dosimetric quantity named as specific absorption rate (SAR). The value of SAR decides the dose for practical applications. We have successfully developed and demonstrated the magnetic fluid hyperthermia in water based magnetic fluid containing phosphate coated iron oxide nanoparticles. Phosphate coating was applied on the surface of the magnetic nanoparticles to ensure bio-compatibility and long-term stability.
We have also carried out experiments on MNP immobilized in a tissue mimicking agar gel, where, ~ 50 % reduction in heating efficiency was observed, as compared to the water based system. This leads to a scary scenario where the nano-particle dose or the amplitude to the AC magnetic field need to increase beyond biologically acceptable levels. To address these issues, we at IGCAR, have demonstrated, for the first time, in-situ orientation of the dispersed MNP using an external DC magnetic field and thereafter, the oriented assembly is subjected to the AC magnetic field, which results in ~ 40-60 % enhancement in heating efficiency, thereby mitigating the practical challenges. Under the influence of the small external DC field (~ 80 Gauss), the MNPs form linear chain like structures along the field direction. These oriented chain-like structures have a larger hysteresis loop area, as compared to the randomly distributed MNPs, which causes the enhancement in heating efficiency.

Using this modified approach to magnetic fluid hyperthermia, the nanoparticle dose and treatment time can be reduced significantly. Here, at IGCAR, we are in the process of continuous development and fine-tuning of magnetic nanoparticles for hyperthermia based cancer treatment. The multi-faceted research team consists of Mr Surojit Ranoo, Mr T. Muthukumaran, Dr B. B. Lahiri and Dr John Philip (team leader). Selected portions of the work are published in the Journal of Magnetism and Magnetic Materials (Vol. 407, 2016, pp 101-113). The latest developments are going to be presented at the International Conference on Magnetic Materials and Applications, at Bhubaneswar, during 9th -13th December 2018.
The annual arrival of monsoons over India is one of the robust meteorological phenomena over the Earth. However, we also face its capricious behavior during its stay. This year there were 1,400 deaths reported in India due to floods during monsoon. In the month of August, the southwest monsoon unleashed its fury over Kerala where widespread heavy rainfall and flooding brought the entire state to a standstill. About 483 people died due to rains. In November 2015, Kerala's neighboring state Tamil Nadu suffered the same fate during the northeast monsoon. Around 500 deaths and Rs.20,000 cr. economic losses were reported in Tamil Nadu. On 1 December 2015, a weather station in Chennai recorded 494mm of rainfall within 24hrs. This was ‘once-in-a-century’ rainstorm. On the very next day, Chennai was declared as ‘disaster zone’ by the state government. Armed forces and the NDRF teams were deployed for relief and rescue operations. The scale of this operation was one of the largest in the recent times.

With the frequent occurrences of catastrophic floods, following questions are raised: Are we able to predict floods? Are they due to climate change? And how should we prepare for them? Satisfactory answers to these questions will come only when we understand the underlying meteorological mechanisms of floods. Here the word ‘flood’ refers to the heavy/extreme rainfall, and not to the surface inundation. However, note that the former is often the cause of the latter. As far as the weather prediction is concerned, modern-day computer models are doing a decent job to predict flood events, thanks to the advancements in the satellite and computing technology. A computer weather model is a set of mathematical equations. These equations laws of fluid
mechanics, thermodynamics, and radiation govern the evolution of entities, such as, temperature, pressure, winds, water vapor. So, if we know these quantities at time t1, by solving these equations we can predict the state of these quantities at time t2. Satellites and ground weather stations do the job of recording the quantities at time t1. Then by running a computer model we can predict the quantities at time t2. However, although we understand the above laws/equations when considered individually, a weather phenomenon couples these laws and evolves in a far more complicated manner which we still don’t understand completely. Thus, without an exact understanding of the working of real world weather that leads to the events at time t2, we are still using these models like a ‘black box’. Further improvements in the models and better comprehensions of their forecasts will happen only when we understand our weather systems well. Part of my PhD research at the Indian Institute of Science is to understand the dynamics of storms using satellites and computer models. I have studied the storm that resulted in the record-breaking rainfall on 1 December 2015 over Chennai mentioned before in the article. The study was published by the American Meteorological Society in *Monthly Weather Review*.

During winter monsoon, many tropical depressions form over the Bay of Bengal and move westwards towards Indian peninsula. They give heavy rainfall over the east coast during their passage. Rainfall accumulations of 100-200mm in a day are normal over Chennai due to these depressions. The study first identifies that the unprecedented flood over Chennai on 1 December 2015 was due to the storm-clouds being stationary over Chennai for about two days. By performing computer simulations of the event, the study proposes a mechanism by which this happens.

Chennai is located right over the east coast, and the Eastern Ghats (EG) are about 200km inland. In the winter monsoon, winds blow from east towards the EG. The study says that when these winds arrive over the Indian peninsula, their fate is decided by the kinetic energy (wind speed) they possess. If winds are strong, they might have enough energy to climb the EG mountains. If winds are weak they get blocked by the mountains (imagine someone throwing a stone up in the air; the greater the throwing speed, the higher the height reached). In latter case, winds are

![Figure 1: Schematic of cold pool piling and uplifting of warm air](image-url)
deflected; they flow around the mountains. Further, if raining clouds also approach east coast with these winds, the raindrops evaporate by absorbing heat from the surrounding air while falling down from the clouds. The evaporation cools the surrounding air. This cold air lying over the ground and below the cloud-base is known as ‘cold pool’. The cold pool is denser than the surrounding air, so winds need to exert more force over the cold pool to lift it over the mountains. If winds are weak, cold pool will flow against the winds and will get disorganised. With stronger winds, the cold pool is pushed towards the mountains by the winds; if winds are very strong, cold pool will be carried over the mountains by the winds. At a critical wind speed (around 10 m/s), cold pool can’t flow over the mountains, but remains organised. It starts accumulating along the mountain slopes and backward towards the coast, very similar to the river water when blocked by a dam. A pile of cold air is steadily held against the mountain by the winds. This pile can be as tall as the mountain itself (figure 1).

The edge of the cold pool can reach hundreds of kilometers backward over the coast. Now, the warm and moist winds that arrive at the coast get uplifted by the cold (dense) air of cold pool. Thus, an invisible mountain of cold pool sits right over the coast, much ahead of the actual EG mountains.

The uplifting of warm and moist winds result in more cloud formation over the coast and the raindrops that fall out from clouds feed the cold air to the cold pool. Thus, as long as the winds supply the optimum amount of kinetic energy and moisture, the pile of cold pool can stand for several hours without getting diffused; and clouds rain continuously over the coast, inundating the surface below it. This is what happened on 1 December 2015 over Chennai. We have known the effect of Western Ghats (WG) on the west coast rainfall for centuries. This is the first study that relates the copious rainfall over the east coast to the EG. With this understanding of the underlying

Figure 2: A 3-day rainfall accumulation from NASA’s GPM satellite. Left panel shows rainfall accumulation for weak depression that was stationary at the coast; right panel shows rainfall accumulation for tropical cyclone Vardah. The track of Vardah is shown in the inset figure.
mechanism of storm stagnation, extreme rainfall over the coastal zone can be predicted with greater confidence. We can predict which weather systems will get stalled at the coast due to EG mountains and which will pass over the coast by climbing up the EG heights. According to the above theory, weaker cyclonic depressions can be blocked by the EG mountains whereas, strong cyclonic storms will cross the mountains. This answers the question of prediction asked before in this article.

Figure 2 shows a 3-day accumulation of rain for two cases on the left, for the blocked weak depression (wind speed of about 10 m/s) in October 2017 and, on the right, for very severe cyclonic storm ‘Vardah’ (wind speed of about 30-40 m/s) in December 2016. The track of Vardah is also shown in the inset. It shows that in the first case, rainfall accumulation is high (reaching 300 mm) over the coastal zone, whereas, over the EG and plateau there is no rainfall. In the second case, cyclone Vardah crossed the Indian peninsula; the rainfall for this case is less intense over the coast (reaching 200 mm) than the previous case and more uniformly spread over the peninsula. This suggest that the weak depressions, if they get blocked by the EG mountains, can cause more severe local flooding than the full-blown cyclone. Therefore, we should not take them lightly and their development over the region should be followed seriously. The infrastructure developed in the coastal area should not only account for the impact of severe cyclones but also for the 2-3 day flooding due to stalled storms. An action plan should be chalked down for these flooding. Action plan designed for the cyclones may not entirely be applicable for the 2-3 day flooding event, considering the discrepancies in the wind speeds, the rainfall distribution, and the lead time available for preparation in these two systems.

As far as the question of climate change is concerned, a research should be undertaken to analyse how the storm-dynamics is getting affected by the warm temperatures, then we will have a more concrete physical evidence for it rather than just the stats. As far as science is concerned, proving a relation with statistics can be clever, but explaining the physical mechanism behind it is more satisfying!
From Waste to Asset: Use of Yellow Gypsum as a Source of Sulphur in Agriculture

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Ever enjoyed burgers with mustard sauce? Or pizza dishes with garlic bread? Oh indeed! It’s an obvious answer given the billion dollar fast-food business worldwide. And what about the different varieties of lip-smacking biriyani, kofta korma, kebabs and other splendid non-veg dishes spread across India? It’s almost impossible to imagine any Puja, without Pet-Puja. Even for vegetarians, and all food lovers everywhere, the ingredient that brings that Su-baas in Bāsmati and tadka in daals, the thing that makes most spices so spicy and oils to smell so nice, is also present as a basic ingredient of Cysteine (26%), Cystine (27%) and Methionine (21%), three beads in the necklace of 23 Amino acids in the Pandora’s box of life. Scientists call that Gem Sulphur!

Yes! This is the 13th most abundant element in the Earth’s crust with an average concentration of 0.06% and yet it has been recognized as the fourth major essential plant nutrient. Not only that, being an integral component of most of the proteins, enzyme (Nitrogenase) and co-enzymes (co-enzyme-A) vitamins (Biotine, Thiamine or vitamin B1) and hormones, it is associated with most of the life sustaining physiological activities in both plants (Photosynthesis, Biological N-fixation, etc.) and animals.

Sulphur can be abundantly found in crops of onion and oilseed groups (specially in groundnut) in the form of volatile compounds and is responsible for the aroma and taste of different varieties of aromatic rice and upliftment of protein quality in pulses.

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But the sad part is, despite being so important for our health and hygiene; it is ignored in Indian agriculture. Almost 40% of our agricultural land is severely deficient in sulphur, and due to constant negligence, this statistic is rising year after year. On the sidelines, this is also inviting a devil to grasp our lush pastures and fertile land in the North-Western part of India. Yes, you guessed it right! It is Desertification! How? It is now a well known fact that a vast portion of agricultural land in western UP, Haryana and Punjab is under threat of soil sodicity, a formidable problem of saturation of nearly all soil exchange sites with Sodium (Na+) ions, that breaks down soil structure (de-floculation), restricts soil aeration, impedes drainage (surface compaction) and eventually leads to lose its fertility status. If this problem persists, we are afraid that we may lose this part of the great Gangetic plain under the sand dunes of mighty Thar desert forever!

We are talking about it because potentially the answer lies within sulphur. Calcium sulphate di-hydrate (CaSO$_4$.2H$_2$O) is well known to curb sodicity problem among affected soils. So, there is no wonder when we’re picking this up for the solution. But, here’s a twist, and guess what, we’re making our approach environment friendly also. Here’s how…

Steel slag is produced during the Linz Donawitz process or the LD process in an integral steel plant @ 125kg/ton of Steel. This steel slag, also known as LD slag is highly basic in nature, as it is rich in calcium bearing mineral phases like mono, di and tri-calcium silicates along with free lime and some metallic iron. Apart from being used for road construction, steel slag can also be used as a sinter ore fluxing agent. However, at the same time these applications can’t take care of the huge stockpile of this slag at the enormous rate at which it is produced. With the rapid development of steel industry, the global crude steel production reached a stage of 1.623 billion tons in 2015. So, disposal of this huge amount of bi-product generated in the process requires substantial monetary involvement in one hand while loss of valuable resources on the other.

Therefore, value addition of steel slag needs to be explored so as to produce materials having diverse applications. In this context, yellow gypsum (of purity of almost 86%) is being synthesized by atmospheric leaching of LD slag with dilute Sulphuric acid at 100°C.

This yellow gypsum contains quite a good amount of essential plant nutrients like calcium, sulphur in huge proportion, while phosphorus, iron, silicon, manganese, magnesium and aluminum in moderate quantity, with a very minute amount of heavy metal (titanium and chromium) as impurity.

As chromium is needed @15-35 mcg/day to regulated sugar metabolism and fight diabetes in the human body, the chromium content in yellow gypsum, instead of posing problem of Cr toxicity, can be an added advantage, if this element can be accumulated in plants grown with it. This led us to explore the possibility of this product, not only as a weapon to fight sodicity, but also as a source of sulphur in different component crops under a vivid range of cropping system.

Therefore, with the objectives to testify the properties of Yellow Gypsum in different properties of soils under experiment, along with exploring its potentiality as an indigenous source of S, Ca, Mg, P, Fe and Si, keeping the risk of heavy metal loading of the soil in mind. Also, effects of organic manures, conventional chemical fertilizers, bio-fertilisers and management options are under observation.
So, we’ve aimed to design our experiment in four types of soil, that have been collected from sodic belt of western U.P. (Sandila, Lucknow), acidic lateritic soil from Bankura, W.B., saline soil from Sundarbans area of W.B. and alluvial soil from Jaguli, Nadia, W.B. and taken under greenhouse facility of Bidhan Chandra Krishi Viswavidyalaya for pot culture experiment in 216 pots (each having 6 kg of respective soils, 6 doses of Yellow Gypsum and 3 doses of Farm Yard Manure as organic manure, all with 3 replications), to be tested under rice-mustard-ground nut and rice-wheat-spinach cropping system.

From a potent environmental pollutant to an asset, we’ve therefore metaphorically planned to raise a phoenix out of ashes, so that one day we can have a beautiful future, with fertile lands and great food with embedded medications to counteract diabetes in the diabetic capital of the world!
Carbon dioxide is a greenhouse gas majorly responsible for global warming in recent years. Its concentration in earth’s atmosphere has been fluctuating for several thousands of years in the fluctuations can be observed by studying the past, and future variations can be predicted. Carbon dioxide gas in the earth’s atmosphere is taken up by the ocean when its pressure is less in seawater than in the atmosphere. Carbon dioxide dissolves in sea water and forms two main components bicarbonate ion (chemical formula $\text{HCO}_3^-$) and carbonate ion (chemical formula $\text{CO}_3^{2-}$). The carbonate ion and calcium from sea utilised by some calcareous organisms in seawater to make its hard parts such as shells which are made out of calcium carbonate. When these organisms die their shell sinks to the bottom of sea and remains untouched and preserved for several thousands and millions of years. In other words these organisms capture the carbon (in the form of carbonate ion) from sea water in their shell during shell formation and preserve it for a very long time. Through the chemical analysis of these shells one can understand the change in carbon, carbonate ion and subsequently carbon dioxide in seawater as well as in atmosphere which happened several years ago.

Similar work was conducted at our laboratory at CSIR-National Institute of Oceanography, Goa, by studying sediment samples dated till 25000 years. The 25000 years are generally classified by scientists into cold and; they are, the Last Glacial Maximum (LGM), from 24000 to 18000 years which was a cold period and the deglaciation from 17500 to 10000 years where in warming took place, and the Holocene, a warm 0000 years to present. The colder and the warmer climate of these periods are mainly controlled by carbon dioxide (greenhouse gas) in the atmosphere. During LGM,
carbon dioxide gas was 180 ppmv which resulted in less greenhouse effect and cooler climate the Holocene period it was 280ppmv contributing to more greenhouse effect and warmer climate. But the mystery is that how carbon dioxide which was low during the LGM suddenly increased during Holocene? Well the answer must lie somewhere in the deglacial period.

We chemically analysed foraminifera (microscopic organism) shells from core From the Arabian Sea and dated till 25000 years. Shells were chemically analysed for their elemental content i.e. Boron (B) and Calcium (Ca), the elements of interest their concentration is measured and ratio taken (B/Ca ratio). The concentration of boron in seawater increases with increase in pH. If seawater has high pH then boron content increases and more amount of boron is taken up by foraminifera in its shell. Hence through B/Ca ratio, pH of seawater can be calculated. The pH of seawater is again related to carbonate ion concentration in seawater and thus, carbonate ion concentration can be calculated from pH and carbon dioxide changes in seawater can be predicted. In this study we used organisms that spend their entire life at the bottom of the sea and hence, tracked and captured the bottom water conditions. The work was carried out at the Rutgers University in New Jersey, USA. The measured B/Caratios were then converted to carbonate ion concentration by an equation given by well known UK scientists Yu and Elder field from University of Cambridge in 2007. Calculated carbonate ion concentration values when plotted with their respective age, higher concentrations were observed during deglaciation and lower concentrations were observed during LGM and Holocene in deep waters.

Higher concentration of carbonate ion in deep waters signifies lower concentration of carbon dioxide in it because as the carbon dioxide concentration in seawater increases the concentration of carbonate ion decreases and vice versa. Although carbonate ion is formed from dissolution of carbon dioxide in seawater increases or decrease in quantity of these two parameters are inversely dependent on each other. So higher carbonate ion concentration signifies lower carbon dioxide and lower carbonate ion signifies higher carbon dioxide in deep waters. We observed a lower carbonate during the LGM in deep waters which means there lies the higher carbon dioxide in deepwas then interpreted that the carbon dioxide from atmosphere was taken up and stored in deep waters of the World esulted in lower carbon dioxide in atmosphere during the LGM time and hence, resulted in cooler climate. Higher carbonate ion concentration was observed in s to lower carbon dioxide in deep waters, which means that the carbon dioxide which was stored in deep waters during the LGM was given out to atmosphere during deglaciation and resulted in sudden global increase in carbon dioxide in atmosphere just after the LGM.

Various scientists from all over the world working on this issue state that during deglaciation the westerlies (winds that blow from west to east between 30-60°S latitude) shifted southward in Southern Ocean and resulted in diverging movement of surface water and upward movement of deep water which exposed deep carbon dioxide from it moved into intermediate waters. These deep and intermediate waters then travelled to all the major oceans of the world and carbon dioxide from intermediate waters was passed on to surface waters of these oceans and then given out to atmosphere resulting in global carbon dioxide increase during deglaciation.
Our study, carried out in deep waters of the Arabian Sea showed higher carbonate ion concentration which signify lower carbon dioxide. Lowering of carbon dioxide must have occurred through its movement in the intermediate waters. A study in Arabian Sea carried out by Sean Bryan and his group in the University of Colorado, USA, in 2010 showed depletion of $^{14}$C in intermediate waters by lighter carbon which must have originated from deep waters and also higher pressure of carbon dioxide gas was observed in surface waters of Arabian Sea by Sushant Naik and his group at the CSIR-National Institute of Oceanography, Goa, in 2015 during deglaciation which was released to the atmosphere. So this makes us conclude that once upon a time in the Arabian Sea during deglaciation, its deep waters released carbon dioxide which first travelled through its intermediate waters then to its surface waters and finally made its way in to the atmosphere and contributed to the sudden global rise of carbon dioxide during deglaciation.
With fuel prices on a rising trend and international authorities putting impending restrictions on emissions for saving the environment; efficiency of any machine (car, bus, truck, ship, etc.) is under scrutiny. On top of that, there is that ever-lingering question which resides in everyone's mind, which was famously conveyed in a television advertisement of Maruti कितना देती है? (How much MILEAGE does it give?) still remains. To answer this question, researchers have been pondering over diverse ways to enhance the efficiency of all mechanisms in the machine. In case of ships, the efficiency (mileage) depends upon its shape and size deciding the drag. Drag is a force acting opposite to the motion or movement of the body with respect to the surrounding fluid (liquid or gas). Objective of every researcher in the field of ship design is to reduce the drag of a ship so that with the same available fuel it can cover a larger distance or with the same available power it can move at higher speeds reducing travel time. Experimental work carried out in the Department of Ocean Engineering, Indian Institute of Technology Madras yielded 43% reduction in the drag of ship, in turn reducing emissions by the similar extent. This methodology developed by Indian Scientist will definitely address all concerns confronted by marine transportation business.

Drag of a body or opposing force is divided into two major components: Viscous drag and Pressure drag. Viscous drag is developed due to friction between fluid particles themselves and surface of the body in contact. Here, the viscosity and density of surrounding liquid plays an important role. Higher the value of these properties, higher is the value of viscous drag. Vehicles

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moving in water experiences more viscous drag than vehicles on land or in the air, as the viscosity of water is higher than that of air. Pressure drag, also known as form drag, is associated with the formation of empty space behind the moving body known as low-pressure area or wake, strength of which depends on the shape of the body. Here, bluff bodies like body with rectangular shape will have higher value of pressure drag as compared to a streamlined body like that of a fish. Generally, all surface or underwater vehicles are streamlined to their maximum limit, hence further reduction in the pressure drag is bit difficult. However, still there are opportunities to reduce viscous drag.

From the previous research, it has been proved that for slow-moving bodies like ships, viscous drag accounts for as much as 60%-80% of the total drag. This forced researchers worldwide to look for opportunities to reduce the viscous drag.

Micro Bubble Drag Reduction famously known as MBDR, has been conceptualised long ago. However, for last many years it is still in the research phase. Researchers from Japan and United States tried this methodology for ships. However, desirable results have not been achieved. In MBDR, air bubbles are injected below the moving body. When air is injected below the moving body, flow containing both air bubbles and water is formed. This reduces density and viscosity of liquid along with other favorable changes in the flow structure, causing considerable reduction in the viscous drag. If the rate of air injection is increased, bubbles begin to coalesce to form a transitional air layer that covers the surface in patches. If the injection flow rate is increased further, a continuous layer of air is formed, reducing direct contact of water with the surface of body, famously known as Air Lubrication System (ALS). Formation of continuous air layer is the ultimate thing, reducing density of liquid in contact with the surface from water to air. Different methods have been tested to inject air bubbles below the body, such as injection through porous plate or using array of small sized holes, etc. Each methodology has its own advantages and disadvantages. Based on past experiments carried out worldwide on the flat plate; it is opined that, method of injection through a series of holes yielded favorable results and is able to achieve 80% reduction in viscous drag. As compared to other methodologies used to reduce the viscous drag, MBDR has additional advantages like it is environmentally friendly, is easy to operate, has low initial and maintenance cost and high savings of energy. Since depth of ships is generally quite high, the static pressure of liquid at that depth becomes still higher. Hence, to inject air below the hull at that depth, air needs to be compressed to a higher pressure. Use of air compressor to initially compress the air before it is injected requires considerable energy, reducing efficiency of the methodology. From the past model experiments on different size and shape of ships, reduction in the total drag in the range of 12%-15% was attained. However, with energy requiring to compress the air and reduction in the efficiency of propeller due to presence of bubbles in the water, efficiency of the methodology was reduced to only 6%.

Thus, in order to increase the efficiency of the process, a well-planned and executed experiment on 5-meter-long model of the ship (Bulk carrier) in the towing tank of Department of Ocean Engineering, Indian Institute of Technology Madras was conducted, which yielded a whopping 43% reduction in the total drag of ship at the slower speed of 06 knots and 22% reduction at the cruising speed of 10 knots. For the experimental investigation, a suitable hull was initially
selected with the wide flat bottom. This caused injected bubbles to stay close to the bottom of the hull due to the action of buoyancy force and, in turn, increased the efficiency of the entire process. For the research, an array of holes was used to inject air. Air compressor was used initially to compress the air, which was then fed into an air injector unit through a valve to control the flow rate of air and then through the flow meter to measure the flow rate. Air injector unit consists of an air chamber which has 225 holes of 1mm diameter each made into its bottom plate. The air chamber is mounted into the wooden model of ship in such way that, the bottom of air chamber is flushed with the bottom of the model. For the visualisation of flow and migration of air bubbles below the hull, the bottom of the model was cut at three longitudinal locations, which was then replaced with 9mm thick acrylic sheet. Special care has been taken to avoid any leakage of water into the model along with proper stiffening of acrylic sheets. The experimental study was carried out for a speed range of 4 knots to 12 knots in the interval of 1 knot. For each speed, effect of six different injection flow rates of 0.5 CFM (Cubic Feet per Minute) to 3.0 CFM in the interval of 0.5 CFM was investigated. In all, 54 experiments were conducted to study the effect of speed and injection flow rate on drag reduction. From the various experiments conducted in the past, it was found that, at certain locations bubbles were escaping in the sidewise direction, reducing efficiency of the entire process. However, as for this experiment, hull was carefully selected, bubbles did not escape till the aft most end of the ship. This was one of the reasons for higher value of reduction in the total drag as compared to previous experiments conducted worldwide.

Due to restrictions from the bottom, inland vessels (ships) operating through rivers usually moves at very slow speeds. Experimental work carried out at IIT Madras opines that, MBDR methodology will be more effective for all types of inland vessels. Inland Waterways Authority of India (IWAI) is the statutory authority in charge of the waterways in India. IWAI has projected that; by the year 2025, 2100 vessels will be operating in National Waterways- 1. If MBDR system is installed on all 2100 vessels as planned by IWAI, one can expect efficiency enhancement, reduction in both fuel consumption and emissions from these vessels. With this system working on all ships, one can make statements like

ये जहाज कम पीती है (This ship consumes less fuel)!
ये जहाज कम छोड़ती है (This ship emits less pollutants)!
ये जहाज सबको पीछे छोड़ आगे भागती है (This ship leaves everyone behind)!

YouTube link for the model test: https://www.youtube.com/watch?v=XFKshj5GSkQ
In basic science, the terminology ‘dimension’ of an object is generally used to specify minimum number of coordinates require to identify a point within that object. For example, a point is a zero-dimensional (0D) object, a line is a one-dimensional (1D) object that has only length, a planar surface is a two-dimensional object (2D) with length and breadth; a cube is a three-dimensional (3D) object which has length, breadth as well as height. This simple parameter ‘dimension’ plays a very crucial role to determine the efficiency of several household devices, which we use often in our daily life.

Carbon (C) material graphite (3D) is a well-known material in the industry since sixteenth century as it is the only non-metal element which is a good conductor of electricity. Leads of pencils are the most common use of graphite in everyday life. Besides, natural graphites are also used in batteries, lubricants, steel making, and brake lining.

A breakthrough in this graphite industry occurred in the year 2004, when a group of scientists (K S Novoselov, A K Geim et al.) from the University of Manchester were able to isolate a single layer of graphite for the first time. This 2D single layer of graphite is popularly known as graphene sheets in material science family.

Invention of graphene opens a new door to the scientists in the field of both basic as well as applied science background. Properties of 2D grapheme is different from its bulk conformation graphite in many aspects, which make this 2D material very special. Thickness of a single layered graphene is of the order of very few nanometre (1 nanometre = 10⁻⁹ metre) or less than that. As a
result, electrons are confined mainly to the surface of the material rather than its volume. So, surface properties are predominant in this kind of ultrathin 2D material, which are generally abbreviated as nano-materials. Devices designed with graphene are not only extremely compact, but they are also very cheap from a financial point of view as carbon is a highly abundant material in nature. During the last few years, a large number of theorists and experimentalists have devoted their research concerns to explore different properties of graphene so that the material can be used effectively to fabricate various devices needed in the industry as well as day-to-day life.

Inspired by the advancement of low-dimensional materials family in the last few years, we have concentrated to analyse several properties of this kind of (graphene) material theoretically so that it may help the experimentalists to design novel devices.

Band gap is a basic parameter to specify the significance of any material for device fabrication. It is well-known that every material consists of several energy bands and electrons stay in these energy bands. The bands which are filled by electrons are conventionally known as valence bands (VB) and the energy bands where no electrons exist are called conduction bands (CB). Electrons in VB are tightly bound to the atoms and they are unable to move freely so, they are called bound electrons. However, an electron can move from VB to CB if some excitations are given to that electron. Illumination of light energy, giving some external electric or magnetic fields can be regarded as excitation for an electron. Thus, an electron has to overcome a finite amount of energy to move from VB to CB and this energy value is generally called as band gap of that material. Electrons in CB are free to move and so they are called free electrons.

After analyzing band gap of graphene, scientists have confirmed that, graphene is not metal, or semiconductor or insulator. Rather it is something special, called semi-metal, where band gap is zero, but this band gap can be opened.

Along with the band gap, optical properties like absorption coefficient, refractive index, reflectivity, electron energy loss spectra (EELS) are some basic but important parameters in the field of material physics. All these parameters are formally called as opto-electronic properties of a material and they play a vital role in designing ultrafast opto-electronic devices.

We have focused our research interest to investigating about graphene quantum dots schematically. If the two dimensions of graphene can be restricted (or confined), then the configuration is a 0D object. This kind of confined graphene sheets are known as graphene quantum dots or simply GQDs. GQDs exhibit many interesting and unconventional properties, which make this material so important. Our results indicate that, GQDs can be used as a good reflector device in nano-industry. The results of this investigation are reported in the ‘Journal of Physics and Chemistry of Solids 99 (2016) 34–42’.

Even after successful investigations and applications of graphene, researchers continue their intensive research work to search for more graphene-like 2D material. As a result, a new material named germanene has got its entrance in this 2D material family very recently. A group of scientists ME Davila et al. introduced this material in 2014 for the first time experimentally. This material is just like graphene, but the C atoms of graphene are replaced by germanium (Ge). That is why germanene is called germanium, a counter part of graphene. In recent times, germanene demands potential application in nano-electronics.
We have analysed opto-electronic and magnetic properties of germanene recently. Germanene is semi-metallic in nature just like graphene. Our study revealed that finite band gap is opened by decorating germanene with foreign elements. Finite band gap opening is necessary for semiconductor device application of a material. We found that a band gap of the order of 287 meV opens in germanene, which is quite suitable for transistor device applications. The results of these studies have been reported in the international journals ‘Current Applied Physics 17 (2017) 573–583’, ‘Current Applied Physics 17 (2017) 1589–1600’ and ‘Journal of Physics and Chemistry of Solids 115 (2018) 332–341’ schematically.

In conclusion, our investigations reveal that 2D materials like graphene, germanene are very important from scientific point of view. These materials can be used efficiently to design electronic devices like smart phones, laptops, microwaves, laser and photo-detectors, photo-voltaics devices, and optical modulators, which are essential in daily life as well as the industry. We have explored several unusual properties of these materials by numerical methods which may be helpful to design novel, smart, efficient as well as low-cost digital gadgets. Opto-electronic properties of these materials are so surprising and unconventional that, they still demand serious research concerns for smart development of our society. We hope, our work may act as a motivation to the readers to study further with low dimensional materials and may shed light to develop graphene and beyond graphene (germanene) elements based nano-industry.
Imagine one day while you are at a restaurant, in front of your favorite dish and suddenly, you are unable to pick the fork using your fingers. You feel confused, you are unable to speak and convey your plight; this is exactly how an individual having a stroke would feel like. Stroke is not a medical jargon anymore and almost everyone knows someone or the other who may have been affected by it at some point in time. Globally, stroke is the second most common cause for death. Within India itself, it was found that 1.8 million people suffer from stroke every year. To describe the disease very simply, it is a brain attack or an insult that causes cell death in the brain due to lack of blood flow. This is caused mainly due to a blockage in blood supply (ischemic stroke) or due to bleeding (hemorrhage). This severely limits the amount of oxygen the cells in the brain receive and within no time, causes brain damage in the affected regions. Due to the complications that stroke causes within seconds of its onset, quick hospitalization, timely diagnosis, rapid treatment and thorough medical intervention are necessary for effective recovery.

The victims from stroke are prone to have varied impairments which seriously affect one’s quality of life if necessary rehabilitative measures are not taken. Post-stroke recovery is an area of utmost significance in clinical neurology as it helps promote the growth of new connections in the surviving neurons, or in a broader sense helps brain to relearn its lost functions. Understanding this phenomenon in the brain is of great importance to enhance the speedy recovery of the patients.

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To study brain functions, generally, the medical community relies on the functional MRI (fMRI) for brain scans. The difference between an MRI and fMRI is that, in the latter specific tasks are administered which are performed during the scan. So, there is a prerequisite to be able to perform such movement tasks (motor) of the hands and legs (this seldom happens in case of stroke patients as lesion in the motor cortex leads to paralysis in the limbs). The whole scan procedure may be a tiresome experience for the stroke survivor. So, it was contemplated on whether there is a possibility to simplify this procedure and get the best out of the patients? This led to the search for something new and a new imaging modality called functional near infrared spectroscopy (fNIRS) came into focus. This instrument, which utilizes optics, has the ability to detect brain signals while performing the motor tasks. It uses near infrared light of specific wavelength to probe the brain and when tasks are performed the change in blood, flowing through specific areas in brain, is detected from the light returning from the intracellular regions of the brain. Though the deeper brain regions are not intrigued upon, peripheral cortical brain areas are well lit up with fNIRS and signals are collected with good quality. This makes it a pertinent and useful tool for analysing the motor cortex of the brain that are targeted disruption sites of motor aphasia.

With this in mind, the area that I focused on in my research puts stress on understanding the post-stroke recovery, particularly to study the inter and intra-functional connections within the motor cortex. For the identification of the affected areas, I decided to utilize fNIRS. The choice of modality for the research was taken after some considerations being:

- It reduced the trauma certain patients faced while they were asked to lie down inside the MRI machine (claustrophobic patients, etc.)
- It reduced the errors caused in the image due to head movement either voluntarily or involuntarily produced
- Being highly portable, the device could be moved depending on the needs of the patients (geriatric patients, ICU, etc.)
- Being non-invasive.

When NIR light is made to illuminate the brain, it penetrates the skull owing to its wavelength range and reaches the brain tissue. The task performed during the scan is reflected in the brain tissue of respective regions and, in turn, the metabolic demand of the region is increased. To cater to this demand, the flow of blood to this region is increased and more oxygen is supplied. The amount of oxygen in the blood changes its optical properties and this can be reflected in the NIR light coming back or reflecting from the brain tissue. The principle of spectroscopy is utilized here: the measuring and interpreting of electromagnetic radiation (here it is light) that is absorbed or emitted by atoms of the sample being used (sample here is blood). This absorption or emission happens when the atoms of the sample move from one energy state to another in the presence of light. To state more simply, it is a science to study how light interacts with matter. Spectroscopy is used here to quantify the relative change in the oxygenated and deoxygenated haemoglobin during the task from the steady state.

In a normal individual who is right-handed, it was observed that the study yielded true findings to the fact that motor cortex in the left hemisphere of the brain is activated when the
A Ray of Light Could Be the Answer to How the Brain Recovers From an Insult

person moves the righthand and vice-verse. But, stroke can alter this pattern and with the advent of modern imaging modalities, researchers have come out with multimodality approaches like functional Magnetic Resonance Imaging (fMRI), Electroencephalogram (EEG), Trans-cranial Magnetic Stimulation (TMS), Diffusion Tensor Imaging (DTI), etc. to apprehend the mechanism behind it.

Though we have been taught from childhood that the brain stops growing/learning after an age, this understanding has become quaint in the recent years with the theory of plasticity. This applies to the case of stroke recovery as well where the brain tries to relearn the lost functions with the help of different intervention strategies. Also, the concept of functional connectivity explains that the activities in the brain are a result of the integration of different brain regions which form networks through their correlated actions. Thus, a hypothesis could be made that there will be new functional network connections (plasticity of brain) involved in the recovery phase after stroke. Twenty healthy volunteers and twenty stroke patients were recruited for this study. The research team included radiologists and neurologists specialized in stroke treatment.

The whole idea of studying the brain network connections during stroke recovery is to aid bigger initiative of patient-specific interventions. Brain Computer Interfaces (BCI) is one such intervention. BCI, also known as mind-machine interface, facilitates direct communication between brain and an external device. The application of BCI could help in the recovery and rehab of the survivors. For example, the Functional Electrical Stimulation (FES), as a tool can be used as a rehabilitation technique to restore lost or damaged functions. This is the prime obsession which motivated me to address the challenges in relatively less studied area of post-stroke aphasia. The promising outcome from the study as well as the potential of BCI clubbed with the effectiveness of the tool keeps on fuelling me to contribute further in the domain through active research interventions. The potential of the tool/technique is massive; a stroke survivor with a paretic arm can be trained using a technique in which the brain can relearn to use the arm by externally triggering muscle stimulation. This could be done by initiating neuro feedback mechanism with the help of fNIRS-based BCI, where the fNIRS detects brain signals corresponding to limb movement. This classified signal can be sent back to the body in the form of muscle stimulation from FES. Through further research, it may eventually lead to the discovery that a ray of light could truly be the answer to all our questions.
Weak Electric Stimulation: An Answer to the Unremitting Voices in a Patient with Schizophrenia?

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Imagine yourself sitting in an auditorium by the window that overlooks a cricket ground. Then imagine your overwhelming passion of hearing your favourite musician or artist perform your beloved piece being overridden by the chaotic shouts and screams coming through the window. How miserable that state would be for a passionate music lover? Multiple this agony and anguish hundreds and thousand times, and you will have the feel of what it is like to be a patient of schizophrenia who hears voices.

This profound experience of a patient who can hear voices, to an otherwise unaware observer raises several questions in the latter’s mind. How can someone be convinced that he/she is being spoken to or with, when he/she can clearly not see anyone at all? Well, a trained psychiatrist would tell you that there are many other unbelievable experiences, but hearing of voices, that is, auditory hallucinations, is one of the most common complaints of the sufferers.

Medical science has worked unbelievably hard to help these patients. Every decade, newer and newer medications are introduced, but the question that has been troubling scientists over the world is that have we succeeded in truly dealing with this challenge? Have we actually pulled these patients away from the edge of the slippery hill-top that otherwise lands them into misery, identity crisis, mirage of a reality and the everyday battle of proving their story to a reluctant “healthy” world?

But, wait. This dramatic prologue does have an interesting afterthought. The challenge of meeting the medical and psychiatric needs of this group of patients has led to the exploration

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of different treatment protocols in addition to the conventional standard medicines. Given the opportunity of being part of a group of highly inspired and passionate researchers involved in a similar scientific adventure, I decided to explore one such treatment procedure called the transcranial direct current stimulation tDCS. If the word “stimulation” has thrown you off-guard, then do not panic. You will know the “how” and “why” about it, once you understand what we are trying to achieve in the first place.

Information in our brain is exchanged in two forms. Neurons, which are the fundamental brain cells, communicate with each other through two “courier” services. One is through the chemicals and the other is through electricity. Please do not hold your breath at the second word, for it is this very electricity that switches on/off our movements, our thoughts, our vision, our touch in our day-to-day life. These chemicals and this electricity work in harmony to provide us the experience of the world we are living in today. Look at them as ultimate message providers, communicating information from one end of your body to the other. It is, therefore, needless to say that any nudge to this well-balanced consortium can end up a person with losing his control over the communication in between his different body parts, making him a stranger in his own body and world.

Medicines help these patients by bringing the equilibrium to the chemical imbalance. And it is quite apt to say that they work wonders in most of the cases. But, what if the neurons of our brain are unable to avail the electricity’s courier service? In simple words, what if the neuron wants to fire an electric impulse and for some reason is not able to, and we help it with just that? What if we do a little favour to the electrical courier service?

Well ECT, also infamously known in our culture as the “shock treatment” basically works on this principle. In simple words, it literally excites the neuron in question, to that point where it fires electric current. And that serves a purpose of awakening a sleeping neuron or disciplining an overacting one. But, although extremely therapeutic, it has been repeatedly found to cause memory loss or poor focus in activities.

So the scientists thought, what if we do not excite a neuron to fire, but rather just bring it to a point from where the neuron would choose to fire if the activity called for it? This way, the neuron would not fire pointlessly and it would have no trouble conducting the electrical information if it needs to. This is akin to saying that we take a horse to a pond and wait until its thirsty enough to drink the water. This is unlike to what is done in ECT, where we make the horse drink the water by assuming that it is thirsty.

And so here is where brain stimulation techniques like tDCS come into the picture. This technique when used effectively helps the neurons to reach a certain point of electrical threshold, from where it is easy to conduct an act for the neuron in times of need. The ball then is in the neuron’s court! It communicates only when there is a need, or when it has to!

The beauty of this treatment is reflected in few very well-designed research projects over the world. Especially in the context of the patients who are distressed by the constant herald of voices, this treatment has found an impressed audience. These studies first delved into understanding what is wrong with the brain. That is to say, they looked into which area of the brain is overactive and
which area is relatively underactive in patients complaining of “hearing of voices”. They realised that a certain part of our brain, the one which is present underneath the skull, a little above and behind our left ear, has increased activity in these patients. This part of the brain is called the temporo parietal junction aka the left “TPJ”. Interestingly, they also found that the part of the brain lying underneath the left forehead has decreased activity. This part is referred to as the left dorsolateral prefrontal cortex, aka the left DLPFC.

So quite smartly, they decided to bring balance to this by decreasing the neuronal communication in the left TPJ and increasing the electrical courier service in the left DLPFC. Using basic physics knowledge, these scientists placed negative cathodal electrode over the left TPJ to inhibit it and placed positive electrode anode over the left DLPFC to stimulate it. Using a small direct current machine that was set for 20 minutes per one treatment session, patients were given 2 mA of current for two sessions every day for 5 days. To check if the patient has actually improved or not, they scored a questionnaire about the “voices” before initiating this treatment and compared the scores after the treatment. It was found that a fair amount of patients showed remarkable improvement.

These studies made a fairly strong comment on the potency of this treatment. But as luck would have it, a newer question clouded us as scientists. What if some patients only have increased activity in their left TPJ brain area? What if we do not want to improve the electrical courier service in left DLPFC since it is doing its job quite fine. Since the direct current machine would expect us to stimulate one part of the brain while inhibiting the other, I hope you realise we would not be able to help this group of patients using this machine.

To deal with this new challenge, my team has been working on a newer advanced research project called the HD-tDCS, an advanced or the high-definition version of tDCS. This is advanced in numerous ways. It has smaller electrodes, thus giving us the privilege of targeting a specific part of the brain (making sure we target only left TPJ). Also, in this technique the electrode of interest has the current of our desired caliber which is 2 mA, effectively disciplining the electrical courier service in the left TPJ area, while the return electrode is subdivided into 4 parts (0.5mA current each), making no one return electrode capable enough to tamper with the electrical activity in the underlying brain area.

Our study with this HD-tDCS treatment has found very exciting and promising results. Most of our patients have shown benefit of roughly more than 20% from this treatment. Majority of the patients reported decrease in the frequency of the voices they heard, while some reported that the quality of that experience after the treatment was less overwhelming as compared to before the treatment.

Though the science of using electricity from outside to manipulate the electricity in the brain of a human being isn’t very new, its application for therapeutic requirements of the patients is still in its early phases. Our study has been able to make a subtle comment on its promising use in future, but we need more rigorous work in this area to ascertain its use with better confidence. Perhaps, we are all moving towards that point where finally we will be able to learn the perfect troubleshooting methods to bring harmony to our brain’s ever functioning, diligent and kindhearted courier services!
ALS, the disease that Stephen Hawking suffered from, is a motor nerve controlled by neurons in the brain or Olympic gold medallist Mohammed Ali surrendered to a fatal disease named Parkinson. Similar to these, there are other brain diseases like Alzheimer, Schizophrenia to Neuralgia and brain tumour affecting people equally poor or rich, common or celebrities. All these diseases cannot be cured till today as we cannot send a drug inside the brain because of the “blood brain barrier’ (BBB). This natural barrier will not allow any foreign body even a drug to cross it to reach the brain.Is it possible to open the skull everyday and put a drug inside for a cure? No, that is not the remedy, so we developed an alternate strategy to create a box like hollow cage which can cross BBB, hiding any drug inside and will deliver in the brain and after delivery will be excreted from the body. We use a very cheap source to design this box from low grade coal abundant in our country costing 5 rupees a kilo!

The perivascular cells in the brain play an important role of selective permeable space between the blood circulatory system and central nervous system which is commonly known as the BBB. It is composed of endothelial cells, pericytes and astrocytes and it protects the functionality of the brain and central nervous system (CNS). Pericyte cells create the BBB with tight junctions to protect vesicle trafficking through the endothelial cells and inhibit the effects of CNS immune cells and pericytes as contractile cells also contribute to controlling the flow within blood vessels as well

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as between blood vessels and the brain. So this BBB due to its neuroprotective role not only blocks the unwanted stuff to get in to the brain but also any drug molecule.

Lipid (fat) soluble (hydrophobic)molecules may penetrate into the brain. Moreover, drug molecules need to be carried by aqueous blood plasma and these should be hydrophilic. So the box environment has to be created which should possess amphiphilic property and this can flow through blood plasma and when it reaches the lipid gate can enter there as well. The width of the extra-cellular space in BBB is 38–64 nm so the box should fit in.

Therefore, the essential need for such a box:

- Synthesis of non-toxic box having maximum 64 nm diameter size
- It should be amphiphilic (water and lipid soluble)
- It should be non-toxic
- It should be self fluorescent (beyond auto fluorescence) to monitor its location
- It should work like a box which can open and close to carry inside anything smaller to its size and can load and de-load under proper stimuli
- It should be readily excreted out after its job is done.

We at Nanoscience and Synthetic Leaf Laboratory at Downing Hall, IIEST, Shibpur, West Bengal, under the mentorship of Prof. Sabyasachi Sarkar developed a new type of carrier (water soluble carbon nano onions, wsCNO) from low grade coal, yes you read it right, low grade coal which is not even used by steel industry for its low caloric value which produces our desired nano carbon cargo (box) to cross BBB. We can now deliver any medicine inside the brain and can monitor it.

**How was this study initiated?**

In 2005, water soluble carbon nanotube was first reported by us in the form of Kaajal and it was predicted that such system can be utilized in biomedical applications. We were able to make different types of water soluble carbon nano particles like onion (wsCNO) with photo
luminescent properties from cheap sources like wood, wool or plant waste by carbonizing these followed by oxidative treatment. We were successful to use these wsCNO for in vivo imaging of the entire lifecycle of the fruit fly (Drosophila melanogaster)⁶ also we showed that such nano carbon can feed micro nutrients as well as adsorbed water to young saplings even in arid zones “like spoon feeding“ as cited in our work by Chemistry World.

Finally, we extracted preformed graphene oxide (GO) from low grade coal with size distribution in the range of 40 to very large in nm. Interestingly these corrugated sheet type GO under aging or any stimuli changed to spherical shaped wsCNO. We optimized the size of such GO under nitric acid nicking to get their shape less than 35 nm in size.

Such wsCNO exhibits pH dependent, open and close form or can be thermally controlled.

Just to understand the utility of our wsCNO as box (Trojan horse) to cross BBB we performed animal study; 6-8 month old transgenic mice were induced with glioblastoma multiforme, a type of brain tumour, and CADASIL, a genetic disorder that contributes to vascular dementia in humans. The experiment involved injecting the wsCNO in the tail of the mice and imaging their brain. We have observed the passage of wsCNO to the tumour and also to the neuronal sites. A movie file

Figure 2: Smart Molecules changing shapes: SEM images of GO prepared from coal, (a) freshly prepared, (b) after few hours changing to sphere, interchanged by pH variation

Figure 3: Left side, from brain slice: wsCNO reaching a) tumour (green fluorescent protein tagged, red our wsCNO, and white level neuron tagged,) and b) neuron sites in brain blue Dapi blood channel; Right side, a) after an hr of wsCNO (red fluorescence) shows presence of wsCNO, b) mouse sacrificed after 3 days to show the clearance of wsCNO
showing live image of wsCNO movement has also been recorded (not shown for space restriction)

Thus we are delighted to establish that wsCNO cross through the BBB and enter the brain near neuron without causing any perfusion. This raises immense possibilities for drug delivery to the brain. These wsCNO do not accumulate in the brain but it is excreted from the body as analysed through the fluorescence study for wsCNO in the excreta for three days.

Now we have utilized the open form wsCNO to encapsulate desired drug molecules and its release. Some representative drugs were encapsulated inside the wsCNO in this study. Using electronic spectra, Drug@wsCNO composites were established and the release was quantified and almost 47% TMZ (Temozolomide) encapsulation i.e. in 10 mg composite 4.7 mg TMZ molecule could be found. In the case of Donepezil, an Alzheimer’s drug it is 42%. These composites of wsCNO are soluble in PBS buffer and the retention and release have been found to be pH dependent. So we have successfully developed a cargo can be loaded with any desired drug or composite drugs and that can be injected through the blood vein and its movement can be monitored and near the affected cell sites the drugs may be deloaded under need-based stimuli.\textsuperscript{[c,d]}

Previous work of our lab related to this work:


Kidney stone is a common disease worldwide. Approximately 12% of the global population suffers from this problem. Among the different diseases affecting the urinary system, kidney stone is the third most prevalent one. It is characterised by deposition of crystals/stones which are usually made of calcium oxalate.

Kidney is an organ which is responsible for purification of the blood and removal of toxic substances from it. The kidneys return the useful substances back to the blood again while the toxic substances are removed and form a part of urine. When crystals are deposited in the kidneys or other parts of the urinary system there is interference in this filtration function of the kidney. This may result in improper removal of the toxic substances from blood and level of these substances may increase in blood. Due to the obstruction, the patients may also experience severe pain in the back or abdominal area. Other symptoms can be nausea, vomiting, foul smelling urine and, frequent need to urinate but urinating very small amounts. As the disease progresses the deposited crystals may also lead to inflammation or damage to that part of the kidney tissue where they are deposited. This further worsens the situation and kidney function deteriorates even more. The damage to kidneys leads to increased excretion of uric acid, urea, and creatinine in the kidney. There is also an increase in damage to the kidneys due to free radicals derived from oxygen.

Another interesting aspect of this disease is that men are affected more as compared to women. This is because of the fact that women in their reproductive years have a higher level of estrogen. This hormone has a protective role and prevents the deposition of crystals in the kidney, while in

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men testosterone leads to aggravation of the chances of stone formation. Other factors may also be responsible for the increased prevalence of stones in one population or group as compared to the other. Citric acid prevents the formation of stones but a diet rich in oxalates may increase the susceptibility to kidney stones. Climate and lifestyle also play a significant role in stone formation. Increased atmospheric temperature (due to global warming or migration of people to urban areas) may increase the chances of formation of kidney stones. Lifestyle changes such as a seating junk food has also led to increased incidence of stones in children and women.

There are currently many treatment options available for kidney stones. Allopurinol, Ibuprofen, Diuretics, Acetaminophen and Naproxen are some of the medicines which can be used. Surgical treatment may include lithotripsy which uses sound waves to break the kidney stones. However, there may be serious side effects, for example, bleeding around the kidney and in nearby organs. However, most of these treatments have side-effects of the other issue is of reoccurrence of stones. Hence, alternative therapies with less side effects are desirable.

Many drugs and active ingredients of medicines are derived from plant sources. One such natural product from plants, saponins is a class of naturally occurring plant glycosides which is characterised by their foam forming properties in aqueous solution. There are many studies which have reported that plant extracts or fractions rich in saponins have the good ability to prevent the formation of kidney stones. Saponin rich fraction from fruits of Solanum xanthocarpum was evaluated for their efficacy to prevent the kidney stones both in vitro models as well as in vivo animal models. It was found that administration of saponin rich fraction significantly prevented the formation of kidney stones and damage to the organ caused by oxygen derived free radicals. Similarly, saponin rich fractions from the plant Herniaria hirsuta were also found to inhibit the formation of kidney stones both invitro and invivo animal models. Seven plants: Verbena officinalis, Lithospermum officinale, Taraxacum officinale, Equisetum arvense, Arcostaphylos uvaursi, Arctium lappa and Silene saxifrage were also tested to see their efficacy in preventing kidney stones. The researchers concluded that the saponin content of these plants was responsible for the beneficial effect and saponins might have a solubilizing effect on the stones. Indinavir is a drug which has had a good success rate in the treatment of HIV/AIDS but causes renal stones in patients. Two saponins escin and glycyrrhizic acid were found to significantly increase the time taken to form the crystals by Indinavir. This further validates the beneficial use of saponins in preventing the stone formation.

Diosgenin is a saponin with beneficial effects in several conditions such as increased oxidative stress and inflammatory events. Hence, our team of researchers chose diosgenin to test its ability to prevent formation of kidney stones in animal models. Animal model of stone was created by administration of ethylene glycol (0.75%v/v) in drinking water for 28 days. Twenty-four male rats of the wistar species were divided into groups of six animals each. Group I: Given only food and water, Group II: Given only ethylene glycol 0.75%v/v in drinking water for 28 days, Group III and IV: Given ethylene glycol and diosgenin (at two different doses). After 28 days, the urine and blood samples from the animals were collected and tests were done to see if diosgenin was able to prevent the formation of stones. Different tests were done including the test of urea levels, uric acid
levels, citrate levels, calcium levels, magnesium and albumin levels in the urine and serum. Kidney histopathology was done to see the extent of damage and crystal deposition. Antioxidant enzymes analysis was done in kidney homogenate to indicate the oxidative stress. In rats administered only ethylene glycol it was found that levels of urea, uric acid and, calcium (promoters of kidney stone) were increased in urine, while the levels of citrate and magnesium (inhibitors of kidney stone) decreased. On the other hand, rats given the test drug diosgenin had a significantly decreased amount of the different promoters (urea, uric acid and calcium) while a considerable increase in levels of inhibitors (citrate and magnesium) was observed. Histopathology studies indicated that rats treated with diosgenin exhibited less damage to kidney components and less crystal deposition as compared to untreated rats. Levels of antioxidant enzymes also revealed less stress on kidneys due to oxygen derives free radicals. All these studies proved that diosgenin has a preventive effect against the formation of stones in the kidney.

Thus, diosgenin can prove to be a potential drug for treating kidney stones. Studies on animals can be extrapolated and through ethical studies on humans further validation of the drug’s efficacy for use in humans can be established. The drug can have a promising role in reoccurrence of stones also as it could prevent the stones from being formed in animals.
Rice an important staple food and the major constraints of its production:

Rice, a member of the grass family, is an important cereal and is consumed by more than 3.2 billion people worldwide as a staple food. About 90% of the world’s total rice production and consumption happens in Asia. Among the Asian countries, India ranks second after China in rice production and are responsible for producing 20% of the total rice produce worldwide. In India, rice is cultivated both in Rabi (grown in winter) and Kharif (grown in summer) crop seasons and about 44 million hectares of land is utilized for this purpose. The major rice producing states in India are West Bengal, Uttar Pradesh, and Andhra Pradesh, among others.

Rice is an excellent source of carbohydrates and energy with about 23% calories. It is also rich in nutrients, vitamins, fibres, and minerals. Being diverse in its way of cultivation and usage, rice has become the most cultivable crop for all lower or lower-middle income countries.

However, the main constraint to rice cultivation lies in the fact that it requires about 35-43% of the world’s total irrigation. Continuous changes in the climatic conditions, increase in population and lack of sufficient irrigation have all led to multiple global hazards. Such effects of non-living factors on living organisms like crops are known as abiotic stress conditions and ‘drought’ is one of them. Drought refers to the prolonged condition of dryness due to the lack/absence of rain or irrigational facilities. It has also now become a threat for rice growth, yield, and development leading to reduced productivity.

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**Reasons behind improving rice varieties:**

World population is increasing continuously and is expected to reach 9.1 billion by 2050. This huge population inflation will also lead to more urbanization, adding up to the already existing food crises. Such burgeoning global population demands the rice productivity to be increased by 26% in the next 25 years. Thus, to meet up with the upcoming demand and population inflation, rice production must grow at a parallel pace, if not faster. More production will require more land, better irrigation facilities, and additional manpower which are all not feasible due to constant urbanization. Thus, rice research is the key to device improved qualities of rice which can withstand adverse climatic conditions without jeopardizing its productivity.

**Genes and their manipulation to generate better quality rice:**

All living organisms are made up of cells, the basic structural units of life. Each cell has a highly coiled thread-like structure called DNA (deoxyribonucleic acid) which, together with proteins form the chromosome. These chromosomes have multiple genetic information coded in the form of ‘genes. Each chromosome consists of many genes, and each gene has the information to synthesize a specific protein responsible for a specific function related to the growth and development of the organism. The process by which the encoded information of the gene is used to synthesize the protein is known as ‘gene expression’.

Recent developments in the techniques used in rice research have led to the provision of influencing the gene expression by introducing some beneficial DNA elements in the chromosome. These DNA elements can either increase or decrease the rate of formation of proteins, i.e. the gene expression in an organism. Thus, for example, if we have the prior knowledge of the gene and its role in imparting drought tolerance, we can increase the expression of that particular gene and develop a better quality of rice that is of more agronomic importance.

**Rice Research at University of Hyderabad: Finding new tools to increase rice production with minimal resources**

Effects of drought are widespread and damaging. In an Indian state, drought can cause a yield loss of about 40% which amounts to roughly $800 million. Thus, Department of Biotechnology (DBT), under the Government of India collaborated with Prof PB Kirti of University of Hyderabad and other eminent scientists all over India in 2010 to address this issue. The project aimed at identifying important genes which can be manipulated to generate improved rice varieties.

The research group used a unique method known as ‘activation tagging’ for identifying the uncharacterized genes in *indica* rice variety BPT 5204 (Samba Mahsuri). Activation tagging involves the introduction of some DNA elements randomly in the rice chromosome which results in increased expression of nearby genes present at the region of integration of the DNA elements, thereby ‘tagging’ them. Such modified plants were then grown under water-limited conditions to observe their growth and development. Those plants which showed better yield and tolerance
towards stress were studied further using various techniques to identify the tagged genes. The project continued for five years and finally, the research team successfully identified some of the important genes which might be responsible for combating abiotic stress conditions. Their manipulation can lead to the development of tailor-made rice varieties having important agronomical characters.

Rice ‘helicase’ was one of the genes that got tagged during the previous work from our group. Presently, we are interested in studying the detailed mechanism of rice helicases in drought tolerance. DNA has a double helical structure, i.e., it has two intertwined threads, which needs to be opened up during various functions of the cell. Helicases are the proteins which are involved in the opening of the DNA double helix so that the coded information present in the DNA can be accessed. Till now, helicases were not reported to have any role in imparting drought tolerance but, our previous findings indicated that these genes might be responsible for stress tolerance since they were identified when plants were subjected to water-limited conditions.

Our aim now is to validate this hypothesis by studying in details the underlying roles and mechanisms of the helicases in drought tolerance. For our study, we have generated customized rice plants and are investigating them under stress conditions. Preliminary results show that these plants have better root growth as compared to the normal plants (plants that were not modified) which is an important criterion for drought tolerance. The yield-related traits are yet to be analyzed.

**Socio-economic importance of the research conducted:**

Agriculture supports 58% of the world population. In the developing countries, close to 75% of the population resides in rural areas and earn their livelihood from agriculture. According to the global reports on food crises (2018) by Food and Agriculture Organization (FAO) in 2017 alone, about 124 million people across the world faced severe food crises. Hazards like drought reduce the crop production by 50%, thus leading to price hike, food insecurity, and malnutrition. According to FAO, food insecurity is defined as a situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life.

For many years, scientists have been trying to scale up the production of food grains including rice by using various measures. Although there has been some increase in the production, still it is not sufficient to eradicate food insecurity all over the world. Also, as mentioned earlier, the surge in population imposes a unique challenge wherein agricultural production must be increased to meet the rise in demand for food and other industrial uses. Thus, farmers need new tools and techniques that produce crops with sustained or increased productivity under limited resource conditions. The research work discussed in this article finds a way to identify and characterize the genes whose potential in combating abiotic stress conditions have gone undetected till now. Utilizing these newly characterized genes and creating tailor-made rice varieties will definitely help in mitigating the yield loss due to environmental factors and encourage more exports at a cheaper rate. Cost reduction would enable the poor to improve their nutritional and financial status.
I was born in the lush green surroundings of Palampur, a small hill town located at the foot of the Himalayas. Born and raised in a place with the diversity of flora and fauna at its best, nature always caught my attention ever since I was a little boy. My intrinsic curiosity about nature, a reflective thought process and tacit questioning of things happening around me, moulded me into a relentless learner. I continually have been inquisitive about the latest advancements in science and technology. “Research is to see what everybody else has seen, and to think what nobody else has thought”, this stimulating definition of research by Neil Armstrong captured my imagination in high school and has since incited and kept alive my passion to pursue a career in research. Experiencing real research during my doctoral studies has been nothing short of a roller-coaster ride and has provided me with a complete spectrum of excitement, intrigue, realization, despair, relief and tremendous satisfaction!

Now coming to the real question, ‘Why did I choose cancer biology as my field of research?’ To answer this inevitable query, let me tell you that right from my childhood, I had heard many stories and seen many people suffering from ailments that have led to their personal and family lives go haywire. This certainly gave me a push to comprehend and try to learn as deeply as possible about the various causes underlying dreadful diseases like cancer so that I could contribute fundamentally to the field of cancer biology and could be of importance to the society at large. The advantage of advanced learning and exploration is always the adventure and the thrill of venturing into the

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twilight zones of our intellect and the existing physical world around us. The quest for the unknown and the prospect of becoming the first to unravel a mystery that can have far-reaching effects on countless lives has always intrigued me and given me the stimuli to learn and master new things in life. With this mindset and a desire to learn and gain intellectually, in my doctoral work, I have been working on the topic entitled, “Elucidating the role of MAPKAPK2 (MK2) as a potential anticancer target in the pathogenesis of head and neck squamous cell carcinoma (HNSCC)”. The title may look complex at first look but has a lot of meaning and significance if you ask me. Let me try to put it down into a simpler story so that its real relevance comes into the picture.

Life is defined by the regulations of its components in a variety of manner which includes the regulation in gene expression patterns too. Depending on the environmental cues and a plethora of stress factors, the cells in our body respond accordingly. The characteristics of a cell are the reflection of its corresponding genes being expressed and regulated at that moment of time. This holds true both in physiology and pathology. The patterns of gene responses and their interplay with other cellular processes hold the key for the better understanding of both normal cellular behaviour and its alterations during diseases like cancer. Cancer, one of the most dreaded diseases, is quite intricately dependent upon gene regulation with kinases (like MK2) playing the central role. In response to diverse extracellular stimuli, MK2 influences crucial signaling events and cellular processes. MK2 regulates important cellular phenomenon, yet surprisingly the biological significance of MK2 in tumour progression has not been well elucidated till date.

During my doctoral work, I was interested in exploring the area of regulatory molecular biology with the perspective of HNSCC in my mind that is one of the most prevalent in this region as well as nationally. I tried to delve deeper into this area so that I can make an original and significant contribution towards understanding the basic molecular biology in order to better understand this disease process.

In India, around 77,000 cases of HNSCCs are diagnosed every year making it the second most common cancer in the subcontinent. The primary causes of HNSCC are various environmental and lifestyle risk factors including sustained tobacco exposure and alcohol consumption. Owing to the steep rise in HNSCC incidences and associated mortalities, it is not at all surprising that monitoring and controlling of HNSCC is becoming a national priority. Despite advances in surgical and other conventional treatment strategies in recent years, HNSCC continues to have a dismal prognosis with 30-47% recurrence rate as well as quite low 5-year survival rate among all the cancers. Unfortunately, to date, selection of medication in HNSCC has not been influenced by molecular testing/targeted therapy. The limited understanding of disease progression and carcinogenesis of HNSCC has posed huge challenges for the development of new therapeutic strategies. Hence, there is an urgent need to define the mechanistic role of different factors involved in HNSCC progression. In this context, we examined the involvement of MK2 in the regulation of HNSCC pathogenesis-linked genes by analysing tissue samples from cancer patients, generating MK2-knockdown tumour cell lines and developing xenograft mice model. Through our in-depth experimental approach and analysis, we have finally reported for the very first time that MK2 is a critical regulator of HNSCC progression as it regulates the transcript stability of important genes
that showcase important roles in tumour pathogenesis. In a nutshell, we have portrayed a critical role of MK2 in modulating HNSCC pathogenesis and have implicated MK2 as a prominent tumour marker in an attempt to unveil it as a potential novel anticancer therapeutic target in the management of HNSCC. I could write the tough-to-swallow gene names, the fold-changes, the expression patterns and the behaviour of the xenografted mice but that would just complicate the things a bit too much. Hence, I am not going into the technical details and in-depth data and experimental discussions because, at the end, what really matters is the outcome and the benefit that society would reap via your findings.

A better understanding of the role of MK2 in tumour progression could provide new insights into the enigma of gene regulation in cancer. HNSCCs are quite challenging to control due to their heterogeneity and demand for improved cosmetic results. Scientific advances in the area of molecular oncology have opened novel research directions. Nowadays, numerous research endeavours have been concentrated towards developing targeted therapies and unveiling novel stage-specific molecular markers which could be utilised in predictions of treatment outcome or in personalised therapies. It is quite evident that further unravelling the molecular tumorigenesis enigma will eventually pave way for novel therapies and better tailoring of present treatment modalities for the patients. Hence, our findings which are the hard-earned fruits of continuous and untiring efforts, can contribute significantly to the understanding of inhibiting malignant development and leading to a better disease-free life for the patients. This could serve to be a boon for the society which has been constantly plagued by this horrendous ailment.

This brings me to put a close on the story of my research for now. At this crucial juncture in my career where I am about to launch myself into an independent researcher, I look back with content at my findings and just hope with fingers-crossed that all the countless lab-hours were worth-it-all. It would be really heart-warming and overwhelming to see my research be of clinical and societal benefits in the days to come. I hope that I was able to communicate the intricacies and the earnest importance of the study in a simple way and put forward a probable answer to the million dollar question, “How can we control and treat cancers?”
Hunting of Treasures in the Wild......

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Searching for the food and hunting was not an easy task for our ancestors, so they started collecting the seeds of some edible plants and re-grew them at convenient places like river banks where they got maximum yield. The earlier domestication began at the ‘fertile crescent’, a crescent shaped fertile area between Tigris and Euphrates rivers. There were eight crops grown initially (called as the ‘founder crops’) including flax, emmer wheat, einkorn wheat, barley, lentil, pea, chickpea and bitter vetch. These ‘plant pets’ caused the Neolithic revolution which transformed nomadic human lives to settlements which later lead to several civilizations. Our ancestors continued their selection of the ‘pets’ according to their own preferences. Domesticates evolved according to the characters preferred by man for their own survival.

The transition from wild forms to cultivated ones acquired them several characters known as ‘domestication syndromes’ that distinguish the cultivated from the wild. The wild forms were preserved in the undisturbed geographical regions with their typical characters with wide variability, where the cultivated forms evolved almost alike with preferable traits.

We consumed the cereals, pulses fruits etc and re-grew their seeds. When the need increased, we started improving the characters. But some of the characters were already lost during the course of evolution due to the selections made by our ancestors mainly for yield. We continued growing the crops giving them all the resources, protecting from all the hurdles and they gave us what we needed- the food, clothes and shelter. But due to our continuous and intense caring, they forget to search for the nutrients by themselves; they forget to fight against the stresses like pests, diseases,

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Hunting of Treasures in the Wild……

water scarcity etc. They became the well behaving lazy pets of humans. They forget to enrich themselves with the nutrients and concentrated on ‘how they can satisfy humans with their yield’. In this age of uncontrollable climate change, they are trying hard to survive and meet our demands. The plant scientists are searching a way to help them. How the plants can regain their variability lost during the path of evolution and domestication?? The only way is to search for their wild relatives or the ‘wild cousins’ of the cultivated plants in which the characters are still preserved in its original form. As a plant breeder, I also wanted to help them to regain the variability…

While entering into the world of crop improvement with limited knowledge in research, I was introduced to these ‘wild guys’ by Dr Sarvjeet Singh, my guide for research in Punjab Agricultural University during 2014-16. He was extensively working on utilizing the untamed cousins of chickpea to improve the characters of the cultivated ones. The winter of 2014, I was given the seeds of the parents and the progenies of the crossing work initiated by my advisor. It was hard to believe that, those rough, black stone like seeds of wild relatives can create wonders. The progenies or the babies were having the seeds with wide variability some were like wild, some were like the cultivated, some with colors and shape of the father with skin of their mother or vice versa. Taking them to the field, I was not sure whether they can develop as plants… to my surprise, after some days, they germinated well. Like the variations present in the seeds, there were variations in the field also. It was not easy dealing the wild or half wild guys. I had to work hard to know their characters. They flowered at different times, some were short, some were heighted… while some guys were standing erect, and some were lying on the ground. I marked each one and observed their characters. While discussing with my guide who knows well about the ‘babies’ with whom I was dealing with, he said “we should tame the more wild ones in the field”. The only way is to cross with the cultivated or the tamed ones. But he asked me to make sure to note down the positive things in those little naughty ones. Climate in Punjab was not at all predictable, it also affected the crop. Some of the plants showed the dying symptoms, which was told as wilt…. Luckily, the pathologist helped me to an extent. The climate never allowed me to relax… The rain was the next villain.

I am really a lover of rain, so as the pathogen of blight disease. It spread well in my field… I lost many lines. To my surprise, those plants I considered as wild, untamable, unacceptable-survived well in all the extremities of the climate. That was the time, I started loving them too. Even though I didn’t care them much, they survived and grew well and stayed clean and green between the wilt or blight affected lines. they were small, with little leaves spreading in the ground like weeds like their wild parents… looking them carefully, I came to know that they were hardy even competing with weeds, have more branches, small but more number of flowers.

My aim was to increase the yield, and they had the capacities to contribute to the yield. They had more number of branches than cultivated and yielded more seeds per pod or the plant. To make them interesting to all, I wanted to tame them as my guide said. They should be popular for their capabilities. I started crossing, the small flowers of progenies were used to cross with the cultivated ones. The season went so fast spending with the wild. My friend from home science was totally stressed from my talks about wild chickpeas. She got familiarized with my research
more than my daily dairy. The seasons walked away and I spent much of my time in the field. The crossing of the plants back with their decent and well mannered parent was done twice to tame them well. The differences were visible in their seeds itself. They found to be more acceptable and less stone-like. Even in the field, they showed some manners. They tried to stand straight, they started mimicking their disciplined mother… but they had some qualities like their father… they were hardy, produced so many flowers, yielded more pods, more amount or weight of seeds per each plant..

There are several hidden potentials in the wild relatives of the present day crops. The plants we see as weeds may have the capacity to create wonders. So before uprooting or destroying a plant, we should think that it is a life…. It grew well facing several challenges and it may create revolution in our lives…. So if we want to improve and sustain our lives, we should respect, conserve and explore the nature and existing biodiversity.
Synergy to Fight the Monster

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It is time to change gear and approach to kill the monster. The monster I am referring to is cancer. One of the deadliest diseases that mankind has faced, and with the passage of time, it has taken various forms. To name a few, brain cancer, lung cancer, skin cancer and stomach cancer, etc. But being a female what concerns me the most and my colleagues around the globe is that, the almighty has further burdened us with an unbearable pain of breast cancer. As per WHO statistics, breast cancer impacts about 2.1 million women worldwide every year and accounted for 627,000 deaths in 2018 that is approximately 15% of all cancer deaths among women.

Treatment modules are there, but the statistical data clearly indicates that it’s time for a change and we need to adopt a more ruthless approach towards the disease but a more caring approach for our female colleagues. It’s like killing the disease without affecting the quality of life for the patient after the treatment is over. A modern day approach which has been adopted for treatment of chronic disease is, treating the disease with some mixture of ingredients which has the capacity to fight the disease along with providing nutritional value with health benefit. It’s like a single sword for killing and for healing.

Being a country of cultural diversity, we provide an excellent platform for such combinatorial approach, i.e., mixing the synthetic with the natural (also nutritional value) healing molecules. Prime Minister Narendra Modi’s initiative of producing ‘neem coated urea’ to improvise the agricultural sector further strengthened the objective of our research work to use a natural and a

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synthetic agent that provides a platform to test the efficacy of the two agents from varied sources in order to bring reforms in the area of cancer treatment.

Nutraceuticals have gained immense interest from the scientific community for their potential in cancer chemoprevention and therapy. In our previous study, our group evaluated the efficacy of curcumin (a natural molecule obtained from *Curcuma longa* sp.) and paclitaxel (another taxane commonly used for breast cancer treatment) in an animal model of the solid tumor. The study revealed enhance anti-cancer effects due to synergism between the two therapeutic molecules and was published in Pharmacological Research entitled as “Enhanced anti-tumor efficacy of paclitaxel with PEGylated lipidic nanocapsules in presence of curcumin and poloxamer: In vitro and in vivo studies”. Taking the reference of our previous study, we assessed the anti-cancer effects of docetaxel (a synthetic drug) and thymoquinone (a nutraceutical) for effective treatment of breast cancer.

Docetaxel, marketed as Taxotere, is a widely used anti-cancer agent for the treatment of breast cancer but the poor water solubility, dose-limiting toxicity, and unwanted side effects present a great challenge with the docetaxel chemotherapy. And also, just as mutations in bacteria create infections which are resistant to antibiotics, the mutations in cancer cells create tumors resistant to previously effective treatments, a phenomenon commonly called multi-drug resistance (MDR). This is another very common issue with docetaxel therapy. Cancer has become such a complex disease that a single drug or even a stand-alone molecularly targeted therapeutic agent may not suffice and has become the major limitation of anti-tumor clinical treatment.

Thymoquinone (THQ), a bioactive principle of the *Nigella sativa* oil (commonly called as black cumin or kalonji), well known in Indian traditional system has shown to possess anti-cancer, antioxidant and anti-inflammatory properties. THQ can also protect against the toxicity caused by conventional chemotherapeutics. Considering the potential benefits of THQ, it was selected to be combined with docetaxel, however, the poor water solubility, the non-selective distribution in the human body and the inadequate accessibility to the tumor tissue, on intravenous administration of the two agents impedes their successful translation to the clinic.

Loading multiple drugs at the right ratio in an impeccable delivery system such as nanoparticles is an innovative approach to deliver the therapeutic agents to the site of action. The researchers worldwide are searching for the “magic bullet” (a concept proposed in medicine by Paul Ehrlich) to selectively target the cancerous cells with precision facilitating disease diagnosis and therapy. The lipid nanoparticles developed in the lab of Prof. (Dr) Farhan Jalees Ahmad explored the very approach of ‘magic bullet’ for targeting the breast cancer cells.

In order to improve breast cancer outcomes and survival, a combination therapy approach wherein two therapeutic agents with profound anti-cancer effects was simultaneously incorporated in a nanocarrier system for delivering the drugs in the right amount at the right place at the right time to obtain the maximum clinical therapeutic effect.

Optimization using statistical design was carried out for the development of chitosan-coated lipid nanoparticles. The spherical shape, the small particle size in the sub-micron range and the presence of two drugs in the developed nanoformulation were checked using several physicochemical characterization techniques. The nanometric size of the particles facilitated their
effective localization to the tumor cells while the chitosan coating on the surface of nanoparticles enhanced their uptake inside the tumor cells via CD44 receptors, which are highly expressed on the surface of breast cancer cells. This process is popularly known as active targeting approach for cancer treatment. The chitosan-coated nanoparticles could be degraded in the acidic microenvironment of the tumor and eventually accumulated in the interior of the cell producing the cytotoxic effect.

We further collaborated with the lab of Dr Angamuthu Selvapandiyan (Team Lead, JH Institute of Molecular Medicine, New Delhi) to evaluate the cytotoxic i.e. cell-killing effects of the developed nanocarrier system and the individual drugs in the breast cancer cell lines. We could observe enhanced cytotoxicity with the lipidic nanoparticles compared to individual drugs. This could be ascribed to the small particle size and the presence of chitosan on the surface of nanoparticles, which could facilitate the efficient delivery of nanoparticles to the cancer cells via passive and active targeting approaches, respectively. The presence of THQ helped to overcome the multi-drug resistance associated with the taxane therapy which leads to retention of docetaxel inside the tumor cells and hence produced the synergistic anti-cancer effects. We are now further studying how this system works in the real scenario using a tumor model.

Cancer is a complex series of fatal diseases, posing a huge health crisis on both the developed and developing countries. Researchers in Dr Farhan’s Lab are constantly striving to bring about a better alternative for successful cancer treatment with the combination chemotherapy-nanotechnology approach that could play a pivotal role in the augmentation of therapeutic response in cancer. Combination therapy may increase the [patients’] chances to live longer, without cancer recurrence, and to live a better quality of life.
The first car in India was run on the roads of Kolkata in 1897. The trend was later followed by Mumbai and Chennai but the usage of car was majorly confined to the elite in those days. It was in 90s that the inertia of car usage in middle-class was broken by the advent of economy cars like Maruti-800. The trend has now caught up with the entire nation and a large number of private cars plying in metropolitan cities are choking its roads. As a result, the transport sector in India is facing a plethora of issues that range from congestion, traffic, accidents, and delays to degraded air quality in major urban cities like Delhi. It is not an uncanny coincidence that out of top 20 global cities with worst urban air quality declared by WHO, 14 are from India. Apart from pollution, the estimated economic loss due to delay and congestion on roads cost around 9,000 million USD to Delhi alone.

Thus solving the transport problems while steering it into the direction of sustainability, seems to be the only way out of this fragile situation. Transport demand modelling is the procedure where the ‘supply’ and ‘demand’ of the transport is assessed and forecasted for future. It prepares the authorities and paves the way for proper management of the impending out-of-hand traffic situation.

In my study, I am working towards a holistic solution for the transport problems. I believe that the respite lies in developing an integrated method of travel demand modelling that incorporates the elements of ‘diversity’ in land-use pattern, multimodal system and integrated travel choice making procedure for various forms and stages of travel demand modelling.

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Including land-use diversity in transport planning process

Land use refers to the various uses a patch of land is put to. Generally, a land can be subjected to residential, industrial, commercial, recreational uses, etc. To understand the impact of land use on the transportation planning and modelling process, its effect was studied on how the perception of value of travel time by a traveller changes. Value of Travel Time (VoT) refers to the cost of (travel) time spent on transport.

For a better understanding, we can assume that Kamta is travelling to work and it takes him 25 minutes to reach his office by his car. The time spent in travelling to work by Kamta could have been spent in some other activity like finishing off his work or shopping for some house groceries. The cost Kamta is willing to pay to devote every minute of time spent in travelling to some other activity is the value of travel time he associates with that travel. In short, VoT is the cost Kamta is willing to pay to reduce his travel time.

VoT is crucial as it forms the basis of performance evaluation of different policies and scenarios in transportation planning like congestion pricing, fixing fares of bus/metro tickets, etc. It does take into account various factors like distance travelled, travel time, travel cost, age, gender and income of the traveller, transport mode used, etc. The land-use parameters and demographic parameters like population density and employment density are also included in the model. To account for the land-use diversity of the area under consideration, an index is calculated that gives a higher index value if the adjoining land parcels have different land-use patterns. For example, if a residential land parcel is surrounded by land parcel of commercial and recreational nature, then the diversity of the area increases and has a higher index. But, if the same residential land parcel is surrounded by other residential areas then the diversity of the whole area remains very low, hence a lower index.

Models were developed for each zone to account for the effects of land-use pattern and diversity on value of time. The estimated value of travel-time so estimated from the study depicts fluctuating values for different travel modes in different zones with varying land-use patterns. The study showed that larger tracts of land dedicated to residential land use leads to lowering value of estimated VoT. This effect is more pronounced in regions with higher population densities.

Including Diverse Travel Modes (Multi-modal) in transport planning process

The transport system constitutes of various modes of transportation including private cars and two-wheelers, public buses, metro, auto-rickshaws, bicycles and the pedestrians referred to as multimodal transport. The interaction of diverse transport modes give rise to complex travel patterns which is not easy to comprehend. Since transport planners have to deal with such complicated travel patterns while modelling of transport system, the factors that dictate the state of multimodal transport at individual commuter level must be studied.

A multimodal transport system apart from being sustainable also enables better mobility of the commuters by providing enhanced access to other services and opportunities. It enables efficient usage of public transit systems along with the usage of bicycle and walking as a means to
reach the bus stops or metro stations. Delhi has a multimodal transport system comprising of bus and metro services but the trips made by personalized modes of transport outweigh them both. The Delhi Metro System and bus services are undergoing extensive expansion. Such huge investments lose justification if they remain underused.

To understand and delve into the determinants deterring commuters to make use of multimodal transit services, it is pertinent to evolve and come up with an integrated urban transport system. The developed model suggested that the inclination of commuters towards multimodal transport is affected more by the travel time devoted to reaching to a public transit facility from home at start of the journey and reaching the destination from the public transit at end of the journey.

Say for example, if it takes a longer time for Kamta to reach the nearest bus/metro station from the starting-point of his journey (home) or the ending-point (office), he will be unwilling to use public transit and eventually would shift to using his personal car or two-wheeler that would provide him quick point-to-point solution. The model further suggests that under highly congested traffic conditions, when the travel time varies a lot due to jams, the commuters are hesitant to use their private cars. They instead shift towards multimodal system of bus or metro where travellers use their travel time in activities like reading, relaxing and socializing.

Towards Sustainable Transport

The results from the study indicate that an entirely new approach is required when we are planning our transport system for new cities or when we are introducing a new transit service in an existing system. The idea is to make the entire travel experience as seamless and as stress-free as possible. The planners should consider the short-term and long-term choices of travellers along with the changing land-use pattern of an area for an integrated travel experience. The travel demand modelling done by planners must have inclusion of feedback mechanism that establishes a synergy between the supply and demand. Integrating land use with transport planning is one of the requisites of ‘smart growth’ and ‘sustainable development’. Integrating economic analysis in transportation planning will fetch economic benefits and cost effectiveness of transportation investment. Thus, integrating community interaction with transportation planning conforms to total well-being of the society.
Traditional Indian Cereal and its Preparation as a Potent Micronutrient Vehicle

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Being born in Bengal I was mainly introduced to a very mainstream traditional “combo-meal” right from childhood, “bhaat-maachh” (rice and fish). These two foods individually or in combination are a part of every household menu each day in Bengal and parents and elders keep special vigil that the children never skip these two in their daily diet. Nevertheless, as I grew up and began studying and working in various parts of the country, I was confronted with the word “malnutrition” in more or less everywhere across the country. Also, being a food technologist and knowing the probable solutions to this National or International level phenomena it would have been unworthy of me to sit back and give it a deaf ear and a blind eye.

“Nutrition Supplements” as well as “Fortified Foods” are common prescriptions to malnutrition. Now, taking a closer look, these formulations have a huge potency in combatting the same but can these be a perfect solution to all economic levels of the country? Not at all. For most people across the country, the MRP of these products is just electrifying. Numerous attempts have been made to come up with cheaper solutions to the problem and some attempts were quite successful also. Now we have enhanced baby foods, milk with enhanced nutrients, oil, rice and many more foods that perhaps will successfully eliminate the problem to a substantial extent but the doubt still persists regarding the rural population. What or how much will they be able to afford these? Or will they at all give a thought to spend on these at all? I don’t think so. Almost whole of our rural population depends on indigenously grown cereals, pulses and vegetables for their staple food hence penetration is extremely narrowed down. So, the solution that can be termed as “perfect” is a big challenge.

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The government has made numerous efforts across the country but those too have their limitations. For example, fortified rice introduced into “Mid-Day Meal” Scheme could only cover the school-going children. Iron and folic acid tonics and pills were apprehended by people to have abortive effects. Fortified grains of darker colours were thought to be insect invaded or damaged grains and were removed during sorting prior to cooking. Hence, giving a thought to all these happenings I started working on fortifying my very own “Chal” or “Chawal” (rice) as we all call it at Birla Institute of Technology, Mesra. The technology being developed has certain aspects which will take it ahead of other available options in this regard. For example, this enhances or fortifies rice in its very native state and uses minimal changes in the traditional way of processing it. This is a physical method and can be easily adopted by existing rice mills by little additional modification.

Heat and water treatments are a mandatory operation for producing the rice consumed in most parts of India. It is during this step or what is technically called as parboiling that the modification will have to be introduced. The resultant grain will be one where the micronutrients will not be just at the surface of the grains but also in the inner layers. Thus, substantial reduction in washing losses is expected. While doing this, a serious problem was observed. Grains that were obtained had cracks and fissures which spoiled the appearance of the grains. These vanished on cooking but a person who will buy or a farmer who will sell it may have to undergo negative impacts because of this since he would not be selling cooked rice obviously. Also, fissured rice may end up getting broken during bulk and long transport to far-off places. Hence, the current stress is more on eliminating this issue. It must be added here that this problem is expected to be solved with ease as there are well-established methods already for the same.

Cooked rice is consumed either during lunch or dinner. That was the next level of thought. It meant that the progress may be limited as the menu is not the same during all meals of the day. As already said, introduction of novel products and change of eating habits is not a feasible option hence the changes needed had to be brought about keeping the menu intact. It was observed that even though the basic meal did not comprise of cooked rice but the morning and evening snacks were based out of the very same rice itself. And this is true for most parts of our country as we Indians are mostly dependent on cereals and pulses for our staples. Now, almost all of us may be aware of puffed rice or if not puffed rice then maybe “Laiyan” for northern Indians, “Bhel” for western Indians, “Mandakki” for southern and “Muri” for easterners. One may be astonished to know that “Muri” in some villages in eastern India is consumed as a substitute for cooked rice owing to its many-fold convenience. This may be consumed with regular vegetable mix or may be mixed with baked and fried nuts and pulses or may be spiced up like “Bhelpuri”. Processing of this snack is easy and requires very little skill. It can also be stored in bulk owing to its high shelf-life. “Muri” can also be further processed into desserts by introduction of sugar or jaggery or may be a processed into a cereal bar.

Thus, the provision of enriched food can be achieved throughout the day if one can fortify the basic snacks also. “Muri” is just one of the many opportunities. The technology worked upon here has no special machinery requirement. Just the conventional processing of salting and puffing is sufficient with only a little change in operation during salting. A major parameter in both the
cases of rice and puffed rice is the amount of available micronutrient present in each or in other words how much of the nutrients present can be utilised by our body. Special care in terms of packaging and storage has been taken to prevent degradation or changeover to lesser utilisable forms because giving enriched meals will never suffice if the contents are very poor in terms of usability. Hence, the target of providing nutrition throughout the day as well as giving it in the form of conventional food is what the main objective of my PhD is looking forward to a healthy and nutritious India ahead.
Humpback whale, a species of baleen whales, has been existing for the past 55 million years. It is known for its most recognizable, distinctive body shape, long fins and its knobbly head. These whales can grow up to 60 feet in length and can weigh up to 36 tonnes. Because of its huge size, humpback whales cannot hunt down its prey like other whales. Generally, the humpback whales feed on plankton and fish schools of euphausiids, herring and capelin. Therefore, it uses a specialized feeding system, known as bubble net feeding. It is a cooperative feeding method used by humpback whales in groups. From the group, the leading whale dives first (alpha whale), it is the alpha whales duty to find the fish while the other whales (Slave) follow the alpha whale in formation. Once the alpha whale finds the fish, it starts creating bubbles encircling the schools of small fish. Studies suggest that these bubbles and its associated acoustics arise from the exhalations of the whales. In addition to that, those airy bubbles make the water opaque, creating an imaginary wall. The following group of slave humpback whales maintains the bubble netting effectively trapping the entire schools of fish. Whales gradually reduce the diameter of the bubble netting eventually creating a small zone around the prey. Using the element of surprise, the whale escapes from the formation one by one and suddenly lunging towards them. During this feeding, it has been observed that the humpback whales travel at a speed of 2.6m/s towards the prey exhibiting its acrobatic behaviours like sudden manoeuvres and underwater somersaults.
Inspired by this highly agile acrobatic manoeuvres performed by humpback whales, researchers look at its control surface the pectoral flippers. They found unique wavy structures over its flippers while majority of the fish belong to this order possess only smooth curvy surface. Initially, it was believed that these bumps on the flippers of the humpback whale made it difficult to swim faster like other whales, but when the aerodynamics of the humpback whale got tested, it turned out that in contrast to the smooth curvy fins, the leading-edge protuberanced wing had 32% less drag, 8% more lift eventually leading to the increased aerodynamic performance.

The marine biologist Fish, investigated the flipper morphology of the humpback whale and identified that they exhibit symmetrical profile resembling NACA 634-021 airfoil. Also, professor Fish and Battle have drawn an analogy between the humpback whale flippers with aircraft wing and wind turbine blades with leading-edge protuberances. One might speculate that the whales move at 2.6m/s in the water while the aircraft moves at relatively higher speeds. This can be substantiated with the explanation that, the sea water density ranges from 1020 to 1030kg/m³ whereas the density of air is 1.225 kg/m³ only. Consequently, the speed of the whale when corresponded to operate at the density of air is almost 1000 times higher. Hansen et al. approximated that the whale operates at a Reynolds number of 1.1×10⁶. Studies suggest that Aircraft wings, and wind turbine blades all operate in the same Reynolds number. Following that, Miklosovic with his group of researchers roughly modelled the pectoral flipper of a humpback whale with and without leading-edge protuberances and tested in a low-speed wind tunnel. Experimental results revealed that in addition to the aerodynamic performance enhancement they have also observed delay in stall characteristics. Another major finding was that these leading-edge protuberances results in loss of lift associated with an increase in the drag during the pre-stall regime and henceforth no improvement in performance was observed between the conventional smooth wing and the modified leading-edge protuberanced wing. Researchers suggested that understanding the flow behaviour to gain a much deeper insight in to the underlying dynamics is deemed necessary to resolve the pre-stall performance degradation issue by identifying the optimum leading-edge protuberance geometry parameters for various applications.
A study focused on this issue performed by Arunvinthan (the author of this story) under the guidance of Nadaraja Pillai at SASTRA Deemed University presented on 8th National conference on wind engineering held at IIT (BHU) Varanasi, reported all possible underlying mechanisms of leading-edge protuberance working mechanisms. Followed by the subsequent computational and experimental studies, it was identified that out of all the mechanisms studied, the “non-uniform separation characteristics” induced by the leading-edge protuberances was the primary reason behind the delayed stall characteristics as well as the pre-stall performance degradation. The oncoming freestream flow is bifurcated by the leading-edge protuberance in such a way that the majority of the flow is directed towards the trough region, thereby, creating enhanced acceleration. This enhanced acceleration at the trough region forms a low pressure region i.e. suction which in turn re-energizes the boundary layer behind each peak by drawing out the low inertial boundary layer fluid from the peak surface resulting in delayed separation. While it is found that this non-uniform separation induced by the leading-edge protuberances is responsible for the delayed stall characteristics over an airfoil, the amount of knowledge over the spanwise vortex formation still remains unclear and is less explored. Additionally, the vortex formed between the leading edge protuberances due to the local spanwise pressure gradient affects the overall favourable pressure gradient existing between the upper and the lower surface of the airfoil. Thereby it results in the pre-stall performance degradation both in terms of decrease in lift and increase in the drag.

Our research group at “Turbulence and Flow control” lab [TFCL] performed several computational investigations and found that the spanwise pressure gradient which is believed to be the reason behind the pre-stall performance degradation as true. Upon continuing the research, the team found that the leading-edge protuberanced wing undergoes sequential stall condition i.e. a combination of stalled and non-stalled region appearing alternatively along the spanwise surface. In the stalled regions, the small vortex formed between the leading-edge protuberances converge together forming a large separation bubble over time. In TFCL, it is discovered that imparting additional momentum in terms of surface blowing near the vicinity of the leading edge at the point of separation bubble tends to divide the larger separation bubble in to smaller ones, thus, enhancing the quality of the flow over the airfoil. This enhanced airflow along with the reduced spanwise vortex thereby enhances the overall favourable pressure gradient resulting in the increase in the pre-stall performance.

Overall, the research showed that the tangential surface blowing near the vicinity of the leading-edge has the ability to augment aerodynamic performance with associated stall delay characteristics in pre-stall angles. The study has been conducted over wide variety of blowing amplitudes and different surface locations. The computational study focussed on this title has been communicated to the “Chinese Journal of Aeronautics”, of which the author is also a contributor. Upon successful practical application, it is believed that this technology will bring India to the forefront of the civil aviation industry.

The research team includes Dr S. Nadaraja Pillai and S. Arunvinthan. The author, S. Arunvinthan is a Junior Research Fellow pursuing a PhD in the field of Aerodynamics under a sponsored project titled “Influence of leading-edge protuberances on the aerodynamic characteristics of tapered and swept wings at subsonic speeds” funded by DST/SERB/ECR under File No: ECR/2017/001199.
Swapnil is a 20-year-old engineering student. Over the past few weeks, he is noticing some changes in himself. He has lost interest in his studies. He doesn't enjoy talking to his friends anymore. He doesn't enjoy playing the guitar. He gets irritated at almost everything. He gets tired very quickly. Recently, he has also started to wonder about the meaning of his life. He has started to wonder whether it would make much difference to anyone if he weren't around anymore. He realizes that he has no conceivable reason to feel this way. He has a loving family and good friends. He has tried to snap out of this despondency. He has tried to shake it off. He has watched many motivational videos on YouTube. All these have had a transitory impact on him. He is not sure why this is happening to him all of a sudden, and he has no idea whom to turn to for help.

Swapnil is going through an episode of Major Depressive Disorder or more commonly known as depression. According to the World Health Organization, depression is currently the leading cause of disability worldwide affecting more than 300 million people. Swapnil is one of those 300 million individuals. Being from India, where mental health literacy is poor, he has no idea that what he is going through can be treated. If he knew that he had depression, he would have

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*I have lost all interest in life. I don't know what to do. Please help me!!*

- An email to us at 3am.

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* Mr. Arka Ghosh, Ph.D. Scholar from Indian Institute of Technology, Kanpur, is pursuing his research on “Developing an Automated Online Tool to Help People with Depressive Symptoms.” His popular science story entitled “Treadwill, A Website for Treating Depressive Symptoms” has been selected for AWSAR Award.
to admit it to his friends and family. The social stigma attached to mental health disorders is one of the biggest deterrents to seeking help. If he gathered the moral strength to “come out” to his friends and family and live the rest of his life with the label of being “mental,” the next difficult step would be to find a good psychiatrist. Whether he will be able to find a good psychiatrist depends on where he lives. Once he finds the psychiatrist, he will have to figure out if he has the time, money, and motivation to visit the psychiatrist regularly. As reported by the 2015-16, National Mental Health Survey of India, all these factors lead to a treatment gap of 85.2% for depression in India. Which means that out of 100 depressed Indians, 85 of them don’t get adequate treatment.

This treatment gap can be bridged, at least partially, if there is a way to deliver online automated and free treatment. While the lack of awareness is a deep-rooted problem which will require a multi-faceted and long-term action plan, an automated online and free treatment can solve the problems of distance and cost and can circumvent social stigma. This approach of delivering automated online mental health intervention had started in 1966 in MIT with Prof. Joseph Weizenbaum. Only in the past decade, however, interest in this area has boomed, and this has been shown to be a promising approach to tackling depression as a public health burden. The latest research in the field recommends providing online treatment guided by a mental health professional. This approach, however, is not suitable in India where the mental health professional to patient ratio is abysmally low. So, under the guidance of Prof. Nitin Gupta at the Department of BSBE, IIT Kanpur, I started working on a fully automated online intervention, TreadWill (www.treadwill.org), to help people deal with depressive symptoms.

For there is nothing either good or bad but thinking makes it so. - Shakespeare

Figure 1: Shows a simplified flow of information when a person faces any situation. For a depressed individual, the “information processing” after the situation is negatively biased, culminates in exaggerated negative thoughts. These exaggerated negative thoughts lead to negative emotions and dysfunctional behavior which are the most visible symptoms of depression. From this it can be inferred that there are two points of intervention to help depressed individuals. One is to help them identify these negative thoughts and take a more realistic view of the situations; the other is to retrain the “information processing” to remove the negative bias.

Cognitive Behavioral Therapy (CBT) is a therapeutic technique based on the first approach developed by Dr Aaron T. Beck in the 1960s. A CBT therapist teaches a depressed patient techniques to identify and evaluate their negative thoughts. Using the different techniques of CBT, the patient realizes that their negative thoughts are unrealistic and gradually learns to take a realistic view of the situations. The structured and time-limited nature of CBT makes it suitable for automated online delivery. So, we have developed TreadWill to teach the techniques of CBT to patients. TreadWill uses slides, videos, and interactive text material to teach the techniques of CBT engagingly. To provide a tailored intervention to patients, TreadWill provides content relatable to the patient’s personal profile. To provide a sense of belongingness, TreadWill includes a Support Group where patients can post their problems and seek help from others. The first version of TreadWill is based solely on CBT. We are currently conducting a clinical trial to test the effectiveness of the first version of TreadWill.

Cognitive Bias Modification (CBM) is an umbrella term for cognitive training tasks that aim to retrain the “information processing” biases in individuals with different mental health disorders like depression, anxiety, and addictions. To get a better understanding of the term Cognitive Bias, read Box 1.

**Box 1**

If you read the sentence and then the word, then most probably the word that came to your mind when you read SO_P is soup. On the other hand, had the sentence in the box been “When you are in depression, you don’t take a bath regularly,” you would have read SO_P as soap. This is an example of priming. The preceding sentence primes you for a very short duration to read SO_P as soup or soap. When someone is going through an episode of depression, they are primed to interpret situations negatively. This is the “information processing” bias or Cognitive Bias. Specifically, depressed individuals have biases in attention, interpretation, and memory. They are more attentive towards negative information, they interpret situations in a negative way, and they recall negative memories when thinking about their past. These biases are modifiable using cognitive training tasks. Multiple research groups around the world have used different cognitive training tasks to modify these biases leading to reduced depressive symptoms. Patients, however, reported that they found the training tasks monotonous. So, it is unlikely that depressed patients, who already lack the motivation to do anything at all, will do these tasks diligently when left unsupervised. So, we are including games based on these tasks in TreadWill. If the patients find the games engaging, they will play it repeatedly making it easier to provide the adequate dosage required for cognitive training games to be effective. We also expect the games to increase the overall engagement with TreadWill. We are including these games in the second version of TreadWill.
The proof of the pudding is in the eating.

The first version of TreadWill is based fully on CBT. We are conducting a clinical trial to test the effectiveness of TreadWill. We will be dividing 600 patients into three roughly equal groups. Each patient will have an equal chance of being assigned to either of the three groups. The first group will receive access to full-featured TreadWill. The second group will receive access to a limited version of TreadWill which will have the same content in a text format, and the third group will be put on a waiting-list for six weeks after which they will be given access to the full-featured TreadWill. If the patients in the first group improve more than the ones in the second group, then we can infer that the interactive features (slides, videos, interactive text) are effective in making TreadWill more engaging and effective. If the patients in the first and second group improve more than the ones in the third group, then we can infer that TreadWill, either the full-featured or the limited version, is better than six weeks of time in reducing depressive symptoms. Currently (as of 29/9/2018), we have recruited more than 400 patients. Patients have reported that TreadWill has positively affected their lives, and they found the interactive features useful. We are simultaneously developing the second version of TreadWill in which we are including games based on CBM and improving existing features based on feedback from the first trial. We will conduct another trial in which we will be recruiting participants from different countries as well.
Investigation on Self-Healing of Recycled Asphalt Mixes - A Method to Incorporate Mixture Properties into the Pavement Design

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In India, there are many new highways being constructed and many major road corridors are being widened. The use of good quality road aggregates and binders in a) construction of new pavements and b) rehabilitation of existing pavements is leading to the depletion of raw material. Research has shown that this material consist of both valuable aggregates and binder that can be reused for construction of new bituminous layers. This material is referred to as reclaimed asphalt pavement (RAP). With the increasing costs of the virgin materials and also the constraint of limited availability of road quality materials, the use of high percentages of RAP in the construction of bituminous layers is being considered as a feasible solution.

Use of RAP material has many potential benefits including improvement in rut resistance. There are mixed views on the effect of RAP on the fatigue cracking performance of the mixes. Cracking is one of the major modes of failure in bituminous pavements. Due to the time constraint during the laboratory experimentation, continuous load pulses are applied unlike the pattern of loading the pavement. The actual period of the rest period between load pulses will vary in the field and usually depends on the traffic volume/speed. Longer rest periods are known to yield longer fatigue lives. The process of recovery from damage is generally termed as “healing”.

Healing is an age-old and interesting concept where the materials are considered to have the structurally incorporated ability to repair damage caused by mechanical usage over time. Many polymeric materials and composites have healing capacity and are being used in different structural applications like aircraft, cars, ships, construction industries and the defence sector.

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Many researchers report that the asphalt concrete used as road construction material has the ability to heal when there is a sufficient rest period. Healing of the asphalt concrete is one of the important factors which are responsible for the significant difference between laboratory and field fatigue lives.

The mechanism of healing in the asphalt mixes is when two surfaces of binder film are placed in contact and the interface gains strength when the suitable time and temperature is available. In this process, the molecules present at the surface diffuse to the other surface and increase in the strength happens due to the randomization of the molecules. The healing capability of the asphalt mixture depends on the type and quantity of binder, traffic and environmental conditions and mix properties such as aging. Healing characteristics of Recycled Asphalt Pavement (RAP) mixes will be different from those of normal mixes since the RAP material consists of aged binder. This will have significantly different healing properties from that of virgin binder and the diffusion between RAP and virgin binders is also known to be complex and non-uniform.

The study explores the healing characteristics of mixes containing RAP. The healing characteristics of the asphalt mixes containing RAP material will be dependent upon the quality of the combined binder. Commonly used surface course mixture for national highways with a nominal maximum aggregate size of 19 mm with varied RAP percentages (0, 15, 25, 35 and 45 %) was used for the current study.

After characterizing the RAP material, mix design was carried out using the Marshall mix design method to determine the optimum binder contents. Mixes were prepared at respective optimum binder contents for evaluating their healing potential. The healing potential of the mixtures has been evaluated for short as well as storage rest periods. Fatigue testing with different rest periods (0.4, 0.65, 0.9 and 1.4 s) after a loading pulse has been conducted to evaluate the effect of short rest periods on the fatigue life.

The effect of temperature (40 and 60 °C) on the healing capability of the mixes has been evaluated by providing storage rest period after inducing damage. Increase in the temperature of storage rest period facilitates the binder flow into the micro-cracks formed due to the mechanical usage. The effect of the initial damage level was evaluated; this would give an idea about the healing ability of the mixture at different stages of its life period. The healing ability of the mixtures remained more or less similar till half of the life is consumed, beyond which the ability is reduced. Once the bituminous pavement deteriorates to a level where cracks are visible on the surface, healing those cracks will be less efficient than the micro-cracked mixtures. Indirect tensile strength test was conducted on the specimens and the failed specimens are placed in split moulds for application of constant pressure and then conditioned for healing. The samples were re-tested after the healing conditioning and it is observed that the effect of RAP is nominal on the healing characteristics of the macro-cracked mixtures.

The healing potential obtained for varied rest periods and high temperature healing at 40 °C followed a similar trend as the branching of the aliphatic side chains present in the binders (obtained through Fourier transform infrared spectroscopy). The healing potential of the mixes where the healing conditioning is done at 60 °C reduced with an increase in the RAP content in the mixture. This is similar to the order of the stiffness of the binder present in the mixture.
It is seen that the healing characteristics of the mixtures change depending on the damage level and environmental conditions. Hence, there is a requirement of a comprehensive methodology (unified model) that would compute the healing potential of the asphalt mixtures by taking different conditions into consideration. To calculate the healing potential as a single number by considering all the factors, tests have to be conducted for different conditions that would prevail during the usage of the particular asphalt mixtures (like temperatures, number of years for which the pavement is being designed, traffic details). Then by using the weighting factors for each of the tests/conditions prevailing for considered pavement location and the healing capabilities obtained, a single index that represents the healing potential of the mixture can be calculated.

Once these numbers are obtained, normalization of the healing potential has to be done by dividing the healing potential of a particular mix one is going to use with the healing potential of the mixtures for which design methods have been proposed. This relative healing shift factor can directly go into the design equation of fatigue cracking as a multiplication factor. The usage of this kind of methodology would reduce the errors in the estimation of the fatigue life of any pavement that is being designed with new types of material/recycled material.
Nanocurcumin: A Point of Care Formulation to Treat Tuberculosis

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The super drug Curcumin, extracted from dietary spice turmeric, can be converted into nanoparticulate form ‘Nanocurcumin’ by a simple and facile in situ (at the site) approach, a new study has claimed. The innovative in situ technology developed by researchers at Institute of Chemical Technology, Mumbai, enables instantaneous generation of Nanocurcumin at point of care. All it requires is a glass of water for dilution. This in situ Nanocurcumin has demonstrated improved clearance of tuberculosis infection.

Curcumin manifests widespread applications and has been employed as an anti-inflammatory, anticancer, antioxidant and antibacterial agent. Curcumin is found to be nontoxic in humans at doses up to 8 grams per day, both as a dietary supplement and as a drug. However, the hydrophobic nature of curcumin, resulting into poor water solubility, hinders its effective utilisation as a therapeutic agent. Converting curcumin to its nano form can overcome these obstacles, state the researchers.

Nanoparticles are submicron-sized particles of size ≤1 micron. Nanonisation of particles enable solubility enhancement and can also improve bioavailability (the proportion of drug that enters circulation on administration) of poorly soluble molecules. Furthermore, such nanosystems when confined to 200-600 nm size range can enable targeted delivery to the reticuloendothelial system (defence system of body involved in infections).

The research team has elaborately described the in situ methodology employed for preparation of Nanocurcumin in their recent publication in Bioengineering and Translational medicine journal.

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The method simply involves addition of preconcentrate (a premix of curcumin and biodegradable polymer in a pharmaceutically acceptable solvent) to a glass of drinking water on-site. The resultant Nanocurcumin has average particle size of ~200 nanometer and good colloidal stability as indicated by the negative zeta potential.

“In situ technology is a radical intensified process that enables rapid formation of nanoparticles at the point of use by simple mixing, overcoming the drawbacks of conventional nanoparticle manufacturing methods”, says Prof. Padma Devarajan, the principal investigator of this study. The method is extremely easy to scale up, thus making it cost-effective and advantageous over conventionally used methods.

The team employed Design of Experiment approach (DOE) to arrive at a stable and robust Nanocurcumin formulation. This approach enabled fixing the concentrations of curcumin, polymer, stabiliser and the solvent in which these were dissolved. The software predicted a final stable composition which was utilised for further studies.

Extensive characterisation of Nanocurcumin was carried out using sophisticated techniques. Dynamic light scattering, scanning electron microscopy and transmission electron microscopy were utilised for assessing size and morphology. The amorphous nature of curcumin indicating its conversion to nano form was confirmed by differential scanning calorimetry and X-Ray diffraction techniques. Stability data revealed shelf life of preconcentrate to be >2 years.

The investigators revealed another interesting fact that the in situ nanosystem is independent of the volume of water in the glass. They propose that the preconcentrate can be added to any amount of water ranging from 2 teaspoonful (10ml) to half a glassful (100 ml) without any alterations in size and other parameters. “We observed that Nanocurcumin is rugged to dilution. This is highly desirable since the system is meant for dilution at user end”, they write.

The research team collaborated with scientists at Radiation Medicine Centre, Bhabha Atomic Research Centre, Mumbai, to evaluate targeting efficiency of Nanocurcumin to the macrophages, the location of intracellular organisms. Macrophages are a type of white blood cells that are
capable of tracking and eating foreign invasions such as microbes, cellular debris and all other particles lacking the typical protein composition. Particles of >200 nanometer size can be readily engulfed by the macrophages. Flow cytometry, high performance liquid chromatography and confocal microscopy techniques confirmed efficient uptake of Nanocurcumin in the macrophages. Additionally, Nanocurcumin revealed negligible cytotoxicity in the macrophages. This indicated suitability of the nanosystem for treatment of intracellular infections.

Tuberculosis is a global health challenge with millions of deaths reported every year. Presently, the only weapon for curing tuberculosis is antibiotics. Side effects of current tuberculosis chemotherapy can be distressing leading to patient non-compliance with long treatment durations. The excellent macrophage targeting ability of Nanocurcumin urged the researchers to study its effect in clearance of tuberculosis infection wherein the causative organism, *Mycobacterium tuberculosis* resided within macrophages. Their findings depicted that the bacterial burden was dramatically reduced following treatment of experimentally infected macrophages with Nanocurcumin.

The investigators went further to understand the mechanism involved in clearance of infection. Interestingly, they observed that Nanocurcumin manipulated body’s immune system rather than targeting the bacteria. Western blot and flow cytometry techniques were employed to understand the exact host stimulation mechanism. They observed that Nanocurcumin induced the cellular responses like apoptosis (programmed cell death) and autophagy (orderly degradation and recycling of cellular components). Autophagy induction was evident by conversion of LC3 I to its lipidated LC3 II form and degradation of p62 protein, a prognostic marker for autophagy. Apoptosis was confirmed by evaluating cleaved poly [adenosine di phosphate ribose] (PARP) expression by Western blot and performing propidium iodide staining for flow cytometric analysis.

“Autophagy and apoptosis are inherent responses of the cells to maintain homeostasis. Induction of these responses by Nanocurcumin boosts the immune cells and leads to faster clearance of the bacteria present inside the cells”, said Dr Pramod Kumar Gupta, collaborator from Radiation Medicine Centre.

“Being a formulation of natural product, side effects of Nanocurcumin are close to nil. As Nanocurcumin doesn’t target the bacteria directly, chances of developing drug resistance are low, thus proving to be a major advantage over existing tuberculosis therapy. Additionally, being a host directed therapy, Nanocurcumin boosts the immunity of the infected individual, indicating less chances of relapse after treatment”, he added.

The study provides basic evidence that Nanocurcumin, prepared by simple and innovative *in situ* technology, can improve clearance of *Mycobacterium tuberculosis* from experimentally infected cellular models. The researchers look forward to perform experiments in animal models to provide conclusive evidence. If proven, Nanocurcumin can be used as a curative therapy for treatment of tuberculosis.

The research team from Institute of Chemical Technology comprises of doctoral research fellow Priyanka Jahagirdar and Prof. Padma Devarajan. Dr Pramod Kumar Gupta and Dr Savita Kulkarni are collaborators from Radiation Medicine Centre. The study has been funded by University Grants Commission Basic Scientific Research scheme (UGC BSR).
Manipulation of Genes: A Promising Avenue for Improved Rice Productivity

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Why rice has been in focus for the crop improvement plans?

Rice is the world’s second most important cereal crop which is eaten by almost 40% of the world’s total population. Elevated temperature and scarcity of water for irrigation both have a negative impact on rice productivity. As per FAO (Food and Agriculture Organization) estimates, rice yield needs to be increased by 60% to keep pace with the exponentially increasing population. Like most other crops in India, rice cultivation is also facing a similar loss of productivity due to unfavourable environmental conditions, i.e., abiotic stress (for example, drought stress caused by lack of sufficient rainfall and irrigation) and devastating diseases caused by bacterial and fungal pathogens. It is of utmost importance for the crops to be able to withstand these adverse conditions and survive without compromising with the yield.

Role of molecular biology in attaining the target of crop improvement

In the present scenario, plant molecular biology plays a pivotal role in looking out for alternative solutions to ensure sustainable rice production and food security by manipulating the suitable genes that can mitigate the unfavourable conditions. The complete set of genes or genetic material present in an organism is called ‘genome’. The number of functional genes in rice varies from

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* Ms. Anusree Saha, Ph.D. Scholar from University of Hyderabad, Hyderabad, is pursuing her research on “Genome Wide Identification of Rice Ribosomal Protein Small Subunit Genes (RPS) Genes for Extraribosomal Functions and Characterization of the Significant RPS Genes.” Her popular science story entitled “Manipulation of Genes - A Promising Avenue for Improved Rice Productivity” has been selected for AWSAR Award.
between 30,000 to 50,000. Genes are the basic physical and functional units of heredity and are made up of DNA (deoxyribonucleic acid) which contains the information as to how an organism should function and develop. The expression of a gene is the process by which the information from a specific gene is used in synthesizing a specific functional gene product such as a protein. A single protein is encoded by a single gene. These gene products (proteins) are the building blocks of life and have specific roles in maintaining the normal functionality of the organism. A huge proportion of these genes also play significant roles in withstanding the harsh environmental changes and thus maintaining the health and yield of the plant.

By using various tools of plant molecular biology, we can manipulate the level of expression of these genes. This means that if we want a desirable gene to express more than their normal state in order to produce more copies of that gene product, we can achieve it. If we can make a suitable gene to express more than its basal expression level, we can get amplified benefits from that particular gene which is advantageous for the plant. But, not all genes are directly related in conferring resistance to environmental adversities. Hence, it is of great importance to find genes in plants that might have a role in combating stress conditions so that they can be utilized wisely to enhance the genetic make-up of the plants.

How mining novel genes is important

To address this issue, a collaborative research project was sanctioned by the Department of Biotechnology, Government of India (DBT) entitled as ‘Identification of candidate genes for enhanced water use efficiency in rice through activation tagging’. The author’s team under the guidance of Prof PB Kirti at University of Hyderabad was directly involved in this project. This project was aimed at mining the uncharacterized or novel genes in rice that can be utilized to tackle the negative impact of water scarcity on rice productivity using molecular biology techniques.

Activation tagging is an advanced strategy and its success in identifying novel genes in rice has proven it to be a goldmine for agronomic applications. The strategy involves a complicated procedure in which a DNA segment from a source other than rice is randomly introduced into the rice genome. This DNA segment is known as ‘enhancer element’ which, when introduced into the plant genome, has the ability to locate itself beside any particular genes and subsequently increases the level of expression to a certain extent. The information regarding this DNA segment is known by the researchers so that its presence can be easily tracked in the plant system.

As we have mentioned earlier, an increase in the expression is directly correlated with production of more copies of that specific gene product or protein. Now, if this protein is beneficial for the plant to combat adverse climatic conditions, elevated production of the same should give the plants the desired benefits under such climatic conditions. We can presume that after introducing these DNA elements (enhancers) in rice plants, a considerable number of genes have been over-expressed. Consequently, when water-limited environment was mimicked under greenhouse condition, we noticed that these plants (with the introduction of DNA elements) were more resistant to wilting and exhibited better vigour than the normal plants (with no DNA elements being introduced).
As these DNA elements can be tracked in the plant genome by molecular biology techniques, we could get complete information regarding the particular genes that have been over-expressing. Hence, we can conclude that these particular genes engage, at least to some extent, in providing resistance to abiotic stress. Thus, activation tagging helps in identifying novel genes and their significance in a single step. Finally, this project led our research team to identify numerous such genes which might have immense agronomic importance in terms of abiotic stress tolerance and some of them were not reported earlier.

**Ribosomal protein genes emerging as potential players to safeguard plants from harsh climatic conditions**

Among other genes that were identified by this approach, two were members of a gene family that codes for ribosomal proteins large subunits. Ribosomes are small organelles present in a cell which are involved in the process of synthesizing proteins. They have mainly two subunits (small and large subunits) which come together along with other genetic elements to form a functional protein synthesizing machinery. Each of the ribosomal subunits is made up of proteins (ribosomal proteins) and Ribonucleic Acids (RNA). There are numerous ribosomal proteins associated with the two subunits of ribosomes, and the number of ribosomal proteins varies greatly in different organisms. Since each protein in a cell is encoded by a specific functional gene, it is important to understand that since there are numerous ribosomal proteins in rice, a large family encompassing a huge number of genes is responsible for the synthesis of these ribosomal proteins. Ribosomal proteins have long been considered to be essential in ribosomal synthesis and in maintaining the structural integrity of both the subunits of ribosomes. But with our previous study involving activation tagging, we could identify two genes of this family with a novel role in abiotic stress amelioration. This inspired us to find out if there are some other genes belonging to this family which could be utilized for manipulating rice genome for obtaining better traits. After going through extensive experimental analysis, we could shortlist few such genes coding for ribosomal proteins that have the potential to induce stress resistance to rice plants.

We then attempted to elevate the expression of these ribosomal protein genes in a very widely cultivated Indian rice variety, BPT-5204 (also called Samba Mahsuri) to validate their functions because the ability to over-express a particular gene allows researchers to explore the functional characteristics of the same. Consequently, engineering the plant genome by over-expressing one of these shortlisted genes, our research group has experimentally demonstrated improved yield and less susceptibility of the modified plants to drought conditions. Further, we are interested in confirming and characterizing the functions of the rest of the shortlisted ribosomal protein genes by increasing the level of expression of these genes.

**Significance of the research**

Rice is an essential crop having national economic importance because food security is essentially a reflection of rice security in Asia. In India, rice is more than just a food crop; it is rather an integral part of the history, culture, and lifestyle in various ways. Although rice yield has exhibited
comparative improvement over the years, recently rice yield in India has dropped down compared to other countries in South Asia. Additionally, the efficiency of rice production has dwindled by extreme climatic changes. Rain-fed rice growing areas are predicted to be wrecked by frequent droughts. Under these circumstances, scientists should necessarily be equipped with approaches to feed the growing world population. Identifying genes that could be possible targets to manipulate the genetic make-up of the plants, in order to enhance the beneficial agronomic traits or decrease susceptibility to diseases, is of great significance. The research discussed in this article is important as it identifies few ribosomal protein genes to have fair prospects to be exploited for crop improvement and sustainability. As rice has a close evolutionary relationship with other cereal crops, genes identified and characterized for improvement of rice cultivation can extensively be used for other important crops as well.
Slippery Coatings for Highly Viscous Complex Fluids on Solid Surfaces

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Surface science has grown as an interdisciplinary area of research where physics meets chemistry meets biology to understand the fundamentals behind it as well as to develop advanced materials and devices for the betterment of humankind. In recent years, interfacial science for various liquid-solid and liquid-liquid interfaces has especially gained attention due to a variety of phenomenon governed by them, for example, wetting, lubrication, printing, adhesion, friction, and erosion. Controlling the equilibrium behaviour of liquid drops on a solid or liquid surface is probably the most important question in interfacial science. Physical properties of involved liquid and solid and the interaction between the two determine the equilibrium behaviour of the liquid.

Wetting physics, that encompasses various exciting physical phenomena, is a rapidly growing field of modern physics. French physicist Prof. PG de Gennes, who received the Nobel Prize in Physics, to demonstrate ordering in liquids (liquid crystals), worked extensively on surface science including wetting of solid and liquid surfaces. He was fascinated on seeing tremendous applications of wetting physics, for example, water drops on windshields of cars and window panes, non-wetting behaviour of leaves of various plants, and breaking of a liquid jet into drops. He observed that small sized water drops move effortlessly on non-wetting surfaces forming complete spherical shape. Later, physicists investigated that hierarchical surface roughness and low surface energy coating are responsible for non-wetting characteristics of these surfaces. Even though these surfaces show excellent non-wetting and repelling behaviour for water drops, they do not depict similar

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characteristics for highly viscous and complex fluids, for example, food items, bio-materials, paints, which is also required in many applications. Hence, it is equally important and demanding to develop surfaces where highly viscous and complex fluids can also move like water drops.

In nature, we have *Nepenthes* pitcher plants, which act as slippery surface for a variety of materials. In a pitcher plant, inner walls consist of microstructures and water/nectar from environment gets locked forming a lubricating layer. If an insect gets trapped inside a pitcher plant, it cannot escape as it slips due to the lubricating layer. Mimicking the *Nepenthes* pitcher plant structure, research group of Prof. Joanna Aizenberg from Harvard University fabricated Slippery Lubricant Infused Porous Surfaces (SLIPS) in 2011. She used functionalized porous structures of a hydrophobic polymer, polytetrafluoroethylene (Teflon), and infused them with silicone oil, which acts as a lubricating layer. Upon tilting such surfaces by only few degrees, various liquid drops slipped effortlessly as if the surface was frictionless. Following this development, many research groups started working in this area to understand various fundamental aspects along with potential commercial applications.

Our research group at the Department of Physics, Indian Institute of Technology Kanpur, has also been actively working on this topic since last 5 years. We have successfully fabricated such slippery surfaces on a variety of smooth and rough solid surfaces including metals, polymers, and ceramics. Based on thermodynamics, there are few conditions that need to be fulfilled for successful fabrication and stable behaviour of slippery surfaces. An ideal slippery surface should offer zero friction to every possible slipping fluid and the surfaces we prepared in our laboratory are very close to ideal in terms of the friction offered to a variety of slipping fluids. We used smooth or rough solid surfaces of metals, glass and ceramics, modified their surface chemistry appropriately.
and subsequently coated them with a thin lubricating film of silicone oil. We used variety of liquids (immiscible with the lubricating oil) to study their slipping behaviour, for example, water, alcohols, alkenes, complex fluids like tomato ketchup, honey, nail paint, and wall paint. All these simple and complex liquids show excellent slipping behaviour on the fabricated slippery surfaces. Hence, they can be very useful in many applications where almost frictionless motion of a liquid is required.

We all know how difficult it is to take out tomato ketchup from a ketchup bottle. We have to apply a lot of thrust and force to bring the ketchup out of the bottle. Also, quite a lot of ketchup is wasted as it cannot be taken out of the bottle completely. The main reason behind this is the stickiness and highly viscous nature of the ketchup. We thought that lubricant based slippery surfaces can also be used for complex fluids like tomato ketchup and many more. Hence, we prepared a slippery coating on the inner wall of a glass bottle. We filled the glass bottle with slippery coating with tomato ketchup and compared its behavior to a normal bottle. The adjacent figure shows slipping behaviour of tomato ketchup on uncoated (left one) and slippery coated (right one) glass bottles. It is clear that the ketchup gets stuck on the sidewalls of uncoated bottle whereas it slips completely on the bottle coated with the slippery coating. The schematics in the bottom of the figure show zoom-in image of uncoated and coated surface of the bottles. Large surface roughness on inner wall of a glass bottle prevents smooth motion of ketchup. Whereas glass bottles coated with a lubricating fluid presents almost no friction to ketchup and the ketchup moves very easily and comes out of the bottle effortlessly.

There are numerous other applications of such slippery surfaces e.g. enhanced condensation, anti-icing, anti-fouling, anti-fogging, self-cleaning, self-healing etc. Lubricating fluid coated slippery surfaces show enhanced condensation which is very useful in heat transfer applications. Self-healing is another excellent property of slippery surfaces. Due to fluidic nature of lubricating oil, the surface heals automatically upon some physical damage like scratching or rubbing. Such surfaces also demonstrate excellent anti-icing behavior as ice condensation is reduced on them. Even if small amount of ice gets deposited on a slippery surface, the adhesion of ice will not be very strong and it can be easily removed by blowing them. Self-cleaning is another very important application where slippery surfaces can be used extensively. Due to the low surface friction, dust particles or impurity won’t stay longer and can be removed when a liquid slips through the surface.

So it is clear that lubricating fluid coated slippery surfaces, inspired by *Nepenthes* pitcher plants, are excellent candidate to demonstrate almost frictionless motion for variety of slipping liquids. I have been working in this research area from fundamental as well as application point of view since last 4 years. Our group has published about 10 research articles in this area along with one patent.
In this world of highly distressing and tiresome activities, one must have some sort of mental capability and self-regulation for better living. Due to rapid healing response, the medication is often preferred and recommended by most people. But, it may lead to the development of drug-resistant strains and other health problems. In contrast, meditation is a natural remedy, which strengthens the physiological and psychological capacities of the body. Moreover, it is mental health training that helps to overwhelm the negative mental states, such as anxiety, tension, stress, and depression. From the spiritual point of view, while involved in the meditation, repeating mantras with closed eyes help get into the deep state of subconscious mind. Some of the ancient records indicate that the historical root of meditation are the ancient Indian texts the ‘Vedas’. In today’s modern era, several meditation techniques were developed based on the secular contemplates unlike the religious perspectives of antiquity era. The secular meditation not only focuses on the spiritual growth but also emphasizes on the healthcare perspectives such as stress reduction, relaxation, and regulation of blood pressure.

So far, many studies have reported the clinical benefits of meditation such as preserving the brain from aging, reduction in anxiety, increased pain tolerance, and improved concentration. The Electro Encephalo Graphy (EEG) and neuroimagingtechniques like Magnetic Resonance Imaging (MRI) and positron emission tomography have successfully been used to monitor the effect of several types of meditation techniques on the brain. Some studies have reported that

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the meditation practice remarkably increases the body temperature, where the contact-type thermal sensors have been used for measurement. But, to some extent, the recording procedures of these techniques might be uncomfortable to the meditators. Primarily, the artefact-free physical connections are required for an effective recording of EEG and body temperature, where it becomes hard to sustain such connections for a long session of meditation. During MRI, the lie-down procedure in a narrow tunnel must be followed, which not only confined the physical movement but also causes fear in a person’s psyche. Moreover, it is a computationally expensive technique and it requires clinical experts or radiologists for analysis. However, these techniques could sufficiently cover the research context but are not feasible to use in self-training and biofeedback systems. Besides, it is not always possible to have experts for the successful conduction of meditation. To address this problem, an infrared (IR) thermography-based automatic approach has been developed which evaluates the effect of mindfulness meditation on the thermal profile (or temperature fluctuations) of forehead region. The IR thermography is a radiometric approach, which measures the surface temperature of objects based on the emitted IR radiations. Primarily, it is a non-contact and human-friendly technique which requires minimal settings for data acquisition without violating the meditation procedure.

The 18 human subjects were involved in the IR thermography-based imaging trial, where 9 meditators and 9 non-meditators were monitored during the mindfulness meditation and non-exercise activities (like typing, reading and listening to music), respectively. In meditator group, there was one meditation expert with the experience of more than 15 years (by whom the start-up call was made) and the rest of them had experience of more than one and half year. The thermal imaging was performed with the aid of FLIR® E60 thermal camera, where the front view of the face was captured. The thermal images were acquired at Meditation Center and Biomedical Research lab, Department of EIE, Sant Longowal Institute of Engineering and Technology (SLIET), where the thermometer and hygrometer were used to consider the ambient conditions for controlling the room temperature and humidity (see Figure 1). Both the meditators and non-meditators were monitored for approximately minutes and thermal images were captured at a fixed time interval, known as dynamic IR thermography. Dr Manoj Sachan, Head of meditation club, SLIET, helped
to effectively acquire the thermal data for this study.

To analyse the temperature fluctuations of forehead region during meditation, the automatic algorithm has been developed and applied on the created dataset. As a result, the algorithm has sufficiently extracted the data from the forehead regions from the sequential thermal images which further automated the process of thermal profile extraction. After successful extraction of thermal profiles, the data has been analysed subjectively and objectively to quantify the correlation between the thermal profiles of meditators and non-meditators. For this purpose, the thermal profiles have been processed to extract the features prior to the statistical analysis. Firstly, the thermal profiles have been examined objectively based on the variance in extracted features. Consequently, it is found that the thermal profiles of meditators are statistically different from those of non-meditators.

Secondly, the thermal profiles have been analysed subjectively (visually) based on the dominance of positive and negative temperature peaks during the session, as shown in Figure 2. In meditator group, the dominance of positive peaks has indicated that the temperature of forehead region increases during the meditation practice as a resultant of increased blood flow in the cerebral cortex of the brain and cutaneous vessels of the face. Meanwhile, in the case of non-meditators, the thermal profiles have indicated that the forehead temperature either decreases (dominance of negative peaks) or fluctuates around the baseline temperature. In brief, the forehead temperature increases during the meditation practice and either decreases or fluctuates around the baseline during the non-exercise activities. In addition, it is observed that the key findings of subjective analysis correlate highly with the objective analysis.

This investigation shows the encouraging signs towards the application of IR thermography in monitoring the autonomic response of the brain during the mindfulness meditation. However, the presented investigation is a preliminary as the meditation technique and number of subjects involved in the study is limited. Also, the proposed approach can potentially be used to monitor the temperature fluctuations during other types of meditations. In future, other facial landmarks such as cheek area, eye region and nasal region may also be considered for better temperature analysis during the meditation practice. Besides, the facial IR thermography can be used as a bio-trainer and bio-feedback system which assists both the meditators and novices to sustain and monitor the meditation performance quantitatively.

Figure 2: Shows the thermal profiles of forehead regions of meditators (red) and non-meditators (blue).
When was the last time you didn’t use a polymer? Chances are, you are reading this on a screen, which is made out of Light Emitting Diodes (LEDs) or is a Liquid Crystal Display (LCD) both full of millions of tiny bits of special is ed polymers. In case you have a printout that paper have multitudes of microscopic cellulose fibres running through it. All around us, humans are dependent on things made from polymers from the bristles of our toothbrushes, to the insulation on space rockets synthetic polymeric materials can be considered as the literal building blocks of our civilization for over the last one hundred years. Indeed, in 1980 when the Nobel Prize winning biochemist Alexander Todd was asked the question, ‘What is chemistry’s biggest contribution to science and society?’ he replied, ‘The development of polymerization.’ Polymers come in all shapes and sizes both at the molecular level and on the macroscopic scale. But here I will be talking about the work that we have done using the simplest polymers of all polyethylene.

Picture two carbon atoms bonded, with two hydrogen atoms connected to each of them. Now imagine this simple system repeat itself hundreds and thousands of times in a chain. That is the nature of the simplicity of this material, first synthesized in 1898 by accident, which today is the polymer with the largest consumption by volume worldwide. We all have heard of polyethylene; also known as polythene, and often colloquially what we mean when we say ‘plastic’. If we look carefully at the various bags, sheets, boxes, wrappers, and pipes that are made of polyethylene, we might see indexes and codes like HDPE, LDPE, LLDPE, MDPE, UHMWPE, and so on. But what

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do these abbreviations mean? These are just the different grades of polyethylene, differing only in their arrangement of carbon and hydrogen bunches on the long chain that I wrote about earlier. For example, LDPE is Low Density Polyethylene, where the main chain of carbon and hydrogen, sometimes has branches as well of the same elements. Our work, in particular, focuses on two other grades from the list above High Density Polyethylene (HDPE) and Ultra High Molecular Weight Polyethylene (UHMWPE). These two species have little or no branching, which makes their molecules essentially long, linear chains. However, UHMWPE chains are much longer than HDPE ones almost 100 times longer which makes their properties and applications immensely different from each other. For example, HDPE is lightweight and can be used to make pipes to carry fluids like water, oil or gas. On the other hand, UHMWPE is extremely strong and is used to make artificial joints that are inserted into the skeletal system of human bodies.

For the last thirty years or so, industries and researchers have tried to blend these two polyethylene grades in varying ratios. The reason behind this is to get the strength and durability of UHMWPE combined with the versatility and process ability of HDPE in the same material. Now the problem that we had taken up was “Can these two polyethylene grades be blended easily and effectively?” The scenario appears to be very simple in a mixer at high temperatures, you take a lot of HDPE and a little amount of UHMWPE powders, and throw them in. Chemically, there is no difference between them as they are both polyethylene species. So, after a short amount of time, the UHMWPE should be well-mixed with the HDPE, the former’s strength and durability getting imparted to the versatility of the latter, thus giving us the best of both worlds. But does this happen so easily? Unfortunately no, there are a few pitfalls along the way.

Long, linear polymers like these, in the hot melted state, are essentially like a cluster of worms in the soil piled up, constantly moving, and crucially, entangled with each other trying to slide away. How easily they can slide away depends on how long each worm is. Let us move away from garden animals to the more appetising analogy of food. Molten commercial UHMWPE is like a bowl of cooked noodles if you try to pull out one noodle, it is quite difficult to because the other strands won’t let you. This is because the long noodle twists and turns through all the others and everywhere it touches, the net friction on it adds up, making it more difficult to untangle from this “network” of noodles. Similarly, each UHMWPE chain forms innumerable “entanglements” with all the others due to their long length. This problem doesn’t appear as much in molten HDPE because its chains are much shorter. So, when a grain of UHMWPE starts melting in an ocean of molten HDPE, these entanglements hinder these chains from diffusing out into the surroundings, thus delaying the blending process. In the polymer processing industry, economic feasibility dictates that these blending processes should occur in a matter of few minutes. But the aforementioned delay in blending takes the process up to several hours to complete which is unacceptable.

In order to tackle this issue, we have experimented with using a different type of UHMWPE than the commercially available one. This type, known as “disentangled” UHMWPE (dPE), is made using special polymerization techniques which prevent the chains from getting quickly entangled in the molten state. Nevertheless, they will eventually entangle like the commercial UHMWPE chains but this will happen after a certain period of time, within which, the requisite dissolution
in HDPE will have occurred. Thus, by delaying the dPE chains to entangle with themselves, we have given them an opportunity to simultaneously escape their own network and blend with the surrounding HDPE environment. The remarkable aspect of using the “disentangled” dPE is that the entire blending process now occurs in a matter of a few minutes, instead of the several hours using commercial UHMWPE.

But how did we verify, or even estimate the extent of this dissolution? The answer lies in the field of rheology. Rheology literally means “the study of flow”, and it is used to measure the response of a material to a physical stimulus. All matter flows under some natural force, for example, consider a rubber ball getting squeezed between your fingers. Your fingers exert a force, which changes the shape of the ball, and the ball experiences some forces on it. Once you release the ball, the forces get dissipated, and the ball relaxes. Using highly sophisticated instruments, we can apply an exact amount of deformation to a material, and then accurately measure the response of the material towards it. Quick, rapid, deformations allow us to probe the effect of the shorter chains in the mixture, i.e., the HDPE, while slower deformations let us study the same due to the dPE in the blend. This is known as oscillatory rheology. From these experiments we can distinctly understand the structure and properties of the material. In the context of our work, rheology on our dPE-HDPE blends sheds light on the nature of how well these two polyethylenes have mixed. By comparing with commercial blends, rheological studies have demonstrated the need to make the UHMWPE “disentangled”, in order to get quick and effective mixing. The next step would be to use theories of mathematics and physics to try explain the phenomena observed.

We believe the outcome of our research will be valuable to the polymer processing industry. Not only have we showed that it is possible to quickly blend UHMWPE and HDPE using a simple tweak, but we have also discovered new applications of these blends. These blends could be used for application where previously pure HDPE could not be employed because of its limitations. Now with the added UHMWPE, there are several new possibilities where the cheap and easily processible HDPE can be utilized effectively. This work also emphasizes the efficacy of the field of rheology in order to ascertain the nature of complex materials.
Utilization of Marine Trash Fish Discards for Organic Nitrogen Enriched Fertilizer Production

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Marine fisheries in Indian coasts disposes large quantity of trash fishes of no commercial value, brought ashore by fishing crafts in harbours and landing centers all over the country. These trash fishes and processing wastes of the seafood industry are discarded in natural open water bodies and dumped in landfills as heaps affecting the coastal sanitation. According to the FAO’s report (2017), it was estimated that 20-80% wastes are generated by small scale fisheries. In a country like India where marine fishery is of multispecies composition and the occurrence of by-catch consisting of several species of trash fishes is quite common. It is estimated that the quantity of by-catch which has been discarded by the trawlers operating along East-Coast was high as 100,000-130,000 lakh tones. In urban fish markets, trash fishes and non-edible portions such as head, skin, intestine, gills, bones and blood of the commercial fishes are segregated by the sellers after cleaning and dumped in municipal garbage bins creating environmental issues. Rotting proteinaceous waste affects sanitation in several ways: producing unpleasant odour, emission of noxious gases - hydrogen sulphide, attracting diseasing, spreading vectors such as flies and ants. This leads to the growth of epidemic infectious microbial pathogens and contamination of soil due to the leakage of organic matter from the decaying wastes. I addressed this disposal issue in fish processing sites of east-coast, Chennai and urban fish selling shops under the guidance of my research mentor Dr Radhika Rajasree. S. R., marine scientist working in the Centre for Ocean Research. We initiated this work to study the problem of the disposal sites and developed a biotechnological solution to clean up the site.

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The wastes were collected from local fish market and brought to our Marine Biotechnology lab. Fermentation process was assisted by protease producing bacteria - *Bacillus subtilis* in fermenters to convert the wastes into organic fish emulsion with less fishy odour. The emulsion had good levels of Nitrogen (1%) and organic Carbon (56.31%) along with high concentration of Iron: 50 mg/kg. We approached farmers in suburban Chennai who faced problems related to low productivity due to lack of sufficient organic nutrients in soil. We treated those lands with our fish emulsion at regular intervals and also attempted foliar spraying on leaves of tomato plants. The effect of the emulsion treatment was analyzed by soil testing method “Alternative Analytical Technology” (AAT), an image processing technology developed by Sri AMM Murugappa Chettiar Research Centre and Indian Institute of Technology (IIT-M), Chennai, supported by DST. The analysis report confirmed the increase in organic carbon levels as evident by the development of spike-shaped circular disc in the chromatogram. We also found that foliar application of the emulsion promoted leaf growth with increased foliage count and fruit yield. Besides, regular spraying of the emulsion also prevented the leaves from pesticide attack. Our experimental results showed satisfactory performance under field conditions. It was shortlisted as innovative product in National Bio Entrepreneurship Competition, 2017 under “Soil health theme” by Biotechnology Industry Research Assistance Council.

We also developed “Trash fish compost” through co-composting method using mixed varieties of small fishes and Bagasse-Sugarcane processing leftover as rapid composting substrate. This is a cost effective method for large-scale production of organic soil inputs with balanced major soil nutrients-Nitrogen; Phosphorus and Potassium (N:P:K) required for plant growth stimulation. This process provides complete degradation of the fish body parts including scales with final product having good earthly aroma. We checked the maturity level of the compost as per the protocols of the Fertilizer control order 1985 and found that the compost had good maturation degree as reflected by its C:N ratio. Phytotoxicity assays also confirmed its growth promotion activity in Fenugreek (*Trigonella foenum-graecum*) and Greengram (*Vigna radiata*) seeds confirming its positive influence especially in root and shoot development. Few characteristics of the fish compost had the appearance of brownish texture; fine particle size with good aromatic smell. It has good N:P:K ratio (2:2:1) with good amount of micronutrients: Manganese 30.84 mg/kg, Zinc- 29.44 mg/kg for supporting soil health. Trash fish co-compost was selected in Top 20 innovative products under “Waste management theme” by Biotechnology Entrepreneurship Student Teams by Association of Biotechnology Led Enterprises (ABLE), 2015.

We also produced an organic acid “Humic acids” from Tuna fish waste compost. This colloidal preparation was specifically formulated for soils suffering from high acidity and lacking sufficient biological functions. This organic acid could act as a “soil conditioner” to reduce acidic levels for supporting the development of microbial flora to promote organic vegetable production. It contains good amount of elemental carbon-53% and Nitrogen-6%. This liquid could be a helpful booster to improve acidic soils suffering from low productivity and completely deprived of vital nutrients. We characterized this preparation by spectroscopic instruments and confirmed that the presence of “aromatic carbon” responsible for its biological function. The colloidal solution is
available in potassium humate form to improve soil cation exchange capacity. This liquid product could be also beneficial to for urban terrace gardeners interested in hydroponic culture system to grow organic vegetables. It was selected in “Top 30 innovative idea” under University Challenge in Indian Innovation Growth Programme (IIGP 2.00) by DST Lockheed Martin, 2017.

**Our Fish waste based fertilizers**

Our research was by funded by Department of Science and Technology (DST) under Science for Equity Empowerment and Development (SEED) scheme for the project “Stabilization and utilization of trash fish and fishprocessing waste as a slow release nitrogenous fertilizer for increased production in vegetable farming”. The work motivated us towards identifying biotechnological solutions to develop organic fertilizer products from fish processing wastes for effective utilization in organic agriculture. We express our sincere gratitude to DST for supporting this project to ideate novel biotechnological solutions to reduce the disposal activity related to fisheries industry for improving sanitation. We are also planning to disseminate the technology to educate workers to adopt effective disposal measures towards marine biowaste management.
It’s morning and about time for office, the husband asks the wife, ‘Have you seen my wallet?’, to which the wife replies, ‘it’s in the same place you kept yesterday after you got back from office’. The husband tries to remember where he left it last night and according to his wife, it’s the same place he’s been leaving the wallet every night after coming back from office. But, he can’t seem to remember! He then thinks if he’s had his anti-diabetic medication before he’s had his breakfast. With a bit of embarrassment, he asks his wife if she remembers him taking the medication to which she says ‘Haanji, you had taken your tablets before having the hot dosas I made for you, you forgot so soon? And the wallet is on the table beside you if you didn’t find it already.’

On his way to the office, he tries to recollect the previous day and he could remember most of the things that involved him, but there were some fine details which he kept forgetting time and again. He said to himself, ‘Have I grown too old so soon? I am just 47 years, my father used to be so sharp at remembering things, how come I don’t have that quality?’

As years progress and we age, we tend to forget things, sometimes insignificant but, at times, small details that are important to us personally. This is a natural process, but when you have a lifestyle disease like Type 2 Diabetes, then losing your memory tends to be on a higher rate, especially when there is an improper management of diabetes with the prescribed medication and proper diet.

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A notification from the Government of India, Ministry of Human Resource & Development was put up to all the universities, medical colleges and research institutions to take up studies that will benefit the geriatric population of our country. This was the inspiration to take up the particular research topic as India is a country that’s in the top 5 nations to have a large population of diabetics that too being diagnosed at ages as young as 30 years. Now, there are many comorbidities associated with diabetes like kidney diseases, loss of vision, general weakness, but memory impairment or forgetfulness is one that is less addressed in general which affects the Quality of Life of the patient.

Memory in the animals is measured using Barn’s Maze and Novel Object Recognition Test (NORT). Barn’s Maze is composed of a circular platform and 12 holes towards the edges of the platform. Out of the 12 holes, only one hole has an escape box where the animal can go and sit comfortably. The animals are placed in the centre of the Barn’s Maze and are exposed to a high intensity of light which makes them search for the escape box as rats prefer dark places when compared to areas exposed to light.

We train the animals to find the escape box within a minute with the help of clues placed in strategic positions. The animals are also trained to commit a lesser number of errors, this is when we observe how many times the rats dip their head in the other holes not containing the escape box which is usually only 1 or 2 errors.

In Novel Object Recognition Test, the animals are kept in a small enclosure and are exposed to two similar objects and we observe the time that they spend on each object. After a specific time, one of the objects is removed and a novel/new object, that is not similar to the older one, is introduced. We then observe how much time the animal spends on the new object, the more time it spends is translated as having a better memory.
Once the animals get trained, they are induced with diabetes using chemicals, which causes the destruction of the pancreas the insulin producer of the body insulin being responsible for the reduction of the raised glucose in the body. The prolonged elevated glucose levels in the animals are allowed to continue for few days to produce signs of memory loss when they are judged on the Barn's Maze, where the animals, which previously took only one minute to find the escape box, takes more than 2 or 3 minutes and sometimes doesn’t even find the escape box, they also tend to commit a higher number of errors usually five or more; and in the NORT the diabetic animals prefer the older object as when compared to the newly introduced object in the enclosure as it spent more time with the older object, this all translates to memory loss according to scientific findings.

The animals, when treated with anti-diabetic drugs like Pioglitazone, showed a little improvement in finding the escape box and committed lesser errors in the Barn's Maze while in the NORT, the animals showed a preference to the new object, but when we treated them with marketed anti-diabetic herbal remedy, they showed a good improvement in memory as they were able to find the escape box within 2 minutes or less and reduced the number of errors committed to 3 or 2 errors while the preference for the new object also was higher in the NORT.

Hence, we are of the opinion that the improvement is mainly due to the antioxidant components in the herbal remedy given to the animals. We also observed a better control over the blood-glucose levels in the animals given with the herbal remedy so this, along with the antioxidants, and the micro minerals and nutrients present would be the prime reason for the improvement in the ability of the animals to retain memory better when compared to the non-treated animals.

This result is indicative that there is indeed a memory impairment occurring in mismanaged diabetic condition and it can be rectified with the help of herbal remedies which contain antioxidant components and proper medication and that management of diabetes not only improves the diabetic condition but also the overall Quality of Life of the patients.
Unified Study for Various Types of Fish-Like Locomotion: Hydrodynamic Characteristics and Propulsive Performance under the Effect of Muscles and Flow-Induced Flexibility

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Extremely efficient performance of natural systems inspired scientists and engineers to imitate the natural phenomenon for engineering applications, leading to the evolution of a subject called “biomimetic”. One of them is mimicking the motion of fish which move smoothly in water without spending a lot of energy. The extraordinary propulsive performance of fish as compared to conventional aquatic propulsion systems (such as marine propellers) is an upcoming topic of research for the efficient design of underwater drones or vehicles.

Majority of the fish comes under a category of Body Caudal Fin (BCF), which is further classified as anguilliform, sub-carangiform, carangiform, and thunniform types as shown in the figure. The classification is based on the type of movement adapted by the body and tail of fish. Note from the figure that all the types of fish have a tail (called as caudal fin) except the anguilliform fish. Anguilliform fish (such as eel) are thin, long, and use a wavy undulation over the whole body which pushes the fluid backwards and generates thrust force to move forward. Thunniform fish (such as shark and whale) have an almost stationary front part of the body and a crescent-shaped tail of hydrofoil cross section as seen in the figure, which undergoes a pendulum like oscillation for thrust generation. With a change in the order from anguilliform to thunniform fish (as seen in the figure), the wavy undulation of the body decreases and the oscillation of the tail increases.

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Most of the fish use some kind of flexible motion for their movement in the water. Some fish generate a flexible wavy motion of their body and/or tail using the coordinated muscles movement, called as muscles-induced flexibility. When fish move, the surrounding unsteady and non-uniform water flow-based hydrodynamic forces may lead to deformation of certain parts of the body and/or tail of the fish, called flow-induced flexibility. Both the muscles and flow-induced flexibilities result in the efficient aquatic propulsion of fish, under various swimming conditions. The effect of both the types of flexibility on various types of fish-like locomotion is studied numerically by solving governing equations for motion as well as deformation of the body or tail of fish and motion of the fluid flow. The resulting coupled structural-dynamic and fluid-dynamic equations are solved using a computational method, called as Computational Fluid-Structure Interaction (CFSI).

Recent researchers in this field focused mostly on the separate study of each of the various types of fish-like locomotion. A new two-dimensional computational study, published in journals Physics of Fluids (https://doi.org/10.1063/1.5041358) and Sādhanā (https://link.springer.com/article/10.1007/s12046-017-0619-7), by the author (under the guidance of Prof. Atul Sharma and Prof. Amit Agrawal at Indian Institute of Technology Bombay) proposed a unified kinematic model considering a hydrofoil for all the types of fish-like locomotion. This unified study will help to design efficient aquatic propulsion systems which take the advantages of all the types of fish-like locomotion.

Our unified kinematic equation is modelled in such a way that one extreme case represents the wavy undulation corresponding to the body of anguilliform fishes and the other extreme case represents the oscillation of the tail of the thunni form fishes. A parameter called as wave-number (number of waves present at an instant) controls the type of motion where a larger wave-number leads to the wavy undulation while a smaller wave-number leads to oscillation of the hydrofoil. We can also say that the wavy undulation represents a more flexible (muscles-induced) motion whereas the oscillation represents almost rigid motion. The intermediate wave-number based flexibility results in a hypothetical fish-like locomotion which corresponds to a combination of the wavy undulation and oscillation.
Our unified hydrodynamics study considered hydrodynamic characteristics and propulsive performance of the different types of fish-like locomotion. The term hydrodynamic characteristics corresponds to the characterisation of flow patterns of water around the fish body/tail represented graphically by colour-contours of velocity, pressure, and vorticity (represents the rotation of the fluid) in the nearby flow region. Propulsive performance includes the propulsive thrust force (acting on the body) and efficiency. The undulation or oscillation in the $x$-$y$ plane (as shown in the figure) results in the surrounding flow based hydrodynamic forces in both swimming ($x$) and lateral ($y$) directions. The force in the swimming direction called thrust force together with the swimming velocity results in the output power. Input power is required for the movement of muscles which generate the undulation and oscillation. The ratio of the output power to the input power is defined as the propulsive efficiency.

We found that oscillation of the tail generates larger thrust force as compared to the wavy undulation of the body of fishes. Our results are in agreement with that reported for real fish – the larger thrust force by the tail is needed for the movement of the heavy anterior part (with little lateral movement) of the thunniform fish (such as whale). Whereas, for less bulky and much thinner anguilliform fish (such as eels), the thrust force required is comparatively less. The oscillation of the tail needs a larger power input as compared to the wavy undulation of the body. To provide the larger power, thunniform fishes are heavier and stronger as compared with anguilliform fish. Furthermore, similar to the results for real fish, we found smaller efficiency for the oscillating tail as compared with the undulating body. Thus, oscillation can be recommended for an aquatic propulsion system with heavy load requirement at the expense of efficiency whereas a proper combination of oscillation and undulation can be used for light and intermediate loads to get the optimum thrust force and efficiency. Further, the wavy undulation is more efficient in the smaller velocity range; vice-versa for the oscillation-based swimming. This can be the reason why anguilliform fish swim at smaller velocity range as compared to thunniform fish.

Our results are correlated with the stabilizing mechanism which is used by the thunniform but not by the anguilliform fish. We reported that the wavy undulation of the hydrofoil pushes the fluid continuously throughout the entire body resulting in an almost constant thrust force, and hence an almost constant swimming velocity at all the time. The oscillation of the hydrofoil results in a reasonable time wise varying thrust force and swimming velocity. These variations can be tolerated by thunniform fish since they have a bulky anterior body along with different types of fins to stabilise the body. Whereas, since anguilliform fish do not have such fins and the resulting stabilising mechanism, it is understandable that they experience time-wise invariant forces and velocity which does not have much effect on the stability of the body. Thus, for an almost constant swimming velocity, anguilliform type of motion is prescribed over the thunniform motion.

Our results are also correlated with the sensing mechanism of the real fish by the disturbance in the flow behind the foil. The disturbance generated by the wavy undulation of anguilliform fish is used by predator fish mostly big fish coming under the category of thunniform fish. They sense the disturbance in the flow generated by the prey fish (mostly small anguilliform fish) using their sensitive organs. Since the evolution is an arms race between predator and prey, the prey fish
try to win over the predators by making the signals as weak as possible. Our results reported a weak disturbance produced by undulating hydrofoil which reduces the chance of detection of anguilliform fish by the predators.

Majority of the studies on fish-like locomotion including our work discussed above did not consider the flow-induced flexibility of the tail fin of thunniform fishes which helps to improve the propulsive thrust force and efficiency. We proposed a new study at the 71st Annual Meeting of American Physical Society, Division of Fluid Dynamics (http://meetings.aps.org/Meeting/DFD18/Session/F23.7), considering the effect of flow-induced flexibility on the oscillation of the tail for a wide range of structural flexibility. We found that the deformation (in addition to oscillation) results in the enhancement of thrust force and efficiency. The intermediate value of structural flexibility results in maximum bending of the hydrofoil (force induced deformation) which leads to the maximum thrust force and efficiency as observed in real fish.

Finally, the above muscle-induced flexibility study concluded that a proper combination of wavy undulation corresponding to anguilliform fish and oscillation corresponding thunniform fish can be chosen (by our generic parameter wave-number) to achieve a desired thrust force, propulsive efficiency, and swimming velocity. Furthermore, the above muscles as well as flow-induced flexibility study concluded that moderate flexible materials can be used for an enhancement of the thrust force and propulsive efficiency. From our research group at Computational Fluid Dynamics Lab IIT Bombay, similar unified studies will be presented for various energy efficient swimming modes and optimum shapes of the hydrofoil in future. The present study can be used for the design of fish-like biomimetic underwater drones or vehicles.
Development of a Broad-spectrum Sunprotective Formulation for Indian Skin using Natural Ingredients

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During a search for my research area, sunscreen formulations caught my fancy, both as a user and as a pharmaceutical scientist. I noticed that many of the Indian cosmetic brands are selling sunscreens with a variety of label claims which were technical and new to the Indian consumer, for e.g. SPF, UVA+, waterproof, broad spectrum, etc. I studied and realized the significance of these terms and the importance of sun protection. When the ultraviolet rays of the sun fall on skin, they cause skin drying, tanning, and photoaging and on over-exposure even photocarcinogenesis (skin cancer). This compels one to use sunscreen products. The efficacy of sunscreen is gauged by Sun Protection Factor (SPF). SPF is calculated as the dose of UV radiation required to produce 1 minimal erythema dose (MED) on sunscreen-protected skin divided by the dose of UV radiation required to produce 1 MED on unprotected skin. Another criterion which is well adopted on the labels of sunscreens is PA system which is based on the persistent pigment darkening (PPD) reaction with UV-A rays of the sun. Accordingly, the sunscreen product is labelled as PA+, PA++, PA+++ or PA++++.

Then, I came across a very interesting research paper published in the Archives of Dermatology (1988) authored by T. Fitzpatrick titled, “The validity and practicality of sun-reactive skin types I through VI”. This paper classifies skin into six categories depending upon their reaction on exposure to ultraviolet rays. Indians have either skin type IV (burns minimally and tans moderately) or V

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(burns rarely but tans profusely). Besides, the Indian skin is blessed with melanin which itself has an SPF 4. It does not need sunscreens with very high SPF while the market is flooded with high SPF sunscreen products.

The more I was reading about sun protection, the more I got interested in this field. Observing my quest, Prof. Sanju Nanda, my research supervisor gave me a stimulus to define my aim and objective of research study. We decided to make a broad spectrum sunscreen formula which meets the need of the Indian skin which is devoid of any adverse effects of chemical sun screen agents.

We chose indigenous drug “Safranal” for development of broad spectrum sun protective formulation. Though the drug was a bit expensive but obviously less costly than the healthy skin. Safranal is a volatile compound present in Saffron “Kesar” which is responsible for its beautiful aroma and this treasure is grown in the state of Kashmir.

In the same year, we presented a poster in 65th IPC in December 2013 on topic, “Growing Use of Sunscreen in India: Dearth of Quality and Regulatory Controls.” Our poster won recognition from many intellectuals.

Further, I carried out a survey to make people aware of sunscreen using a questionnaire in the Delhi metro train. I was surprised to see the lack of consumer awareness regarding the use and knowledge about sunscreens.

In the initial phase of laboratory work, I started with an established porous delivery system, Microsponges. These are porous delivery systems that can imibe or entrap a wide variety of substances. Working with a liquid drug, safranal and designing its novel delivery system was a challenging task. I made many trial batches by changing polymers and process parameters but could not obtain the desired results. The delivery system which boasted of encapsulating liquid drug actually did not work well in this case. I had to start afresh by going back to more literature survey. We decided to take up a lipidic based drug delivery approach this time.

Meanwhile, I presented a poster in the National Seminar organized by P.D. M. College of Pharmacy, Bahadurgarh, and Haryana on 7 April, 2015. The topic of my poster was, “Innovative technologies available in sunscreen: Decide one for yourself,” and I got the Best Poster award. Such an event boosts the morale of a researcher and motivates further research.

Among the lipidic delivery system, I found Solid Lipid Nanoparticles (SLNs) as the most suitable one because of their light scattering properties. Using design expert software, I applied central composite design and made formulations to select the best. The experimental results came out to be positive this time. Taking the best as lead, other characterization techniques such as particle size analysis, electron microscopy, etc., were performed.

Then I tried natural colourant to make my final sunscreen without ill-effect of skin whitening. I used a herbal drug as colourant which also had additional properties of anti-aging and which is indigenous to my country. I coloured zinc oxide; a physical sunscreen agent with an extract of same and got a perfect shade of skin. The Indian land is full of vegetable resources which have been used since ages due to their established ethno pharmacological applications, but they are not patented, they are not a part of compositions or products used in modern society. So, the very idea of exploring our own natural resources was exhilarating.
Going through the literature of antioxidants, I came across a marine product with anti-aging properties. It is really a God gift that even shells of marine animals serve as useful products. I explored one such agent and incorporated into my sunscreen.

With an aim to use natural ingredients to boost sun screening activity, I also extracted oil from hen egg. It offered tremendous advantages and I used it in my formulation as well. I got the third prize in a poster presentation on the topic, “Exploring egg oil as a natural sunprotective agent: An initial study,” in the National Conference in M.D. University on March 19, 2015. While conducting my research, time flew by and the start of year 2017 was great. I got a review paper published titled, “Hen egg yolk oil: A potential source of bioavailable lutein and zeaxanthin for skin and sun protection,” published in World Journal of Pharmaceutical Sciences; 5(1), Pg 71-80, 2017.

I also tried anti- enzymatic activities of my drug to prove its antiphotoaging activity. For this, biochemical investigation was done. The establishment of the same with good results led to a research paper titled, “In-vitro evaluation of antioxidant, anti-elastase, anti-collagenase, anti-hyaluronidase activities of safranal and determination of its sun protection factor in skin photoaging,” in Journal Bioorganic Chemistry volume 77 in 2018.

Citations of my article increased day by day and this brought a smile to my face. I started getting invites for various conferences and also got recognition. This secondary impact of my research brought positivity to my life as well. Meanwhile, I also got a review paper published titled, “Nanotechnology Driven Cosmetic Products: Commercial and Regulatory Milestones,” in Applied Clinical Research, Clinical Trials & Regulatory Affairs, 2018, 5, 112-121.

The positive results motivated me towards my goals. Finally, I came up with a purely natural sunscreen with broad spectrum activity. It was free from any chemical agents and also met the international standards of sunscreen. My product had a result of Boots Star Rating of ***. Boot star rating is a proprietary in vitro method used to describe the ratio of UVA to UVB protection offered by sunscreen with 1 as lowest value and 5 as highest. My product also gave the value of PA++ which means the protection Grade of UVA between four and eight.

The formula of my sunscreen is purely novel and not been used or mentioned in literature. So, a thought of patenting came to our mind. A patent to your name gives you a strong feeling of being an inventor. Currently, I am in the process of getting permission to get my formula patented. I am writing my thesis and shall be submitting it in a couple of months.

Research is the foundation of development of society. But it takes constant effort and faith in one’s work to achieve success. Through this scientific deed, I would like to convey to society that the right quality, right quantity of sunscreen should be part of one’s pouch if one has to remain longer in the sun. I am proud to contribute something novel and natural for the Indian skin which is made up of our own resources. I am grateful to almighty, my guide Prof. Sanju Nanda and my Department of Pharmaceutical Sciences, M.D. University, Rohtak, for providing support. I am also thankful to UGC for offering the BSR fellowship and my family members for their support.
The term “cancer” was not very much familiar few decades back but nowadays it is being known by the general public. The people got scared by listening this word and the patient after knowing that he is suffering from cancer would loses hope for life.

What is cancer??? What is the reason for frequent conversation of this term???

Cancer is the proliferation of abnormal cells in the body which replaces normal healthy cells and disturbs the homeostasis of the biological system.

The first and foremost reason for this awareness about cancer is the day by day increasing incidence of cancer in the world including India where cancer is one of the leading causes of death among adults. Recently, the Indian Council of Medical Research proposed that by 2020, India might register over 17 lakh new cases of cancer and over 8 lakh deaths associated with it. Research is being carried out on cancer from the past many decades but still there are various things yet to explore. The exact phenomenon of its occurrence is not known but it has been observed that the changes in lifestyle, environmental deterioration and mutations in the genome contribute to the increasing cancer incidence. Cancer ranges from solid tumors (includes cancer in an organ like cervical, bladder, renal cancer, etc.) to blood cancers (or hematological malignancies such as leukemia, myeloma, lymphoma, etc.).

The deaths due to cancer are on rise either because of delayed diagnosis or inappropriate treatment. With the advent of science and technology, numerous therapies have been emerged which have undoubtedly increase the lifespan of the cancer patients but at the same time, these are
not effective enough to completely abolish this disease from the biological system. Hence, most of the cancer patients relapse which arises many questions yet to answer. One such deadly blood cancer is Multiple Myeloma (MM) in which abnormal plasma cells proliferate and accumulate in the bone marrow. This is the second most common hematological malignancies after Non-Hodgkin Lymphoma and accounts for 2% of all cancers & 13% of all hematological malignancies. MM with high relapse rate despite the presence of various sophisticated therapeutic approaches demands some highly effective treatment for the better prognosis of the disease.

With this objective in mind, we initiated to identify some targets having involvement in Multiple Myeloma. The way we are surrounded by various people in our day to day life without whom our life is in vain, similarly, every cancer including MM requires the surrounding tumor microenvironment or niche for their growth and development, hence, we aim to target bone marrow microenvironment in MM. This microenvironment comprises of various proteins, proteoglycans, growth factors and cytokines and we focused on proteoglycans. As per the published literature, out of various proteoglycans, chondroitin sulfate proteoglycans are found in the majority in extracellular matrix and one such chondroitin sulfate proteoglycan is “Versican” (VCAN) which have been reported to have crucial role in several solid tumors but no reports were available for VCAN in MM when we started working on this.

As there were no studies available, we firstly studied the expression of VCAN and molecules associated with it in MM patients. The expression of VCAN and its associated molecules were found to be higher in bone marrow and blood of MM patients in comparison to controls in both circulation and at molecular level. To examine whether this upregulation has some role in identification of MM or not, its diagnostic potential has been calculated and we found that VCAN showed 100% sensitivity and specificity in serum for diagnosis of MM and we have published this finding in *Clinica Chimica Acta* journal.

The increase in the levels of anything does not reflect its importance in any disease, hence, we moved a step further to investigate whether increase in levels of VCAN is limited to diagnosis of MM or it has some involvement with development and progression of the disease. To explore this hypothesis, we performed certain experiments with MM patients sample and cell lines which represent the cancerous myeloma cells in laboratory. As known by the reports, VCAN is produced in the surrounding microenvironment by the cells present in the stroma. We therefore isolated bone marrow stromal cells from the bone marrow by primary culture followed by their characterization. The expression of VCAN was determined in these stromal cells and found to be significantly higher in comparison to controls. These stromal cells secrete VCAN in the microenvironment to act on tumor cells, hence, conditioned medium (culture supernatant having VCAN) of these bone marrow stromal cells was collected and complemented in the culture medium of MM cell lines. Keeping the fact in mind that conditioned medium would consists of various components including VCAN, we supplemented VCAN antibody with conditioned medium to inhibit VCAN for comparison with the effects caused by conditioned medium alone.

The conditioned medium of bone marrow stromal cells enhanced cancer properties such as proliferation, angiogenesis and reduced apoptosis in myeloma cells which got neutralized by
supplementing VCAN antibody which shows the potential of VCAN not only as a diagnostic marker but also as a therapeutic target. Further, we identified the signaling pathways adopted by VCAN and we found that FAK and STAT downstream signaling pathways are activated by VCAN.

Subsequently, after identifying the tumorigenic potential of VCAN and discussed it as one of the important targets in MM, the question arises for its regulation to inhibit VCAN. To fulfill this objective, we first scrutinize certain non-coding RNAs, i.e., microRNAs from the target scan and literature search and found some regulating microRNAs for VCAN. We first determined their expression in MM patients and found these microRNAs at lower level in MM. Moreover, microRNAs were negatively correlated with levels of VCAN in MM proposing that upregulation of VCAN might be due to decrease in levels of microRNAs but this needs further validation.

In order to validate this fact, we used microRNA mimics and added into the primary bone marrow stromal cells and observed that levels of VCAN decrease upon transfection. Moreover, the effects caused by conditioned medium in myeloma cells were also neutralized by the action of microRNA mimics. The proliferation and angiogenesis decrease and apoptotic markers increase followed by the decrease in the downstream signaling pathways activated by VCAN.

Taken together, it could be stated that VCAN is an important molecule as far as its diagnostic and therapeutic potential is concerned in MM and it could be regulated by microRNAs. But this should be kept in mind that human body being very complex employs numerous molecules and proteins and effect of this strategy on biological system might be different. Hence, this work needs further validation in myeloma xenograft mice model in vivo which will be carried out in future and if results were optimum, clinical trials could also be performed by employing microRNA therapy. Furthermore, microRNA therapy could also be tried in combination with standard chemotherapeutic drugs which might substantiate the effect of current regimen and would be highly effective for the treatment of MM in clinical settings in future. Every research should be a successful one if it could be translated from bench to bedside. This piece of work is indeed the first key in this direction which opens up a new window for another success to employ an effective therapeutics for the treatment of Multiple Myeloma.

The work discussed in the article is my doctoral work performed under the supervision of Prof. Alpana Sharma at Dept. of Biochemistry, AIIMS, New Delhi. This article is original and has not been published elsewhere.
Tropical forests are a treasure trove of incredible wonders. Orchids are one among them. Did you know that Orchidaceae is the most successful family of flowering plants in establishing itself all over the tropics? These orchids are grouped into epiphytes, terrestrial and saprophytic based on their habit. Interestingly, epiphytic orchids form 70% of all orchids. In evolutionary science, recent concepts suggest that terrestrial orchids climbed trees with time in search of light and nutrients and became epiphytes! It could also mean that orchids are sensitive to climate and other requirements. Although widely distributed, scientists believe that forest types, climate in the regional scale and close vicinity could influence habitat of orchids. This even makes them eligible to become a group that can give warnings (indicator group) as we move towards changes in climate (sometimes micro) or forest structure. Further, the flowers are specialized in architecture, sometimes deceptive to pollinators and above all, have magical roots called velamen to absorb moisture from the air! Here is the importance of research that can perhaps unravel these mysterious mechanisms of the orchids. I was determined to know more when I learnt that, though most charming, they are the least studied in terms of their relationship with environment (ecology)!

Ecologically, epiphytes, in general regulate canopy climate and, thus, local climate. Additionally, they keep up pollinator diversity of a region and keep the system in balance. They are also proved to favour huge diversity of arthropods and thereby birds. Epiphytes store nutrients from rain and storms and release them during unfavourable times. Thus, epiphytes are a 'keystone...
resource’ that plays a significant role in maintaining the forest canopies. Today, these unique features of epiphytes fetch great attention from the few canopy researchers across the world. Being the most successful epiphytes, it is time orchids are studied as a major component of tropical forests. Apart from its ecosystem services, how are orchids beneficial to the common man? Orchids have always played a role in different cultures for thousands of years. Preparation of medicines with the help of orchids in China dates back to 28th century BC! The prospects include cultural, medicinal, food values apart from the recent high demand in ornamental plant sector.

It surprised me when I realized that, of all the research carried out on epiphytes in the world, only one addressed ecology of epiphytic orchids in the Western Ghats! This work suggested that forests that are managed (for other uses by man) are very different from natural forests in epiphytic orchid composition. This raised many questions in my mind. The Western Ghats presently suffers from huge man-made pressures throughout its range. As per global research findings, changes related to human growth and global warming pose serious threats to plant and animal diversity. As a corollary, conservation strategies have to be developed at the earliest. If the ecology of aspecies not even known from the forests, no conservation methods can be developed! It means these species would be history before we even know about them. And probably a group of other taxa that are dependent, along with them. What would be the current status of epiphytic orchids in the canopies of the Western Ghats in the context of current threats? Are they in danger of extinction with changing climates, destruction of forest or natural calamities? There are only taxonomical records available about orchids. According to them, the Western Ghats own diversity as high as 307 species. Of which, the orchids restricted to the region (endemic), the Western Ghats are high (113). The specific habitat or climate or other features that sustain this huge diversity have to be identified. Without which, conservation of orchids becomes unreal. Therefore, it should interest researchers to take up unaddressed aspects of orchid ecology. These concerns pushed me towards my research proposal that asked questions never asked before.

I started my Ph.D. research in 2014, the first doctoral research on epiphytic orchid ecology in the Western Ghats, asking major questions in orchid ecology. My research proposal focused on basic ecological questions about epiphytic orchids. The pattern of distribution of epiphytic orchids in different spatial scales, such as a forest type, a host tree, and micro-habitats (such as branch types/outer canopy, etc.) was studied. It differed from other global orchid researches (that have been mostly single tree specific) in considering different spatial scales in a single study. Due to the vast expanse of the Western Ghats, forests in Kerala across an elevational gradient were considered. It was so challenging that no earlier work was available in this regard nor an accepted method. It made me to test used methods in epiphyte ecology in global research. A year-long trial and errors finally yielded the development of an effective integrated method called Linear Line Transect with Selective Tree Scanning (LLTSTS). This was based on plotless sampling. The sampling was time-consuming but measured the characteristics of a vegetation type, host tree and orchid substrate. At times, the tree had to be climbed to survey the canopy. Can you imagine the beauty of being up in the canopy feeling the clouds? The feasibility for the same was different in northern, central and southern Kerala. I, therefore, had to resort to mostly binoculars with high magnification for
observation. Regional climate of Shenduruny Wildlife Sanctuary was recorded using rain gauges and outdoor climate loggers to understand the influence of climate on epiphytic orchids. Data collection involves a lot of effort and sometimes risks money and health of a person or a team. However, I learnt that research in the forests makes you humble, inquisitive, patient, complacent, and emotionally, mentally, spiritually and physically healthy and prepares you for life!

After another three years of research and extensive travel, I was able to come up with significant patterns of distribution of orchids from the Western Ghats of Kerala. The new method is identified as effective to sample endemic/epiphytic orchids of the Western Ghats as supported by a paper presented in the International Symposium ‘Ecology 2017’ in Turkey. Endemic orchids preferred mid altitudes and evergreen forests. In general, the diversity and abundance pattern of epiphytic orchids showed significant patterns along mid altitudes and vegetation/habitat types. For example, evergreen forests hold higher diversity of orchids with the old trees in the lower reaches and highly branched short trees in the hilltop forests. This agrees with theories that suggest a mid-elevation richness of biodiversity in the tropics. It means these factors could actually be a predictor for epiphytic orchid diversity. On a host tree level, the epiphytic orchids are not specific to host species but characteristics such as tree size, tree height, bark types and crown cover. These factors play a role in the selection of host trees during colonization. Spatial occurrence of epiphytic orchids on host trees can be identified into zones such as trunk, lower canopy, middle canopy and outer canopy. Epiphytic orchids have a preference towards a zone depending upon their physiological needs. You could observe epiphytes on trees lining the roads and record their positions for your own research. Further, on the substrate level, branch types, canopy soil, diameter, etc, influences the exact space of establishment for orchids. Regional differences in diversity and abundance of epiphytic orchids in Shenduruny WLS was explained by regional climate (light, temperature and humidity and rainfall). I will have more results in my thesis and research papers that are in the pipeline. Although patterns are described, mechanism under each pattern has to be studied individually for long term in order to fill in each ecological question. These findings are first from the Western Ghats (and India) and therefore, unlock a new field of plant ecology called ‘Orchid Ecology’ for science enthusiasts.

My research improved knowledge about the ecology of orchids and suggests a long-term large-scale study to fill the gaps. Also, a detailed mapping of species and draft of conservation strategy for orchids may be needed in the future. Terrestrial orchids should also be studied in an integrated method to enhance Orchid ecology. I look forward to take up more specific questions in the future for my post-doctoral research because there are many questions yet to be addressed, Orchid ecology presents a unique world with immense opportunities for learning. I believe more researchers would explore this area and give further insight. Could it be you?
Ever wondered how a lizard sheds its tail and regrows a new one later? How cutting an earthworm into two halves leads to formation of two new earthworms? Scientists call it ‘Regeneration’. Can humans regenerate too?? Well, not completely. The closest that we humans could get; is regenerating our livers. Liver is one of the most hardworking and multifunctional organ in our body. It regulates key physiological processes like nutrient processing, xenobiotic detoxification, waste processing and excretion, energy and nutrient storage and regulation and production of serum proteins. The functions that it performs are so vital that any failure to perform them can lead to serious patho-physiological conditions and in extreme cases even death. The liver homeostasis, also termed as ‘hepatostat’, therefore; needs to be very critically maintained. Could this be why nature has conserved the regenerative ability of liver? May be.

So how exactly does liver dysfunction occur? In a normal scenario, liver bears all the metabolic load of the body while maintaining its own needs. The routine consumption of alcohol, coffee, drugs, heavy metals and energy drinks makes the load even worse. A long term exposure of drugs prescribed to treat various diseases e.g. tuberculosis, add to the stress of already strained liver; eventually causing liver damage. However, in most such situations the treatment cannot be terminated, or else, the patient will die of the disease. Drug induced liver injury (DILI) is one of the mostly cited reasons for withdrawal of an approved drug from the market and unfortunately, while there are many drugs that affect liver, there are no drugs available as such to reinforce liver

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functions. Currently, the only treatment that has been followed for severe liver diseases is liver transplantation. The surgical procedure is extremely complicated, risky and expensive. Also, the number of patients needing a liver transplant outnumbers the donors available. Therefore, there is a major emergency in the field that demands urgent attention towards finding therapeutics that could improve liver regeneration and/or protect from DILI.

Our research team led by Dr Chetana Sachidanandan at CSIR-Institute of Genomics and Integrative Biology, New Delhi, has taken up this challenge. We utilise zebrafish as a model system to address this problem. As the mechanisms of liver function are very well conserved between humans and zebrafish, discoveries made in zebrafish can be extrapolated to humans. In addition, the small size and transparent nature of zebrafish embryos makes it an ideal system to visualise internal organs and carry out chemical screens for discovery of therapeutics. Using this handle, the team utilised a transgenic zebrafish line which has a red fluorescent protein (mCherry) in its liver that allows visualization of liver in live organism. The protein is fused with a bacterial enzyme Nitroreductase. When these transgenic fishes are treated with a drug Metronidazole (Mtz), it gets converted to a toxic product thereby killing liver cells. This way, liver damage can be achieved and as Mtz is washed off, liver starts regenerating. Both these processes can be monitored by changes in mCherry fluorescence. Since liver regeneration is directly dependent on the type and extent of damage, we needed to standardise these parameters. It has been established that liver can regenerate as much as 75% of hepatic insufficiency. Our team figured out 2.5mM Mtz treatment for 24 hours is sufficient to cause almost 70% reduction in liver size and also allow regeneration by 48 hours post Mtz removal. Using multiple means, we demonstrated the robustness of this model and established an assay to perform a chemical screen for hepatoprotective and/or hepatoregenerative drugs.

In order to perform a targeted chemical screen, we used hundreds of small molecules that could lead to potential drugs in future. 3 dpf (days post fertilization) embryos were treated with DMSO (control), Mtz and Mtz along with small molecule. After 24 hours of exposure, the embryos were scored for mCherry fluorescence as a marker of liver size. As expected, in comparison to control embryos, Mtz treated embryos showed liver damage. However, what our team looked for was; which compounds when co-treated with Mtz were potent enough to protect from liver damage caused by ‘only Mtz’ treatment. We were able to identify a handful of them, of which CS-KIH03 served to be the most potent and promising one.

As mentioned earlier, in spite of the associated liver injury, the prolonged drug treatment for many diseases still cannot be terminated. The best alternative to this is to have an antidote that would prevent the upcoming liver damage. In clinical terms, it is known as prophylactic treatment. Considering this need, the team tested if pre-treatment of CS-KIH03 could lower the risk of upcoming liver injury by Mtz. Interestingly, the small molecule showed a potent prophylactic activity when post treated with Mtz. We further tested if CS-KIH03 also possesses regenerative activity. After almost 70% of liver damage, the transgenic zebrafish embryos were allowed to regrow their liver naturally and in presence of the small molecule. We were delighted to find that the embryos treated with small molecule were able to show captivating increase in the rate of regeneration as compared to the naturally regenerating livers. This led to further characterization of CS-KIH03 as a therapeutic for DILI.
Clinically, the most common drug for liver injury is Acetaminophen (Paracetamol). Our team selected two more drugs called Isoniazid (drug for TB) and Thioacetamide that have been reported to cause liver injury. We created similar DILI models in zebrafish using all these drugs and characterised them. Further, we performed experiments to assess whether CS-KIH03 is able to protect from liver injury caused by all these drugs. To our surprise, the newly identified small molecule could successfully prevent liver injury in all three toxicological models of liver injury, highlighting its generic potential.

In all, our study utilises a genetic model for liver-ablation in zebrafish in order to perform a chemical screen to discover therapeutics for DILI. We found CS-KIH03 to be a highly potent compound with hepatoprotective, regenerative and prophylactic activity. In addition, protection by CS-KIH03 in various kinds of toxicological models of DILI highlighted the potential of this drug to be the prospective antidote against liver damage. Further, our team aims to dissect the mechanism of action of this drug using small molecules that are known to have similar functions like CS-KIH03. The mechanisms are under investigation and knowledge earned from this study would pave a way towards understanding DILI in more detail as well as discovering therapeutics of targeted functions.
It was a stuffy July morning when my sister, Nidhi, returned from her regular morning workout session, baffled with her corpulence. She sat on the couch gulping water. After taking a deep breath, she devoured a sliced papaya hoping to flatten her paunch. Nidhi had read on Google that papaya has an enzyme named papa in which helps in digestion, is rich in fiber, antioxidants, Vitamin A and C. She read that papaya gives a feeling of fullness and eases the bowel movement, culminating in weight loss.

“Didi, what are these green circles I find everyday while peeling off papaya?” Nidhi asked, pointing at the rings on the papaya.

“Ah! These are not circles but rings dear. They are caused by papaya rings potvirus (PRSV) disease”, I replied.

“And what does this disease do? Where does this virus come from?” Nidhi asked again.

“Well, this disease affects taste, fruit quality and yield of papaya. If left untreated, it can destroy the papaya plant”, I explained.

“How does this virus reach the papaya?” she asked in a daze.

“These viruses are transmitted to the papaya by a bug named aphid, the carrier vector of PRSV”, I added.

“If it is such a deadly disease, then why don’t papaya growers treat these viruses by spraying something?” she inquired.

* Ms. Swati Kumari, Ph.D. Scholar from Amity University, Lucknow, is pursuing her research on “Genetic Engineering of Papaya (Carica Papaya L.) with Tr-Cp Gene for Conferring Resistance against Papaya Ring Spot Virus.” Her popular science story entitled “Tailoring Papaya Resistant to Papaya Ringspot Virus” has been selected for AWSAR Award.
“My dear, viruses can’t be destroyed so easily. One can kill bacteria using antibiotics and fungus by spraying fungicides but there is no such thing as viricide” I told her but her questions didn’t stop. “Then what I am eating is bad? How can we combat this disease? Why doesn’t anybody do something about it?” Nidhi shot an array of questions.

Nidhi’s inquisitiveness pushed me to collect more information about this disease, its origin and what research has been carried out so far. I wanted to satisfy her curiosity about what is making her favorite fruit so ugly. I went through a number of scholarly articles about papaya and this disease in particular. Being a Post Graduate in Biotechnology, I could conceive the crux of the science behind this disease and research to fight against it. After a thorough reading of about a week, I called Nidhi to answer all her questions.

What is pathogen derived resistance?

Way back in 1984, Prof. Roger Beachy, Washington University, USA, propounded the theory of PDR i.e. pathogen derived resistance. Polio vaccination works on the same principle. Prof. Beachy developed tobacco virus resistant plant employing PDR which brought a sea level change across the countries engaged in developing virus resistant plants. In PDR, the pathogen itself is utilized to provide resistance against its attack, thereby, protecting the plant from infection. This technique utilizes a specific gene (coat protein), carrying our desired traits, which is taken from the pathogen and mobilized into a transformation vector. This vector acts as a vehicle to deliver the desired gene to the plant by using any of the available direct or indirect gene transfer methods. The plants, thus, produced are called “transgenic” as they have genes from another source.

Devastation of blooming papaya industry in Hawaii

Hawaii comprises many islands and it is surrounded by the Pacific Ocean. Continuous volcanic eruptions from Mauna Loa affect the agroecology of this state. PRSV was first reported in 1940 in the island of Oahu, Hawaii. Kapoho is the most dominant variety of papaya which is sold in the mainland of USA and also exported to Japan. However, after the disease infestation, the entire Kapoho belt had to be shifted from Oahu to Puna is land of the state. Puna grew about 95 per cent of Hawaii papaya covering around 2500 acres of land. Up till 1960s, there were no cases of PRSV in Puna. However, in 1990s, the entire papaya industry was devastated by PRSV. Within a span of six years, Hawaii papaya industry lost 50 per cent of its crop due to the virus.

Technology led revival of papaya industry in Hawaii

To strive against PRSV disease Dr Dennis Gonsalves, who was a musician by chance and scientist by choice, adopted the method of PDR which was discovered by Prof. Beachy. Dr Gonsalves not only developed two transgenic varieties, namely ‘Rainbow’ and ‘Sun Up’, but also successfully commercialized it. Transgenic papaya covered about 85 per cent of total sold papaya available in supermarket, besides other non-transgenic fruit crops. The virus free ‘Rainbow’ yielded about
125,000 pounds of marketable fruit per acre per year, whereas non-transgenic ‘Sunrise’ (PRSV infected) produce was 5,000 pounds of fruit per acre per year.

After the sale of transgenic papaya in 1998, Puna received 53 million pounds whereas non-transgenic papaya grossed only 26 million pounds in 1992. Hence, it can easily be concluded that transgenic papaya gave around twice the profit to papaya growers in comparison to non-transgenic papaya. As transgenic papaya fields expanded in Puna, the PRSV inoculum also reduced due to replacement of non-transgenic fields with the transgenic ones. Rainbow accounted for around 50 per cent of the fresh fruit production in Puna. The bearing acres of transgenic Rainbow were about 595 whereas that of non-transgenic Kapoho was recorded to be 380 acres only. Despite being one of the most developed countries with highly stringent and strict food safety norms and regulations, Japan and Canada signed the treaty and deregulated the import of transgenic papaya varieties to their countries. Japan held 20 per cent while Canada had about 11 per cent of Hawaii’s export market. This signifies that transgenic papaya is safe and it should be adopted more widely across the globe.

In the process of transgenic papaya commercialization, on the one hand, Dr Gonsalves was admired by the farmers for his endless efforts in saving the papaya industry as he was helping farmers to earn their livelihood from papaya again. On the other hand, he was denounced by the anti-GMO activists. However, his approach was always pro-farmer and he only focussed on end goal without getting disoriented. Dr Gonsalves said, “Don’t just be a test tube scientist, and do something to help people. This kind of work is not for the faint-hearted. When you put the human part of Biotechnology into the equation, it gets easier to continue the work. Science and Technology is the only move to feed 9 million people”.

**Transgenic papaya research in India**

Hawaii, Thailand, Jamaica, Brazil and Venezuela have also developed transgenic papaya. However, India is quite new in this fray. Indian PRSV isolates exhibit about 11 per cent variability as we move from North to South. So, a transgenic papaya developed in North India will not show resistance in Southern India due to different serotypes of the virus. Hence, a biological process called RNAi has proven to be the only approach which can help in combating the disease in India. It kills the virus irrespective of its serotype variability.

Research on transgenic papaya using coat protein gene was started in Southern parts of India like Tamil Nadu Agriculture University, Coimbatore and ICAR- Indian Institute of Horticultural Research, Bengaluru, but with scanty success. Later, a vast networking project of ICAR with its two premier Institutes, ICAR-Indian Agricultural Research Institute (IARI), New Delhi, and ICAR-Central Institute for Subtropical Horticulture (CISH), Lucknow, came into the picture to solve this problem. ICAR-IARI developed the gene construct for this program while ICAR-CISH designed a successful delivery system for transferring the gene construct into the papaya plant.

As per biosafety regulations in India, scoreable and selectable markers cannot be a part of the transgene after integration into the plant. So, the gene construct used in the study has been
made marker free. It is to be noted that marker removal from the gene construct makes the job of screening transgenic papaya very cumbersome because then each and every plant needs to be tested whereas the plants having gene construct with markers need not be screened individually as the non-transformed plants get killed in the selection process. After the transgenic plants are screened for stable transgene integration, the plants are acclimatized and hardened. About 60 per cent of transgenic plants die during the course of acclimatization as they are unable to cope with the natural climatic conditions. To increase the successful acclimatization of transformants, biotization technology is practised. In this technology, the endogenous bacteria are utilized to ease out the process of rooting and acclimatization. A few transgenic lines have been identified and are under advance stage of evaluation. So far, three generation advancement has been achieved.

“Oh! This means India will also be equivalent to Hawaii, not only in terms of producing the PRSV resistant papaya but also in exporting its transgenic papaya varieties to countries abroad. This is really awesome, Didi!”, exclaimed Nidhi with enigmatic pride, who was engrossed in listening to the long story about her favorite fruit till now.

“Yes, my dear, why not! But we have a long way to go in terms of regulatory mechanism to achieve our goal with glorious success. Amen!” I replied.
The Future of Communication: Nanotechnology and Light

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There was a time when a group of humans used to signal other groups by either lighting fire or blowing a trumpet. As we evolved, the mode of interaction between societies improved. We started using pigeons for information sharing, some used them to share king’s secret and many used them for their love letters. Later, post-cards were introduced marking our entry into the era of rst formal mode of communication. Finally, Marconi changed the entire situation by inventing the first electronic form of interaction, the telephone. Connecting Delhi to Bengaluru was no longer a dream and the exhaustive process of writing post-cards swiftly found a place in grandfathers’ night tale. However, with time we realized just voice exchange is not enough for numerous commitments and a more comprehensive mode of synergy became a necessity. What if you wanted to text or video call or e-mail or send pictures of your dog?

Normal telephones couldn’t deliver because of two reasons; the device had only number pads that couldn’t do anything else than dialling numbers, and wires used to connect telephones were not capable to transmit information other than voice signals. So, two types of revolutions were needed. One that can change the telephone device processing capabilities and second that can make the connecting wires competent enough to carry several formats. And indeed, these two revolutions did happen. One we know as ‘Transistor’ invented by Bardeen, Shockley, and Brattain and the other Optical Fiber Communication pioneered by Maiime, Payne, and Kao. The revolution was so massive and significant that almost all the celebrities listed above were awarded the Nobel Prize.

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Now we use cell-phones, building block of which is a transistor, and the cell-phones over long-distance networks are connected by optical fibers. These two revolutions have made it possible to connect from India to America with the click of a button. The optical fibers go underground and under oceans to reach out to anyone, anywhere on earth. Your cell phone has millions of transistors on a single chip processing the information and there are multiple chips working together for you to make video call or attach a document with your mail. With these two revolutions and efforts by scientists for constant improvements, we can now enjoy variety of experiences that our ancestors had never thought of. You see any electronic components around, either transistors or optical fiber networks or a combination of both are working in the background.

But when was the last time humans settled on anything for good? The more we evolved the more hungry we got for even better quality entertainment and data. We don’t just want to watch cricket/football matches anymore; we crave for High Definition (HD) videos, we are not satisfied with 3G but want 4G or above; we are dissatisfied with 1080p YouTube videos and slowly moving toward 2440p and higher quality videos. The more superiority of service we desire, the faster the device and broadband the communication channel must be. Since the fiber channels works at ultra-high frequencies, it can handle vast amount of data without breaking down. But what about the device? Will the data transfer between the transistors and between chips our demands, and with stand the ever-growing pressure for quality and speed?

The answer is a big NO!

And the reason has already been taught to us in our basic electromagnetics course. The chips are located on a printed circuit board that uses copper wires to spread the information. Several chips are connected by the help of well-placed and complicated routes of these copper wires so that different chips can connect to each other. But as the appetite for speed and quality is intensifying, the copper interconnects are required to carry more data. In technical terms, the copper connections are required to operate at higher bandwidths, or higher frequencies, while maintaining error free operation. The problem with metallic connections like copper is that they exhibit something known as ‘Skin Effect’ at higher frequencies. This effect makes the electronic energy to flow at the surface of the metallic wire. One severe manifestation of this effect is leaking out of the data in the form of radiation. The radiation not only reduces the data power being transmitted but also interferes with the other metallic wire connections running between the chips.

To overcome this issue, two lines of thoughts originated within the research community. One wanted to keep improving the current interconnects by exploring the material used to make interconnects or coming up with more advance signal processing units to nullify the effect of information loss. The other group wanted the interconnects to be future proof and advocated for a paradigm shift in the way chips communicate with each other. They advocated for what is frequently described today as ‘optical interconnects’ and have since transformed the way the entire industry looks at the problem. We are already using optical fibers to connect continents, have profound understanding about its technology and have expertise to remain future-proof for many decades.

However, reducing the size of optical components to fit on a chip and develop strong technological framework to produce reliable optical interconnects is not as easy as it sounds.
There must be a complete hierarchy of functional units to make the interconnect work and each functional must add any additional benefits in the existing electronic systems. One major advantage that optics brings to the circuit is ‘wavelength’. An intrinsic property of any electromagnetic wave, wavelength is something we never talk when discussing about electronic circuits. Just like electrons carry the information in any electronic circuit, photons carry the information in optical circuit where each photon is identified by its wavelength. Several wavelengths can be used to carry the information and hence this mode does not suffer from bandwidth issues.

Since so many wavelengths are involved, a wavelength selective device is a mandatory requirement to select a wavelength and direct it to its intended receiver. We work towards designing, fabricating, and demonstrating such wavelength selective devices. Now the term wavelength selective might sound a difficult scientific term to understand but in fact it can be understood by what we already know from our senior secondary physics class days. In the Young’s double slit experiment, one coherent wave was passed through two small holes followed by a screen. Whenever the path length difference was odd multiples of pi, we got a dark fringe and whenever it was even multiple of pi we got a bright fringe. These odd and even multiples define whether light wave destructively or constructively. We use the same principle with the only change that wave interaction is now happening on a nanoscale device and the double slit is replaced by a ring resonator. The ring has two waveguides evanescently coupled to it and the waveguides carries all the wavelength required for the communication between chips to take place. The transmission port of the resonator shows power-nulls at the wavelengths satisfying the resonant condition and the drop-port of the resonator shows power-peaks at the same wavelengths.

Ring resonators became the most popular choice amongst researchers and industry alike for their versatility. However, there were certain issues that came out with practical resonators. Since the waveguides are nanometre in dimension and tightly confine the light inside them, any roughness appearing on the waveguide walls will inadvertently lead to scattering of light and hence a total loss in the power. A close analogy will be a very fast flowing water in pipes. If there are tiny holes in the pipe along the length of the pipe, water will slowly seep out resulting in a net loss of the water output. In resonator, these scattering points lead to excitation of unwanted modes that start interacting with each other and cause the resonance to split in two notches. A resonator that was supposed to work at a wavelength is working at two other wavelengths and not at the intended one. The two wavelengths cannot be predicted by an engineer while designing the device and can only be detected once the device has been made. This has led to a deep concern among research fraternity and has been an unsolved problem for many years.

We came up with a very counter-intuitive solution where we knowingly split the resonance in two wavelengths. We model the cavity in such a way that the modes generated by scattering points decay quickly in the cavity whereas the extra mode that we desire to excite has enough power to interact the conventional mode of the resonator to split the resonance in two wavelengths. In this way, we solved the long-standing problem of resonance splitting in a Silicon resonator. In simplest terms, we intentionally create defect in the resonator to make it defect-free! With this solution, we don’t need to predict the splitting before the device is made. We make the device and then just engineer the property of light in the cavity post-fabrication to get the desired resonance wavelength.
Five-year-old Iris fainted when she saw the mice inside our rickety car. But the mice themselves were at fault. They were quite cute, with white furry coat, curious eyes and orange-brown tails. Each of them had arrived in separate ventilated cages all the way from the Jackson Laboratory in the United States.

Unlike my daughter, I was thrilled to meet them. The Jackson mice were famous. In fact, they were revered as if they were rock-stars of the animal kingdom (like their namesake Mr. Michael Jackson). Journal after journal screamed headlines about them in the scientific world. Their specialty was that they naturally developed diabetes, like some of us humans do. High glucose levels in these mice mimicked this disease.

Diabetes is a troublesome disease. In fact, there are two types, and the more common type of diabetes affects adults. In our community we have an uncle who looks much older than he actually is. He takes 12 different kinds of tablets daily. It turns out that he is a diabetic and takes doses of insulin injections too. Each day, insulin is produced normally in the body when we take our meals. The more glucose we consume, the more insulin our body synthesizes. Highly specialized cells in the human pancreas, the beta cells, are our factories that manufacture insulin. The scientists, Banting and Best, discovered this hormone 100 years ago. Now commercial insulin is available in syringes and vials.

* Ms. Neenu Jacob, Ph.D. Scholar from Post Graduate Institute of Medical Education & Research, Chandigarh, is pursuing her research on “Suppression of Type 1 Diabetes in Non Obese Diabetic (NOD) Mice by the Induction of Colonic Regulatory T Cells.” Her popular science story entitled “Doctor of Mice” has been selected for AWSAR Award.
A particularly vicious type of diabetes affects kids. The immune system in these children mistakenly attacks the beta cells. The beta cells die and disappear. So instead of playing around in the parks, children who have diabetes inject themselves with insulin. They become smaller in size compared to other children. Insulin is a lifesaver for many of them, but a large dose of it could kill instantly. Thousands of children die each year with diabetes and its complications.

My thesis was founded on the premise that our habits of daily life play a crucial role in the progression of diabetes, specifically diet. It is common knowledge that the Indian diet has changed in modern times. We now have many children eating processed and ready-to-eat food. These changes automatically lead to disturbance in the intestinal bacteria. There is good and bad bacteria in our intestines. Science tells us that commensal bacteria are our friends and they help us. These are the good bacteria. They feed on dietary fibre and generate short-chain fatty acids. Fast food, poor infibre, changes the bacterial flora of our intestines. The short-chain fatty acids are of vital importance to the local immunity. One of these short-chain fatty acids is butyrate. Sodium butyrate increases T cells in the intestines. These T cells are the guardian angels of our immune system. Their presence tones down and quells the immunological battles that the human body regrettably wages on its own cells. This is called immune tolerance.

Both pancreas and intestines are closely connected, like my husband and me- married to each other; made for each other. As per my logic, the same immune cells patrolling the intestines extended to the pancreas. But science demands proof of such ideations. So the mouse pancreas had to be explored for the presence of T cells. Plenty of T cells meant that the beta cells would be protected from the immunological hara-kiri of diabetes.

The Jackson mice developed diabetes over several weeks. I fed them a special diet, looked after their water intake and otherwise set them free to, well, socialize. What I needed to find out was the
changes in their pancreas, those glands that produced insulin. For this, at regular intervals, the mice came to me for a blood and urine check.

For years, I watched the mice in two animal facilities in our city. One was an advanced lab, dedicated to breeding them. And then I transported them to the lab in the hospital. I monitored their glucose levels by withdrawing blood from their tails.

Some of the mice were like those children taking insulin. They were sluggish and lethargic. The polar opposite of the garden variety of mice, which scoot the moment you look at them.

I administered sodium butyrate mixed in drinking water to the Jackson mice. This was performed after the mice were confirmed to have high glucose levels in the blood. I followed up their blood glucose levels, keeping them on a regimented diet. The blood check-up continued for several weeks. I hoped sodium butyrate would decrease their blood glucose levels. But it turned out to be more complicated than I had anticipated. The mice got pregnant and gave birth to second, third and fourth generations. Many of them turned diabetic while they were pregnant. Their glucose values fluctuated considerably. For many months, I simply collected data; I could not make any sense of it.

My husband is a surgeon. He couldn’t quite believe when I told him I needed a pair of the surgeon’s scissors. Instead of chopping vegetables in the kitchen, I cut out the pancreas in the lab. No more curry masalas. In their place, I mixed solutions to identify immune cells under a microscope. And instead of sipping coffee in the balcony, my disgruntled husband waited in the car for the lights to dim in my lab.

As a next step, the mouse pancreas were viewed under high power magnification. We used red and blue colour dyes on glass slides. In a sense, the pancreatic glands were dressed up and photographed. We found intact beta cells in these pictures. Further, I measured the percentage of T cells in the intestines and the pancreas. This was achieved with the help of flowcytometry, a new tool to measure microscopic amounts of intestinal lymphocytes. The increased percentages of T cells showed that sodium butyrate could bring about immune tolerance.

My study pointed out that addition of fibre in diet favorably influences insulin. The progression of diabetes can be controlled. A diet enriched in fibre results in alterations at even the cellular and microscopic level. The effects that I found in mice may change a diabetic child’s future tomorrow. My experiments over five years also taught me that managing diabetes is a continuous process. It has its ups and downs. It requires time, dedication, discipline and patience. Just like my work in my lab.

My daughter Iris just started kindergarten. She is a chatterbox. The other day, my daughter’s class teacher asked her what her parents did. My daughter replied that her father is a doctor of operations and her mother is a doctor of mice!
Have you ever thought about drinking water we consume, whether it is safe from all emerging contaminants (i.e., new and unknown types of contaminants, such as pharmaceutical compounds, nanoparticles (NPs), personal care products) or not? If not, then it's time to think about it, as we only think about removal of bacteria, viruses, organics, ions from water, whereas more subtle constituents, such as hazardous NPs (one dimension <100nm) might also be present in our water. Sources of these particles are multiple, for instance, discharge from chemicals industries, nanopesticides from fertilizer industries, medicine from pharmaceutical industries and others. These substances have been shown to damage cells of human body and pose risks to environment.

The aim of this brief essay is to highlight information about NPs, its sources, and possibility of removal in treatment plant so that proper action can be taken to reduce chances of exposures to humans.

We all know the benefits of nanotechnology and how it has made our life easy. However, we might have never thought about the emerging threat which it might pose to environment and human health. Nanoparticle has become a part of day-to-day life due to its increasing usage in the fields of medicine, electronics, and personal care products. Examples of NPs include fullerenes (C60), single and multi-walled carbon nanotubes, silver NPs, metal oxide NPs, i.e., zinc oxide, titanium dioxide, copper oxide. Because of a variety of applications, NPs can enter the environment through many pathways. The NPs are released during various stages of production, use and disposal from product and will ultimately find its way to air, water, soil and plant environment (Figure 1).

* Ms. Tanushree Parsai, Ph.D. Scholar from Indian Institute of Technology, Delhi, is pursuing her research on “Fate of Nanoparticles in Different Environmental Matrices.” Her popular science story entitled “Is Nanotechnology-Related Pollution a Threat to Environment?” has been selected for AWSAR Award.
River water, we use for drinking, may contain NPs which may reach the water treatment plant and human population, if not removed from water. Similarly, NPs released from various products may reach the wastewater treatment plant and if not removed may end up in the aquatic system and affect aquatic life. If not given attention now, the problems posed by these small sized particles can aggravate in the future.

Toxicity of NPs depends on its shape, size and reactivity. It can directly affect human health or indirectly through contaminated environment. These products can enter human body through various routes of inhalation, oral or through skin. The effect depends on concentration of these NPs in varied products. Similarly, these small NPs can be ingested through water contaminated with NPs we drink, through ingestion of plants grown in soil contaminated with NPs. Researchers have reported harmful effects of NPs on animals and human as well. NPs entering into aquatic systems, such as lake, river, ocean, might pose harmful effects on aquatic ecology, thus disturbing ecosystem balance. NPs are extremely slow degradable contaminants and hence, have long persistence in any matrices, creating the worse situation.

There has been a lot of development to treat suspended solids present in water or wastewater in treatment plants. But, at present time, no one has thought much about the need for removing nanoparticles from water treatment plants. Here lies the question whether removal of NPs from water is worth exploring with regards to its reported harmful effects to aquatic species and human and impacts on environment. This area needs to be explored much more to answer question. Behaviour of these NPs is very different from that of micro-sized particles present in water. They undergo various chemical processes in suspension, like aggregation (i.e., formation of bigger flocs by combination of two NPs), dissolution (i.e., release of ions), and transformation (i.e., change of
shape and properties). Even, the filters available for removing suspended solids are not economical to remove these NPs from water for potable purposes. Hence, if we think of removing these particles on a large-scale, we might need to carry out research and understand processes taking place in a water suspension.

In India, very few scientists are working on understanding issues and challenges in removing NPs from water. In this regard, the researchers at IIT Delhi (Er. Tanushree Parsai, Research Scholar, Civil Engineering, Indian Institute of Technology (IIT) Delhi; Supervisor: Prof. Arun Kumar, Associate Professor) have been trying to understand what exactly happens to NPs in different water matrices. During doctoral research at IIT Delhi, the author, mentioned above, have been experimenting to understand settling and change in size of mixture of zinc oxide and copper oxide NPs. These NPs were chosen due to their usage in various industries of medicine, personal care products, etc. The study of mixture of more than one types of NPs is important as it represents a realistic condition of contamination of a water body. Earlier, there has been lot of studies for understanding what happens to single type of nanoparticle in water, but, there has been scarce information on behaviour and fate of mixture of NPs in a water body. The research is ongoing to determine whether these NPs have settling capacity to settle down easily or have properties to remain in suspension for a long period of time under environmentally-relevant conditions (such as river water matrix or lake water matrix). The initial findings of ongoing research indicate that the presence of more than one types of NPs have the ability to increase the removal of NPs by sedimentation than that in a single nanoparticle-type system (Figure 2). Hence, such study gives us an insight on how mixture of NPs might behave once they are discharged to river water or in a standing water body. It could also help in understanding what design improvement can be done to treat water containing multiple NPs in a sedimentation tank.

Figure 2: (A) Suspension showing settling and aggregation of single and mixture of nanoparticles (B) Transmission electron microscopy image for mixture of zinc oxide and copper oxide nanoparticles
Through my doctoral work, I am trying to obtain more information on NPs presence/behaviour in water system and also in other environmental systems like soil, which might ultimately create groundwater pollution. There may be less knowledge available as of now on potential risk, what nanotechnology might pose on humans or environment; however, it requires research to ascertain different aspects with scientific evidence and to inform public, regulators and manufacturers. We are trying to provide solutions to treat wastewater containing NPs, which in the coming future, may lead to a threat in safety of both environment and its community.

Research team includes: Er. Tanushree Parsai, Research Scholar, Department of Civil Engineering, IIT Delhi, and Dr Arun Kumar, Associate Professor, Department of Civil Engineering, IIT Delhi. The research team has published an article and submitted a paper related to this work.


Parsai T. and Kumar A. “Understanding effect of solution chemistry on Heteroaggregation of Zinc Oxide and Copper Oxide Nanoparticles using a 2^{4:1} factorial approach” - (Submitted)
Glass: Superhero in the World of Construction Materials

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The role played by glass in the modern structures is no less than those of superheroes. In each of its application be the “Glass Bridge” in China or “Glass Envelope” of the world’s tallest building Burj-Khalifa, glass ensures that you are thrilled, awestruck by functional performance and mesmerized by its classy and elegant appearance. It has become the enduring symbol of transparency and glittering prosperity. But the journey of glass to this star-status was not easy and still is an ongoing process. My research work, performed under the umbrella of Structural Glass Research and Testing Facility at IIT Madras, is part of this on-going process. It consists of evaluating the critical loading scenarios through experimental investigation, analyze it and then formulate effective design methodologies, to ensure safe and reliable application of glass in envelope of high-rise buildings. To understand the technical terms in a simpler and appealing manner, let me draw an interesting analogy between research developments in glass and turning points (milestones) in the lives of superheroes from famous movies/comics. Figure-1 gives an overview and explains the analogy adopted.

Hidden Potential: Potential of glass as construction material was recognized from very early times, but its pros like transparency and ability to enhance aesthetics were overshadowed by its cons. Low load carrying capacity, shattering of glass pieces on failure, difficulty to produce the glass of large dimensions or glass with uniform thickness, distortional defects reducing the transparency were some of the major drawbacks. These lacunas limited the use of glass to specific locations like

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windows and gave it a status of ordinary construction material.

**Defining Moment**: Time when the lead character in a superhero movie recognizes that, if he allows his weakness to govern the path for future, then it will lead to a disaster. And hence, he decides to counteract. For example in the movie “Iron Man”, when Tony Stark is kidnapped and put into a dungeon by a terrorist group which eventually leads him to counteract by designing the Ironman suit to rescue himself. Similarly, the defining moment in the life of glass was established by Sir Alastair Pilkington, when he invented the “float glass manufacturing process” in year 1959. This invention allowed the production of large size flat glass with controlled thickness at a comparatively low cost. It also resolved most of the problems related to the optical distortion increasing transparency. This was the defining moment which initiated the process to raise the bar for glass as a construction material and called upon it to embrace its extraordinary destiny.

**Evolution through hard work**: To be a superhero, only recognizing the potential is not sufficient. Skills must be thoroughly polished and weaknesses should be overcome. This was done with glass through the processes like: (1) Heat Strengthening, which enhanced (almost doubled) the load bearing capacity of glass and (2) Lamination, where the two glass panel are bonded together by adhesive interlayer which prevents the shattering of glass by holding broken pieces of glass in place even after failure.

**Arrival of Superhero**: Today, glass has overcome almost all lacunas like low strength,
production difficulties like size limitation and uneven thickness, danger of shattering of glass hurting people nearby, optical distortions and so on. These all are nothing but the super-heroic achievements, expanding the applications of glass at exponential rate and announcing the arrival of a superhero.

Identification of Villains: Journey of a superhero does not end with just the attainment of the power and finding the possible avenues to use them. It actually begins when the superhero is confronted by a mighty villain. In case of glass, the villains differ depending upon the type of application. In my research work, I am concentrating on the application of glass in envelopes of high rise buildings. It is a well established fact that the wind loads increase rapidly with increase in height of building. Hence, high wind pressure acting on the surface of the glass panel trying to breach the envelope, is identified as the major villain. The primary objective of my research is to formulate strategies to ensure safety of these glass envelopes under extremely high wind pressures, as even a small breach in envelopes has dangerous consequences. First of all it restricts the building from performing its most important and primary function, which is to protect the occupants from harsh exterior environment. It also alters the pressure inside the building, increasing the chances of propagation of envelope failure to a large extend. Once this first line of defense formed by envelope falls, all the expensive interior is exposed to the secondary villains like rainwater, which further increases the economic loss. Failure of glass at higher elevation also endangers the life of people in proximity and in the case of cyclone these broken glass panes add to the wind-borne debris, which can cause serious injuries even to people far away. All these consequences emphasizes the need of the current research which aims to pave the path towards safe and reliable design of glass envelopes in future.

Defense Strategy: No superhero can be effective against the mighty villains unless he has a strong team backing him. Generally, team consist of “Information Collectors” a group of spys (like Black Widow or Nick Furry in the Avenger Series) who collect all the critical information about the villain like his plan of attack, time of attack and so on. One of the major objective of my research is based on the task performed by this team. As discussed, in case of glass building envelopes, wind load are the major source of damage (main Villain). Hence, the information like wind pressure distribution over the envelope surface and the direction of critical wind load are very important. In my research, this task of acquiring information is accomplished by performing several wind tunnel tests on scaled models of the high-rise building. In this testing, the wind profiles resembling the actual wind at building location are simulated with help of big fans inside a tunnel shaped experimental setup. Then these generated wind profiles are passed over the building models, which are planted with the pressure gauges to measure the pressure distribution over the envelope surface. This experiment is repeated for 36 wind directions (at interval of 10 degrees) so as to ascertain the most critical wind load and its direction. Further team of superhero also consist of “Strategy Planners”. This is the group which analyses the information obtained and make superhero ready to take up the challenge presented by the villains.(E.g: Techno-genius Mr.Lucius Fox, who helps the Batman to design his Bat-suit and Bat-pod (modified street-bike) in Batman Series). In my research this role of strategy planner is performed by “International Design Standards” which
provide guidelines on how to design glass panels for the wind loads. I have developed a computer program, based on these guidelines to help reliable design of glass envelopes. Program can be linked with pressure data obtained from wind tunnel test and ascertain the level of safety available as per the different glass design standards. Results from parametric study showed that there are some limitations and inconsistencies, which need to be overcome to increase safety in design of glass envelope. Details of this study are discussed in my paper titled “Issues in Probability Based Design of Architectural Glass in Building”, presented at the International Conference on Advances in Glass Sciences and Technology held at CSIR- Central Glass and Ceramic Research Institute, Kolkata in January 2017.

**Face-off with Villain:** This is the unwanted situation where mighty villain attacks. In real life, this situation arise when extreme wind events like cyclone hits the urban landscape and glass building envelopes here are challenged by the high velocity winds. I was able to witness one such event when Cyclone Vardah caused destruction in Chennai and surrounding areas. Events like this though very unfortunate, can be considered as an opportunity to learn from the failures. Hence, immediately after Cyclone Vardah, I carried out a detailed field investigation with specific focus to evaluate the failure of glass building envelopes. The information obtained from observation of 164 building envelope failure is classified into different categories, damage potential of each category is ascertained and the corrective measures are being formulated. The research paper about learning from failure during Cyclone Vardah is in process and will be soon available in public domain.

**Assurance of Safety:** This is the final milestone and sole purpose of a superhero, which is in sync with the direction of my research work, to achieve safe and reliable design of glass envelopes in high-rise buildings. With this research I wish to contribute a step towards establishing glass as the superhero in the world of construction materials.
The summer of 2015 was an incredible time for me. With India’s recent exit from the ICC World Cup, I had nothing much to do and yet a lot to look forward to. I had just bid farewell to my short-lived stint in the roaring corporate sector to pursue a career in scientific research. Fuelled by the confidence that’s characteristic of the early 20s, I was looking for what they call ‘fulfilment’. Patience, not my strongest suit then, was fading. Desperation peaked and ‘where to begin’ continued to be my biggest dilemma. This is when I saw an advertisement for a research fellow which caught my attention. ‘Study of anticoagulants and platelet aggregation inhibitors from Indian cobra venoms’ it said. I wasted no time in perusing the background of this research topic and two hours later, I had made up my mind.

That’s where my journey began and this is my story.

About five centuries ago, when Paracelsus, a man with an exemplary knowledge across a myriad of disciplines, amalgamated his wisdom in chemistry and biology, it gave birth to a promising branch of science—Toxicology. Honoured as the ‘Father of Toxicology’, his famous quote, “the dose makes the poison” pioneered the search for therapeutics from toxins.

Out of all the toxins studied, what makes snake venom toxins so intriguing is not just the enigma associated with them but also the wealth of life-saving molecules present in them.

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Snakes, especially cobras, have been a vital element of mythology and culture for several hundred years. While greatly feared, these ophidians are also hugely revered and even worshipped in some cultures. Despite their lethality, snake venoms are comprised of some biomolecules that can serve therapeutic purposes too. Snake venoms are categorised based on the area they target in their prey: Neurotoxins, affecting the nervous system; Cytotoxins, affecting the cells; and Hemotoxic, affecting blood cells. Their pathophysiology resulting in bleeding disorders makes snake venom a goldmine for anticoagulants and antiplatelet agents.

In the event of an injury, clotting of blood is vital to prevent excessive loss of blood. However, formation of an undesirable clot, called an embolus, impedes the smooth flow of blood through the blood vessel by obstructing its path. This embolus could travel through the blood vessels to and lodges itself in other parts of the body, mostly the leg or the arteries of the lungs, which can be fatal. Despite the availability of many synthetic anticoagulants like Heparin, Streptokinase, Urokinase, etc., the accompanied side effects press the need to look for alternative sources of these drugs. The goal is to find a drug, which can dissolve blood clots or prevent unnecessary clotting by drawing a perfect balance between haemostasis and haemorrhage. This can be achieved by exploring the mechanisms of blood coagulation and identifying the major arsenals that need to be targeted in manipulating and regulating haemostasis.

The process of blood coagulation is akin to a chain reaction and hence called ‘The coagulation cascade’ and is initiated when collagen, a protein found in skin, is exposed in the event of an injury. Following this, a battery of chemicals, called clotting factors, are recruited at the site to draw the attention of the surrounding platelets and direct them to the injury site to achieve the three phases of haemostasis:

1. Binding of platelets at the site of the injury and to each other,
2. Formation of Fibrin sheets, (a protein derived from the plasma protein Fibrinogen), which encapsulate all the bound and aggregated platelets into a haemostatic plug, and
3. Gradual dissolution of the clot which promotes wound healing.

Cobra venom mainly affects the nervous system, resulting in respiratory failure and eventually the death of the prey. This points to the fact that cobra venom mainly consists of neurotoxins but, in our laboratory, we have found that it possesses some biomolecules that show potential as an anticoagulant.

My research is aimed at finding drug leads from *Naja naja* (Indian spectacled cobra) venom that can be used to develop anticoagulants and antiplatelet agents by being potent at lower dosages with minimal side effects. My work is designed to achieve four milestones:

1. Finding an anticoagulant/antiplatelet protein from the Indian spectacled cobra venom and purifying it,
2. Characterisation of the protein(s) to ascertain their activity and potential,
3. Determining the effect of these proteins on human cells under laboratory conditions, and
4. Determining the mechanism by which the protein(s) exert their physical effect.

The venom was received in a dry, powdered form, devoid of all the moisture content so that its biological activity is preserved. This was separated into its constituent proteins by ion exchange
chromatography that works one simple principle, opposites attract. The proteins present in the venom were separated on the basis of the charge they possess. The separated proteins, called fractions were then collected and subjected to a multitude of biochemical tests. The purity of these fractions is examined by Polyacrylamide gel electrophoresis (PAGE), which involves passing the protein fractions through a gel, under the influence of an electric field, which allows for separation into its constituent proteins on the basis of their mass and charge. The protein fractions were assessed for their fibrinogenolytic activity and the result was viewed using PAGE. Fibrinogen, a protein found in the plasma of blood, exhibits three bands on PAGE. Three of the protein fractions, let’s call them X, Y and Z obtained from chromatography showed fibrinogenolytic activity. This was manifested by the digestion of one or more of Fibrinogen’s bands, thus rendering it unavailable for cleavage into Fibrin sheets. The next step was to determine if these proteins had any effect on platelet aggregation that is induced by chemicals like ADP and collagen, also called agonists. For this, human blood was treated with X, Y and Z, followed by treatment with the agonists. On the surface of platelets certain protein molecules called receptors are present that facilitate the binding between them to form a clump of platelets. Proteins with antiplatelet activity cap these receptors, thus preventing the platelets from aggregating. The degree of platelet aggregation was measured by an electrical phenomenon called impedance. The effect of X, Y and Z on platelet aggregation was determined in comparison with the two standards: blood treated only with the agonist which showed maximum platelet aggregation and consequently, the highest impedance and untreated blood which showed the least impedance. Interestingly, only X and Y were found to effectively inhibit platelet aggregation and this activity was seen to increase with an increase in dosage. But, Z did not show any significant effect on platelet aggregation. This observation suggested that X, Y and Z target different components of the coagulation cascade.

While these assays were intended to prevent the formation of a clot, studying the effect of these protein fractions on preformed clots demanded equal attention. This facet of the challenge was studied by treating induced clots with X, Y and Z. The proteins that have fibrinolytic activity dissolve the clots by degrading the fibrin sheets which hold the clot together. The standards of comparison employed here were Fibrin treated with saline (which failed to dissolve the clot even after 48 hours) and fibrin treated with a known anticoagulant like Urokinase (which dissolved the clot in a few minutes). While proteins X and Y were found to dissolve the clot in 120 minutes, Z achieved this feat in 90 minutes, thus validating their immense anticoagulant potential.

It was also observed that when brought in contact with untreated blood, X, Y and Z were all found to significantly prolong its clotting time to 22 minutes, a process that would normally take 5 to 8 minutes.

While these protein fractions show promising potential as anticoagulant and antiplatelet drug leads under simulated conditions, one has to bear in mind the challenges that are likely to accompany their introduction into living cells. For this purpose, the effect of these proteins on cultured cells will be studied. The degree of invasiveness of the fractions, their cytotoxicity as well as the minimum dosage at which they harm the cells will be investigated.
The final leg of my research will involve cumulating all the results generated from the laboratory experiments to erect a framework based on which the correlation between the physical structure of these proteins and their biological activities, and the mechanisms by which these proteins exert their activities can be comprehended.

Although the work towards the completion of my PhD will end with the fulfilment of the aforementioned objectives, the journey of research is a never-ending one. Everyday, mankind faces a new challenge that prompts the curiosity of a hundred zealous minds. They say ‘curiosity killed the cat’ but I think, curiosity is the cornerstone of science. It is, in fact, the only path that helps us unravel the mysteries of this big wild world that we call home.
A Unified Modeling Approach to Improve the Atmospheric Predictability

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The meteorological conditions of any place are dependent on the surface characteristics of the nearby regions. The changes in any of its property gets reflected on the atmosphere above it, which will further influence the circulation pattern surrounding it. These conditions are often responsible for triggering or suppressing the different atmospheric phenomenon. These changes follow the basic primitive Partial Differential Equations (PDEs) governing the atmospheric motion and thermodynamics. These equations are framed together and are discretized using various numerical difference schemes and form a numerical model. Every model has its own way of discretion and setup of other physical processes including boundary layer friction, atmospheric convection and cloud microphysics. Each model requires certain initial or boundary condition to produce a solution. The model solutions are known to be highly sensitive to these conditions. Certain studies have even shown that a model setup with minor changes in initial condition will provide entirely divergent solutions. Thus the major focus of the scientific community has always remained to improve the initial conditions so as to provide accurate results. This is the reason that the operational forecasting community relies always on ensemble runs. They provide a set of possible solutions which they call ensembles corresponding to imperfect initial conditions and mathematical model formulations to study the tendencies of possible future state.

The initial conditions are already highlighted by the scientific community, one should also not ignore the importance of boundary conditions. The boundary conditions help derive the near

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surface heat fluxes balancing the radiation budget and controlling the heat and moisture content of the atmosphere. Their importance has been realized by many studies in literature, a study performed by Prof. J Shukla has even shown that two divergent solutions can be made convergent for a region, if the boundary conditions are similar. Therefore, for better understanding of the atmospheric processes, the present state of the art numerical models use different schemes for representation of surface boundary conditions. Since these models are meant to predict the weather and climate accurately, any discrepancy in their parameterization will lead to a large bias and their usefulness will be questioned. Their reliability becomes more important when a natural disaster or monsoon condition is to be forecasted. The scientists have put in a lot of efforts to capture the Indian monsoon realistically, but when it comes to storm related warnings, our country still lags behind others. It is still struggling with modeling the atmospheric state for the extended and seasonal range scale prediction. The reasons are apparent; we rely on models which are developed by foreign countries, so they are better representative of their region. One has to gain more expertise in tuning in the input parameters to improve our spatiotemporal model solutions. Secondly, we are trying to represent our weather and climatic conditions through these models but hardly intend to modify their inherent parameterizations or add the required factors of our concern. For largescale flows, the scientific community always relies on General Circulation Models (GCMs). But due to the nonlinear atmospheric perturbations and chaotic conditions, the model solutions appear to diverge from their true state and, thus, one has to depend upon the observations. The GCM outputs are trustworthy only when they are merged with observations and an assimilated output is obtained for the scientific usage. The bias generated in these models arises due to imperfect initial conditions, atmospheric uncertainty and the lack in our present understanding of the physical parameterization of boundary surface and its response to the surrounding atmosphere. The GCMs are designed to be run on coarser grids (>50 km), therefore, the land surface distributions are not always accurate in them. Moreover, these models use only few surface parameters, rest of the others are being neglected. For example, the contribution of ocean is very limited to the atmosphere in these models. We are only using SST to force a GCM, rest of the other variables are either ignored or considered to be passive.

One of such variables is Salinity. The present modeling generation still considers it as a passive tracer and very few studies are based on it. But, it has a great impact on general circulation and evaporation rate. Studies have come up with the fact that when saline water accumulates, there is less vapour pressure over it. While Arabian Sea (AS) is known to be saline, Bay of Bengal (BoB) has relatively low salinity because of the freshwater input from the Indo Gangetic plains. Thus, BoB and AS have very contrasting influences on the atmosphere. The region above Arabian Sea remains relatively drier because of its geographical conditions and influences from the African region. On the other hand, BoB remains moist and is known to have higher CAPE during pre-monsoonal and monsoonal seasons. The negative heat fluxes during this period around these regions are still an open question to the scientific community. A more puzzling paradigm is observed when the SST over the bay remains warmer in spite of the negative heat flux anomalies. The BoB depressions intensify to form severe cyclonic storms in the presence of low fluxes, nobody knows how are
they fueled even when the surface fluxes are negative. The reasons can be synoptic or local, but are still unknown to the scientists. There are still uncertainties about flux tendencies and their relationship with subsurface parameters. Therefore, we need to perform more experiments with surface and subsurface parameters so that a reliable estimate of these variables and an acceptable parameterization is obtained.

Similarly, the representation of clouds in climate models has been a major issue till date. The lifespan of clouds is limited to a few hours and its spatial extent is also very low. Thus, the present day models are only capable of representing large scale cloud and rainfall patterns in them. They are unable to capture the convection explicitly with or without using any cumulus parameterization scheme at the cloud resolving scale. Since the radiation budget and atmospheric heat fluxes are highly dependent on these clouds, we are getting their unclear profile with respect to the climate. The same issue is with land surface schemes in climate models. The low resolution climate models contain a blurred profile of vegetation and topography values, this limits our understanding of subgrid scale processes that have much contrasting influence on climate. These issues are resolved in weather prediction models, but they cannot be used for climate-based studies. They are run at a higher resolution and are computationally more expensive.

Thus, we need to adopt a unified approach that can be used for weather as well as climate-based studies at finer resolution. The aim can be accomplished by making little changes in the model design and numerical schemes used in it. The ultimate goal of the meteorological community is to get, “Accurate predictability with least dependence upon the observations”. This can be achieved only if we become well equipped with theoretical as well as experimental physics.
India is the world’s 2nd largest smartphone market (according to The Hindu), however, lagging behind in manufacturing. With the existing huge market of smartphone, demand is also growing for electric 2-wheelers, e-rickshaws, 4-wheelers, etc. All of these devices require lithium ion batteries to operate. As per the projection by NITI Aayog, 300 billion U.S. dollar market (2,11,80,84 crores INR) exists only for electric vehicles, within the time period of 2017 to 2030. The report (‘India’s Energy Storage Mission’ 2017) also says, 80% of market coverage is possible if India goes for battery manufacturing rather than importing them. Undoubtedly, it is a great time for India to move into lithium ion battery manufacturing.

Now, the most shocking fact is that conventional lithium ion batteries are prone to catch fire. Case in point is the notorious Samsung Galaxy Note 7 cell phone saga in which there were a lot of incidents of phones unexpectedly catching fire or blow-ups, causing concerns among users, especially during air travel. In addition, incidents of electric vehicle battery explosion have been in the news. The story of Tesla Model S explosion in Florida is well-known. Recently, the Government of India has been pushing hard for the adoption of electric vehicles and renewable energy. Unfortunately, for a country like India, it is very difficult to run an electric vehicle as the average temperature is quite high in most cities in the country. Running an electric vehicle at a higher temperature will obviously increase the chance of battery explosion, risking life.

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Prof. Sagar Mitra’s research group at the Indian Institute of Technology Bombay (IITB) is involved in lithium ion battery fabrication from 2009. His team is focused on developing safe lithium ion batteries by replacing the commercial materials. Obviously, those materials should be made available in India at a low-price, compared to the commercial one. The author is one of the key members of Prof. Mitra’s battery fabrication team. He has come out with a new material which can be made available at a 1/4th cost of a commercial material. At the same time, that material can provide ultra-safety featuring higher energy density and impressive battery life. The synthesis of the material fortuitously happened at the IITB laboratory and was further scaled up for commercial level production with a very high conversion efficiency of more than 97%.

Now, the question is the meaning of ultra-safety and its importance for India. It is well-known that a lithium ion battery explodes due to dendrite formation. This can happen due to overcharging, avoid of protection circuit to make a cheaper battery, fabrication issues and many more. Scientifically, dendrite is actually a grass-like form of lithium metal which can grow like a spike onto the anode material, graphite. Thus, short-circuit the battery internally by connecting both the electrodes and can explode randomly. Fortunately, smartphone batteries are small compared to an electric vehicle’s. Hence, the concern is not so much for small devices. But a vehicle battery is much bigger. Hence, the safety issue must be considered. It is expected that an electric vehicle battery will not explode at any cost and at the same time should be capable to endure high-temperature operation. So, the technical meaning of ultra-safety for Indian is a dendrite-free battery which will never swell even at high temperature in any region of India. The current lithium ion battery technology cannot offer all of these criteria. So, the overall battery development has to be India specific. The new material, developed by IITB actually solve all these issues as it has been solely developed for India. With the advent of that material and India specific electrolyte, the battery does not allow dendrite formation as well as tolerate high-temperature operation which is suitable all over India. This is the reason we are calling it ‘ultra-safe battery’.
To prove the claim, ‘ultra-safe’, dendrite tests were performed with commercial and IITB batteries. Both batteries were opened at a fully charged environment in IIT Bombay, inside the inert atmosphere and the graphite and IITB electrodes were safely collected. Further, they were placed in sealed packs, separately. In the next step, both sealed packs were opened and the electrodes were exposed to air. As the battery was in charged condition, lithium metal was supposed to be present onto the graphite surface for the commercial one. For the IITB battery, it had to be different as the newly developed material was used instead of graphite. The assumption of this eye-opening experiment was very simple. Lithium dendrite catches fire immediately coming in contact with air. Exactly, the same thing happened at the time of the experiment. Commercial anode caught fire within 25 seconds of exposing to air. On the other side, IIT Bombay anode did not catch fire as the used material stored lithium in a different form which was actually non-explosive in nature. Hence, there was no chance of catching fire. For the IIT Bombay anode, the experiment was continued for 6 minutes; however, no signature of fire or getting warm was observed. This test can be considered as a benchmark test to examine ultra-safety of a battery.

In addition to ultra-safety, this indigenously developed battery offers many more features. Firstly, it can store 4 times the energy per unit mass as compared to graphite, which translates into a potential weight and volume reduction of ~15-20% and ~10-15%, respectively. Secondly, the material is cheaper to produce as compared to graphite because of the simplicity of the manufacturing process and cheaply available raw materials, especially in India. Lastly, this material is synthesized at a much lower temperature (~500 °C) as compared to graphite (~3000 °C), which makes it less energy-intensive or greener as compared to graphite. With this new material, lithium ion and lithium polymer batteries can be made available at 10-15% cheaper price compared to a commercial one. These batteries are widely applicable to mobile phones, tablets, laptops, electric vehicles, grid storage, telecom towers, drones (defense applications) and many more. Additionally, it can support the advanced fast charging feature which is a recent trend in smart gadgets.
The ultra-safe battery program at IITB under the direction of Prof. Sagar Mitra has been demonstrated several times in technological exhibitions. This year, the ingenuity and material innovation were awarded the first prize among 300+ participants in the Academia Industry Training (AIT) program, jointly organized by the Govt. of India and the Govt. of Switzerland. Recently, IITB had organized an R&D exhibition on the last convocation where our hon’ble Prime Minister was invited as the chief guest. This project was also demonstrated as a selected entry from IITB, in front of Prime Minister Narendra Modi.

The ultra-safe battery team (called InSTech) includes Prasit Kumar Dutta (the author), Sunil Mehta, Vishwas Goel, Aakash Ahuja, Abhinanda Sengupta, A. T. Shashidhar and Prof. Sagar Mitra. The ultra-safe technology involving material preparation has been filed as an Indian patent.