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#3 | May' 25

InSight

**InSight is a volunteer-run science magazine,
hosted by IISER Kolkata | scicomm.iiserkol.ac.in**

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From a BS-MS Student to An Independent Scientist: My Academic Journey

Sayan Choudhury (HRI Allahabad, Prayagraj)

Sayan Choudhury, an alumnus from the first batch of IISER Kolkata talks about his academic journey in this article. He reminisces about his education and research experiences at IISER, and his trajectory beyond IISER: first, as a PhD student and a post-doctoral fellow in the USA, and now as a faculty member at HRI. The article concludes with a message for current students.

REVIEWED BY
Abhirup M, Ayan B and Chitradeep S

SUBMITTED
Mar' 28, 2025

CATEGORY
Meta

I have very clear memories of the summer of 2006. I had just graduated from high school and was exploring options for the future. I had been fascinated by Physics in school and wanted to pursue it further. At that point, an advertisement for IISER appeared in the newspaper and I applied. After a round of counseling, I was allotted a seat at IISER Kolkata. During the counselling session, we were told about the vision of IISER. One of the big points that was emphasized was that science was becoming increasingly interdisciplinary, and the coursework at IISER would embrace this interdisciplinarity. I found this pitch very attractive and decided to join IISER.

The IISER journey: A walk down memory lane

Being the first batch at an Institute is a unique experience. For starters, there's no Fresher's welcome! However, at the same time, we received immense support in pursuing various kinds of projects. From the very beginning, the importance of getting involved in research was emphasized to us. Our lab courses had a project component, where we worked in groups on some experiments that we designed. This was a fascinating experience - we learnt to design problems, work in groups, and present our results. The courses were also very interesting at that time. Since, we had very few permanent faculty members, we were often taught by Professors from research Institutes in Kolkata. These professors often had a very different view on what should be taught to undergraduates, and consequently, we were exposed to several advanced topics. For instance, the first Biology class was a discussion about Daniel Koshland's article entitled 'The seven pillars of life'. In the third or fourth Biology class, we learnt about Ludwig Boltzmann and his entropy formula: We had a biology quiz where we were asked to design a question and then answer it. We were taught the RSA algorithm in the first semester Maths course by one of India's leading cryptographers. It was fascinating and motivating! The courses continued to be very interesting throughout the 5 years of my stay.

In this context, I must mention that a major highlight of my IISER experience was the approachability of our professors. It was a common sight to find young BS-MS students engaged in discussing science with senior professors at the local tea stall. These interactions played a significant role in our development as scientists. Another cherished tradition was special Saturday



Fig 1: First year Chemistry lab at the Salt Lake Campus of IISER.

morning seminars, where faculty members would present accessible 'colloquium style' talks on some cutting-edge topic. Through these interactions, courses, seminars and projects, I found that learning and doing science was great fun. On a side note, Inquista was conceptualized during our time, but the first edition took place after we left. A science fest was a unique proposition and there were a lot of spirited debates about the name of the event, but that's a story for another day.

Research experience at IISER

I was lucky to get opportunities for getting involved in research from the summer of my second year. During that summer, I was exposed to quantum information theory and performed some calculations on the entanglement entropy of cluster states. After the summer, Prof. Prasanta Panigrahi encouraged me to write up my results and submit it to *Prayas: Student Journal of Physics*. Writing this paper was a very enriching experience and it gave me a lot of confidence. Eventually, I ended up doing a more serious project with Prof. Panigrahi and our results were published in *J. Phys. A*. I also went for internships to other Institutes - SINP (as an Undergraduate Associateship Program), IISER Mohali (IAS Summer Fellowship) and the Georg-August University at Gottingen (DAAD Fellowship). These experiences exposed me to several other directions of research, and I finally decided that I wanted to work on a project in Condensed Matter Physics for my MS thesis.

I thoroughly enjoyed my final year at IISER. We needed to take very few courses that year, and the emphasis was primarily on the MS thesis. I worked with Prof. Siddhartha Lal and Prof. Prasanta Panigrahi for my thesis. Siddhartha had just joined IISER then and I was his first student. Siddhartha treated me as a bona-fide graduate student, and we had long and intense discussions on my MS thesis project. My project started as an exploration of the dynamics of Bose-Einstein condensates in one-dimensional optical lattices. I learnt about a lot of things - from the Gross-Pitaevskii equation to Luttinger liquids. As we delved deeper, we found that we needed to borrow ideas from non-linear dynamics to proceed further, and we roped in Prof. Anandamohan Ghosh for discussions. Even though, we never wrote a paper to disseminate these results to a broader audience, I am very proud of my MS thesis. We finally graduated in May 2011. Unfortunately, our convocation happened much later (probably 2013) and I missed it. However, I cherish all my memories of IISER Kolkata. It was a wonderful time!



Fig 2: The first Science Day celebrations at IISER in 2010.

Academic life beyond the BS-MS at IISER

After graduating from IISER, I went to Cornell for my PhD. Cornell has perhaps one of the most beautiful campuses in the world and I had a great time there. There were waterfalls on campus and the seasons were gorgeous. My IISER education kept me in good stead during my PhD and I had the opportunity to work with and learn from wonderful people like Prof. Erich Mueller and Prof. Jim Sethna. I obtained my PhD in 2017 and headed to Purdue University for my Postdoc. Amongst other things, I collaborated with another IISER-K alumnus, Rishabh Khare on a project during this period, and we wrote a paper together. After Purdue, I joined the University of Pittsburgh as a post-doctoral fellow. Interestingly, at Pittsburgh I worked with Prof. W. Vincent Liu, whose early papers on quantum chaos had been very important for my MS thesis. Finally, I joined HRI Allahabad as a faculty member in October 2022.



Fig 3: The first batch of IISER students after a visit to the Variable Energy Cyclotron Center.

The different positions I have taken up in my career have come with their own set of challenges and rewards. Out of these, my current role of a professor is probably the most satisfying and difficult. I am immensely grateful to my professors who have taught and mentored me, and now as I teach and mentor young students, I sincerely hope that I am able to share the joy of doing science with them.

Message for current IISER students

IISER Kolkata is poised to step out of its teens and enter the second decade. An Institute is known not only for the quality of research and teaching, but also for the success of its alumni. Despite its relatively young age, IISER-K has already produced a significant number of alumni who have established themselves in academia and industry. Our alumni have become faculty members and academic group leaders, established companies, and achieved success in corporate jobs. Current IISER students should tap into this network. Whether you are wondering about applying for a PhD/Post-doc/Faculty position or thinking of establishing a start-up, the alumni network can be a powerful resource who can help you. So, don't be shy about asking your seniors for help even if you don't know them personally. I wish you all the very best for your journey!



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Smart Moves: Temple Langurs Master the Art of Begging

Dishari Dasgupta (Department of Biological Science, IISER Kolkata)

In Dakshineswar, a popular tourist and religious site in Kolkata, primates like the Hanuman langurs are adapting in surprising ways. Once wild foragers, these temple-dwelling monkeys have learned to strategically beg from humans—using deliberate gestures to get food. A three-year study reveals their sophisticated tactics, with 81% success rate, showing how human interaction is reshaping primate behaviour in real time.

REVIEWED BY
Archita S, Ayan B, Ishita B, Shibraj S and
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SUBMITTED
Apr' 5, 2025

CATEGORY
Biology

For

many non-human primates (NHPs), human-modified habitats are no longer fringe territories—they're home (1). In parts of Asia, where primates like macaques and langurs hold deep religious or cultural significance, humans have historically shared space with these animals. Out of devotion, curiosity, or simply habit, people feed them (2). But what may seem like a small act of kindness or devotion is quietly transforming how these animals behave.

Previous studies show that in human-dominated spaces, NHPs are shifting from foraging leaves and fruits in the wild to relying on processed, human-provided foods (3,4). For these synanthropes, the line between "wild" and "urban" has blurred. The result? A new generation of primates that doesn't see humans as potential threats, but as reliable food providers. Over-habitation is no longer an exception—it's the new norm (5) for these urban adapted NHPs.

Urban Adaptation and Emerging Behaviours

Across the urban-rural gradient, these primates are not just tolerating human presence—they're thriving in it. Bonnet macaques in southern India make specific cooing calls to solicit food from passersby (6), while Balinese macaques have mastered the art of bartering stolen sunglasses in exchange for snacks (7). These examples aren't just anecdotes. They're signs of adaptation unfolding in real-time, shaped by human interaction. This study focuses on one such adaptation on another NHP – the Hanuman langurs (*Semnopithecus entellus*).

These striking black-faced monkeys, commonly seen around temples and residential neighbourhoods are revered as embodiments of the monkey god, Lord Hanuman. Owing to this religious significance, these langurs often receive generous offerings from temple-goers and devotees, increasing their interaction with humans (8). Hanuman langurs are folivorous colobines whose troop size generally ranges between 12-31. They live in harem system with most troops being uni-male multi-female in their demographic structure. They are found across India, with distribution ranging from Rajasthan to West Bengal (8). This study focuses on the Hanuman langurs of Dakshineswar, a temple and a popular tourist site located in West Bengal, India. Interestingly, they have developed a clever strategy. One that helps ensure the flow of food keeps



Fig 1: Dakshineswar Temple, it is a Hindu shrine and very popular Kolkata landmark. Built in the 19th-century, this temple is located on the banks of the Hooghly River.

coming their way. A strategy, that has not been previously reported for the Hanuman langurs till now (9).

Monkey see, monkey ask: Decoding their Strategy

In the heart of Dakshineswar (Figure 1), there lives a thriving troop of 31 langur individuals. Our team, curious about the behaviour of these langurs, began following the troop with a camcorder and notebook in hand. We observed them throughout the day for three years, splitting our time into three slots: morning (9 am to 12 pm), afternoon (12 pm to 3 pm), and evening (3 pm to 6 pm). As time went by, the langurs became used to our presence.

And during our observations, what we saw was more than just passive food acceptance. These langurs were *asking*. Not randomly or instinctively—but deliberately and repeatedly. Some stretched out a hand. Some stood upright on their hindlimbs. A few pulled people's clothes gently. These weren't clumsy bids for attention; they were patterned, strategic, and entirely directed at humans. A behaviour, that we did not observe in rest of our field sites (Howrah, Batanagar). We started noting them down carefully, eventually identifying seven distinct postures used to beg (Figure 2, Table 1).

One particular behaviour stood out. Near the temple's food stalls, vendors often encouraged visitors to feed the monkeys. The langurs, it seemed, had learned to watch these interactions closely. As soon as someone approached a vendor, langurs would arrive near them and begin to beg—not aggressively, but deliberately, positioning themselves within reach, near both the vendor's cart and the human. We called this behaviour *Provocation-Initiated Begging*, or BGpi.

Across our study period, we recorded a total of 1,293 begging events. Remarkably, 81% of these ended in the langur receiving food. These langurs weren't just lucky. Over time, the langurs had refined their strategies, becoming more efficient. This might be because each food that was offered to them acted as a positive reinforcement that strengthened this behaviour.

Some begging gestures worked better than others. BGpi had the strongest positive correlation with success ($r = 0.801^{***}$) (correlation values are presented as *** if the p-value is < 0.001). Other gestures, like simply extending a hand (BGe) or tugging at clothing (BGc), also showed strong correlations with successful outcomes. Interestingly, BGc—the most frequently used gesture—was also linked to *unsuccessful outcomes* ($r = 0.77^{***}$). At first, this seemed odd. But it made sense: being the most commonly used (34%), BGc simply showed up in both outcomes more often.

BEGGING CODE	BEHAVIOUR
BGp	Bipedal begging
BGq	Quadrupedal begging
BGe	Begging by embracing legs
BGc	Begging by holding cloth
BGh	Begging by holding hands
BGa	Begging with aggression
PB	Passive begging

Table 1: Ethogram of seven begging gestures as observed in Dakshineswar.



Fig 2: (a) The seven begging postures employed by the Dakshineswar langurs. Art credit: Sourav Biswas. (b) Langur begging using postures as seen in Dakshineswar.

Who Begs Best? Age, Sex, and Success Rates

We wanted to explore whether life stages played a role in begging outcome or not. Adult langurs, especially females, were far more successful in their begging attempts (Adults: $r = 0.96^{***}$, adult females: $r = 0.96^{***}$) than sub adults ($r = 0.5^{***}$) and juveniles ($r = 0.06$). Infants did not participate in begging behaviour. Interestingly, adult females had high correlation with both successful and unsuccessful events ($r = 0.75^{***}$). That might be due to sheer numbers—there were more adult females in the troop, and thus more adult female beggars (Troop details: 31 consisting of 1 adult male, 9 adult females, 3 subadult, 12 juveniles and 6 infants). Another fascinating detail was the importance of the sequence in which the langurs received food items from nearby humans. We found that first offer—the first food item extended to a begging langur, had the highest correlation with success ($r = 0.98^{***}$). However, correlation between successful begging

event and begging sequence decreased as the begging sequence proceeded further to sequence two ($r = 0.325^{***}$) and three ($r = 0.061$). While they were mostly quick to accept the first offering, there were instances where the langurs did not ‘like’ the first offering and went onto continue their begging gesture till they received their ‘preferred’ food item (Table 2).

We also ran a random forest model to test the strength of our observations. It predicted begging success with 96.43% accuracy. The model confirmed what we saw in the field: first offer, adult female, and the BGc posture were among the most critical factors influencing successful outcomes (9) (Figure 3).

The langurs of Dakshineswar are more than just passive dwellers of an urban landscape. They have cultivated a unique approach to food—one that treats humans like part of their natural ecosystem. Through repeated, successful interactions, they’ve developed a gestural solicitation strategy, where certain postures or cues prompt people to feed them. Their ability to observe, adapt, and innovate reveal that they are responsive not just to food, but also to context, timing, and social cues.

A Future Shaped by Our Choices

As cities expand and wild spaces shrink, these interspecies encounters are becoming more frequent. What we feed, how we react, and the boundaries we set (or don’t) are all shaping how animals learn to coexist with us. Feeding a monkey near a temple might feel like a spiritual act, or a small moment of connection. But for the monkey, it’s a lesson—a pattern reinforced, a strategy confirmed. Over time, these lessons accumulate. What we’re seeing isn’t just survival. It’s adaptation.

Understanding this behaviour means accepting our role in it. The monkeys aren’t just evolving in a vacuum—they’re evolving with us. And in that shared space, the choices we make—what we feed, how we interact—are reshaping animal behaviour in real time.

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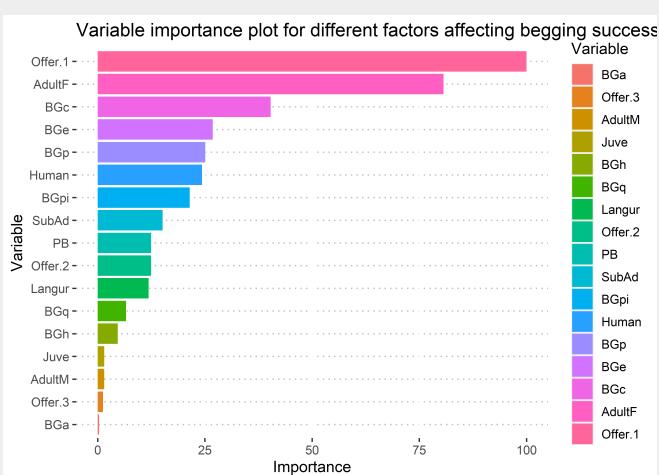


Fig 3: Variable importance plot generated after running random forest model. Here the Y axis has all the variables affecting successful outcome of begging and X axis has the importance of these variables on bringing about a successful outcome. First receiving sequence (Offer 1), Adult females and BGc contributes heavily to the successful outcome of begging.

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Dishari Dasgupta, currently a PMRF scholar at the Dog Lab, works under the joint supervision of Prof. Anindita Bhadra and Dr. Manabi Paul. Her research focuses on the urban adaptation of free-ranging langurs and their interaction dynamics with free-ranging dogs and humans. Since her studies are conducted in the natural habitats of langurs, she frequently travels between her six field sites across southern West Bengal. Beyond her academic work, she is passionate about making healthy snacks and recently launched her passion project, Alt Snacks.



Secret of the Wings: Nanostructures on a Dragonfly

Debanuj Chatterjee (Marie Curie Postdoctoral fellow at CNRS, University of Lille, France))

Dragonflies are one of the marvels of natural creation. The secrets of their flight dynamics, mate selection, predation, and visual information processing are all awe inspiring. During a trip to Puri in India, I had an interesting encounter with a group of dragonflies. A few of their pictures revealed some hidden mysteries about the nanostructures present on their wings. In this article we use scientific knowledge to develop a peeping hole into those hidden mysteries.

REVIEWED BY
Suman H

SUBMITTED
Mar' 04, 2025

CATEGORY
Biology

It was the summer of 2017 when we visited Puri, a coastal city, in eastern India. On the fall of evening, the beach side road was bustling with tourists as my parents hopped from one shop to another, testing their price negotiation skills with the local shopkeepers. While my parents were busy in their shopping spree, I was having a fun time clicking pictures of some beautiful handcrafts in a souvenir shop, with my camera. While clicking one of those pictures, something interesting caught my attention. I found out that some of the items hanging near a bright light bulb outside the shop had become a playground for stray dragonflies. This species of dragonfly is also known as the globe skimmer (*Pantala flavescens*) due to its long migratory flights [1]. Around a hundred of them swirled in a chaotic yet mesmerizing dance, basking in the warmth of the incandescent bulb. It was quite serendipitous to discover such a gathering of one of my favorite insects, the dragonfly, while I had a camera in my hand. Before continuing with the story, I cannot resist a brief digression to explain why dragonflies are my favorites as an insect species.

First of all, dragonflies are beautiful, with their large colorful compound eyes and their aerodynamic bodies, perfectly designed for flight (see some of my shots in Fig. 1). Additionally, dragonflies can control the flapping of their four wings independently, allowing them to take off vertically, fly in any direction—including forward, backward, right, left—and hover with unmatched precision. Moreover, while hunting, they can predict their prey's trajectory and make fine adjustments to their own, in real-time all while airborne. The secrets of their flight dynamics, mate selection, predation, and visual information processing are all awe inspiring, making me feel the true ingenuity of Mother Nature.

That evening, instantly I found myself capturing hundreds of close-up shots of these incredible insects. While taking these shots, I observed something very striking. In one of the shots, when I looked closely on the wings on the display screen of my camera, I noticed the insect's wings had a faint opaque blueish pattern (see Fig. 2 (a)). It was quite surprising for me, because I always thought dragonflies had transparent wings. Then I had a look with my bare eyes at those insects. Yes, their wings were transparent to my naked eye. What, then, was that bluish pattern that my camera was displaying on the wings? Trying to answer this question I came across one of those feelings where I realized scientific research is no short of being in the shoes of a detective, trying to solve a case where the answer is apparently omnipresent, yet invisible to the common eye (pun

intended). After thinking for a while on this, I had a closer look at some of the other images of dragonflies I captured the same day. I found out that in some of those images, the blue pattern was visible, while it was not present in the rest. For example, in the shot shown in Fig. 2 (b), we do not see the characteristic pattern clearly as seen in Fig 2 (a). In fact, the lower right wing in Fig. 2 (b) seems completely transparent. So, what was going on?

That evening, instantly I found myself capturing hundreds of close-up shots of these incredible insects. While taking these shots, I observed something very striking. In one of the shots, when I looked closely on the wings on the display screen of my camera, I noticed the insect's wings had a faint opaque blueish pattern (see Fig. 2 (a)). It was quite surprising for me, because I always thought dragonflies had transparent wings. Then I had a look with my bare eyes at those insects. Yes, their wings were transparent to my naked eye. What, then, was that bluish pattern that my camera was displaying on the wings? Trying to answer this question I came across one of those feelings where I realized scientific research is no short of being in the shoes of a detective, trying to solve a case where the answer is apparently omnipresent, yet invisible to the common eye (pun intended). After thinking for a while on this, I had a closer look at some of the other images of dragonflies I captured the same day. I found out that in some of those images, the blue pattern was visible, while it was not present in the rest. For example, in the shot shown in Fig. 2 (b), we do not see the characteristic pattern clearly as seen in Fig 2 (a). In fact, the lower right wing in Fig. 2 (b) seems completely transparent. So, what was going on?

The first clue came when I noticed that the blueish pattern appeared when the line joining the light source and dragonfly's wing was at certain angles to the line joining the wing and the camera lens (see Fig. 3). Does it ring a bell? The first thing that came to my mind was Mie scattering. Mie scattering describes how a small particle (typically dielectric) scatters incident light in different directions. The amount of scattering depends on the angle by which it is being scattered. In other words, when a small dielectric particle is illuminated by a beam of light, it scatters varying amounts of light at different angles. Also, an important aspect of Mie scattering is that it is efficient when the wavelength of the light is of the same order of magnitude as the size of the illuminated particle. Thus, if this blueish pattern on the dragonfly's wing was due to some small structures present on the wings of the dragonfly, those structures must have been similar in size to the wavelength of the incoming light (visible spectrum : 400 nm to 700 nm). In this case, the incoming light was in the visible spectrum, with wavelength ranging from 400 nm to 700 nm. I immediately remembered, a professor at IISER Kolkata once told us in our classes about nanostructures found in the feathers of a peacock. He said that a peacock's blue color does not come from pigment but instead results from light scattering by nanostructures. The same principle applies to some species of blue butterflies. Could



Fig 1: Shots of colorful dragonflies.

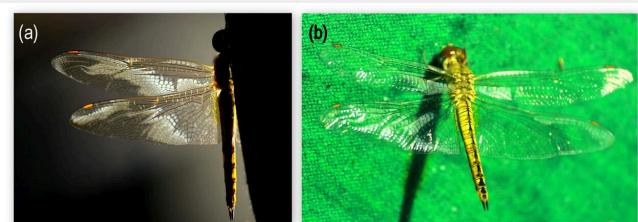


Fig 2: Two different shots of a dragonfly (*Pantala flavescens*) from two different illumination angles.

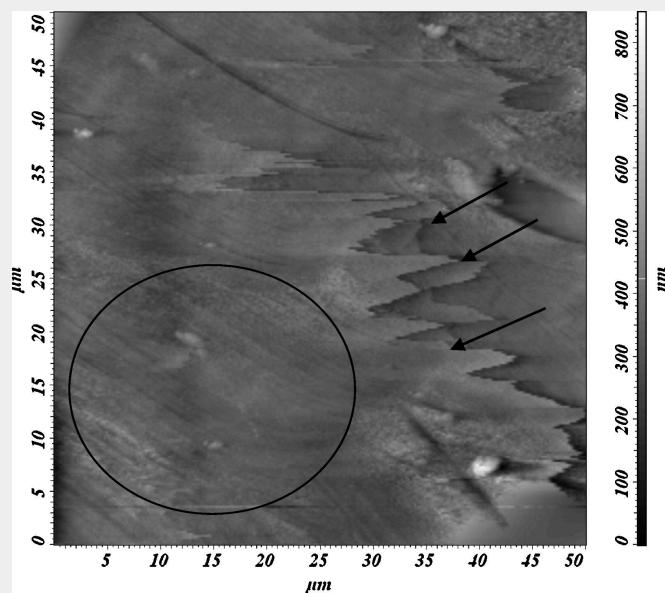


Fig 4: Atomic force microscopy image of a dragonfly's (*Sympetrum vulgatum*) hind wing, depicting a multilayer arrangement. Reproduced from [3].

the dragonfly's wings be exhibiting a similar phenomenon? It was time to find out!

To investigate further, I turned to Google Scholar. I found a few papers that studied the structure of dragonfly wings and to my surprise I found ample evidence of the presence of nanostructures on their wings [2,3]! In fact, dragonfly wings contain nanoscale pillars, ridges, and pores composed of chitin, often combined with a thin wax coating. An example is shown in Fig. 4, where an atomic force microscopy image from [3] is shown, indicating multiple nanoscale layers (see arrows) and a "ripple wave morphology" (see circular region).

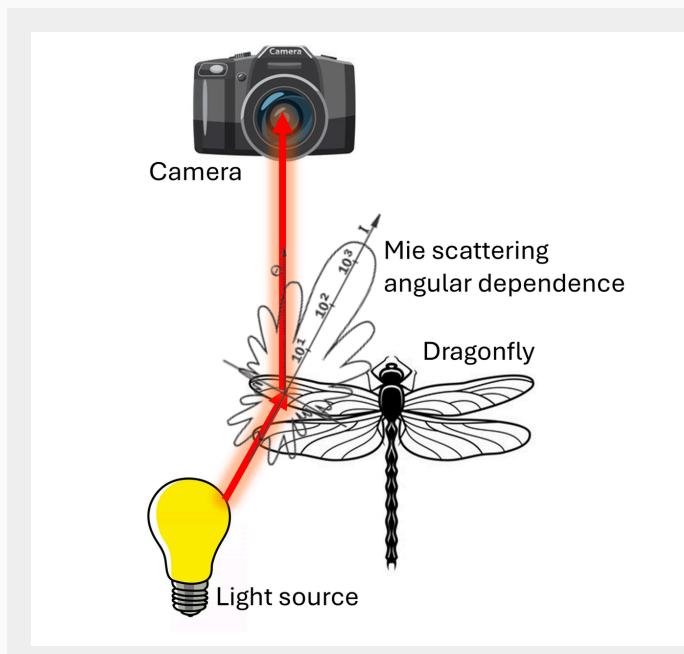


Fig 3: Illustration of angular illumination of the dragonfly's wing and the angular strength of Mie scattering.

But then shouldn't the dragonfly wings look blue all the time, like peacocks, rather than only from a particular angle? Maybe not. Here I remembered that those faint blue colors on the dragonfly's wings were not conspicuously visible to my bare eyes. I could only see them through the camera. This might suggest that these colors were outside the visible range of my eyes but detectable by my camera. The Canon EOS 1200D camera I used has a CMOS sensor which is capable of detecting wavelengths from approximately 350 nm to 1000 nm, though infrared wavelengths are often filtered out optically. As a result, the camera can detect wavelengths slightly beyond the blue end of the visible spectrum. This suggests that the scattered light had a spectral signature just outside the visible range but still within the CMOS sensor's detection band. Interestingly, a paper suggested that non-iridescent, angle-dependent color formation can occur at wavelengths between 350 nm and 500 nm due to electromagnetic resonances caused by the random aggregation of silica nanostructures [10]. However, whether this is the same mechanism for the dragonfly wings, needs to be verified through a detailed scientific investigation. Another interesting question that came to my mind was about the visibility of these patterns to other dragonflies. It is true that humans cannot see shorter than 400 nm wavelength on the blue side, but what about the visible range of dragonflies? It turns out that dragonflies have a particularly sensitive vision in the wavelength range of 300 nm to 500 nm [4,5], and body and wing colours carry important visual cues influencing their behaviour [5]. Which means one dragonfly should be able to see the patterns on another one. Perhaps this is why they were hovering around the bright light source, where they can see those structures in its aesthetic eminence. Or maybe those nanostructures play a role in their mate selection? In fact, research on the structural properties of the wings of a dragonfly witnessed a boom in the past decade. The wings' nanostructures revealed antibacterial properties [6,7], opening potential application avenues in biofilm design for medical implants [8] or even in the food processing industry [9]. In a world of emerging technologies, I strongly believe in the potential of the dragonflies to inspire the next generation of biomimetic innovations.

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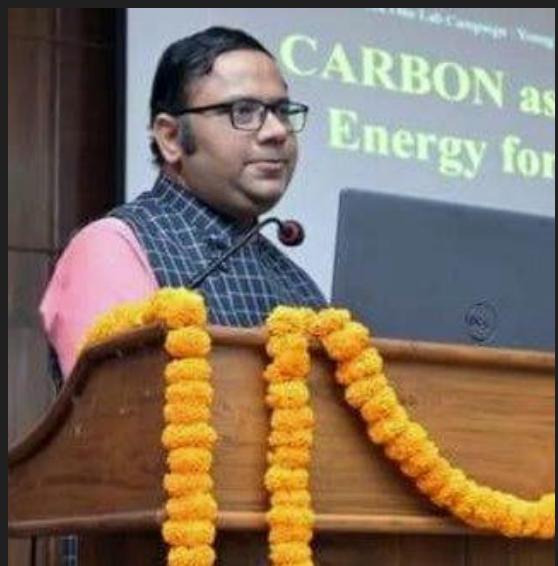
Debanuj Chatterjee is a Marie Curie postdoctoral researcher at the PhLAM lab in the University of Lille, France, working in the domain of light matter interaction, nonlinear fiber optics for development of advanced spectroscopic techniques. He obtained a PhD in Physics from Université Paris-Saclay, France in 2021. Curious as a scientist, he often finds himself treading down the alleys of history in search of philosophical, scientific and artistic aesthetics.



In Conversation with Dr.Chandra Shekhar Sharma

Swarnendu Saha (IISER Kolkata)

What does it take to become a professor at an IIT before even defending your PhD? In this captivating conversation, Prof. Chandra Shekhar Sharma from IIT Hyderabad shares his unconventional academic journey, the evolving landscape of Indian higher education, and the pivotal role of young scientists in shaping research and policy. From navigating academia without a postdoc to leading global scientific communities, his insights challenge traditional career trajectories. He also unpacks how IIT Hyderabad's innovative curriculum is redefining interdisciplinary education and fostering entrepreneurship.



SS:

Good afternoon sir. I am Swarnendu Saha from team InSight and it is nice to have you here. I plan to discuss some of your scientific background, your scientific journey and your journey with the INYAS. So to start with, where do you come from and how did you reach here? Where you are today?

CSS: Hi. I am Chandra Shekhar Sharma, currently Professor in Chemical Engineering at IIT Hyderabad and I did my B. Tech from Aligarh Muslim University (AMU) in Chemical Engineering itself. In fact, I did my doctoral studies directly after the B. Tech.

So, I didn't do my master's. After my Bachelor's, I did a job for almost a year in one of the CSIR labs. During that time, there was a special program on CSIR research internship. So, that is how I was in CSIR, National Metallurgical Laboratory in Jamshedpur, for almost a year in 2004.

And since then, I joined the PhD program at IIT Kanpur directly after B. Tech and completed PhD in 2010 and immediately after finishing the PhD, I joined IIT Hyderabad as a faculty in the department of chemical engineering. In fact, it was kind of a rare occasion when I received the faculty position offer from IIT Hyderabad without even formally submitting my PhD thesis.

SS: Really ?

CSS: Yeah, so, I mean, I got the faculty position offer in May 2010, while I submitted my PhD thesis in October 2010. And in December finally, I joined the institute and I defended my PhD after four months. So, I defended my PhD thesis after 2011, but I started guiding a PhD student from January 2011. So, that is how it was. (laughs !)

And yeah, I think it is a long journey now. I mean, it has been almost 14 years in IIT Hyderabad and now I am currently a professor there for the last two years. So, that is my professional journey. I joined the Indian Young Academy of Sciences(INYAS) as a member in 2017. This was the third batch because when the INYAS, was founded in 2014 and first batch of membership was in 2016 and then 79 joined. And later I became the chair of Indian Young Academy of Sciences from 2020 to 2022. Then I also became a member of Global Young Academy in 2020 and that is where I currently represent Global Young Academy as its co-chair. And this is only the second time that India has been honored with the co-chair, our founding chair of INYAS Dr. Anindita Bhadra being the first one. She was also the first



Fig 1: Prof. Sharma did his PhD at Indian Institute of Technology (IIT) Kanpur directly after his B.Tech

co-chair from India for the GYA and I am the second co-chair now for the Global Young Academy for 2024 to 2025.

Meanwhile, after becoming professor at IIT Hyderabad in 2022, I was then assigned the responsibility of a Dean of Research and Development, which I just completed in my two years tenure. So, I think that is my scientific and professional and leadership journey so far.

SS: So, from a student like me who is going for a PhD, we always think if we have to find food in academia, research academia, it is a long journey. People tell us, if I have been frank, it is a long journey. So, from there, standing out as a rare example before us; how did it happen and how does it feel?

CSS: I consider myself lucky because, between 2008 and 2010, many new institutions were being established. In particular, the eight new IITs (Indian Institutes of Technology) started in 2008, and each of them was aggressively seeking to expand and recruit qualified faculty members. During this time, I was about to complete my PhD, so I decided to apply. To be honest, I thought, 'Let me apply and see what happens.' Generally, in India, by the time you apply, get shortlisted, and are called for an interview, it takes almost a year.

Assuming that it would take a while for the interview call to come, hopefully after I submitted my thesis, I decided to apply. However, things moved much faster than I expected. Within three months of submitting my application, I received the interview call. I was interviewed in March, and by May 1st, I was offered a faculty position. Of course, it was a conditional offer, subject to the completion of my PhD. But I think that's how things turned up, favorably. I believe I made the right decision to join immediately after my PhD. The experience I gained in those initial years, setting up my lab and building my team, was just as valuable as any postdoctoral experience could have been.

SS: My next question would be if you look back as an IIT student and today as an IIT teacher, what similarities and differences are defined because you are from an IIT which needs no introduction, the IIT comfort. But frankly speaking, you are now in IIT which is much newer compared to even 50 years, not even 25 years. So, I mean what legacy IITs have for the previous seven IITs. So, I mean what differences and similarities do you find and then from the fun point, from the bench to the chair, How do you just change direction?



Fig 2: Prof. Sharma joined as a faculty at Indian Institute of Technology (IIT) Hyderabad in the department of Chemical Engineering even before formally submitting his PhD thesis

CSS: I think it's an interesting question because I was a PhD student at IIT Kanpur and then joined a new IIT that was still in the process of being established at the time. So, yes, there are a lot of differences, as well as similarities, and I would consider both aspects.

Of course, when you come from an established IIT like IIT Bombay, you have certain advantages: the reputation of the institute, the guidance from well-established professors, and the legacy that the institute creates. These advantages are definitely there when you come from older IITs.

However, when I reflect on my journey at IIT Hyderabad over the past 14 years, where I've graduated 17 PhD students—many of whom are now faculty in various IITs—I see both sides. While my students, as graduates of a new IIT, did not have the legacy or institutional reputation, they gained something equally valuable. If they worked on challenging problems, published quality papers, and most importantly, had access to the R&D infrastructure that these new institutes provide, they were at an advantage in certain ways.

For instance, at IIT Hyderabad, we have state-of-the-art research facilities, which in some cases, may even surpass those of older IITs. This infrastructure provides a significant edge, so if students are working on the right problems and publishing quality research, they can compensate for the disadvantage of institutional legacy.

I believe one should focus on the positive aspects rather than worrying about what can't be changed. Yes, IIT Hyderabad is 16 years old now, but that's something beyond our control. What we can control is how we leverage the best facilities, the new campus, and the positive research environment to do better science and better research, so we can be just as competitive as graduates from any other IIT.

SS: These days, we often discuss interdisciplinary work, especially in fields like basic sciences or, in my case, applied sciences. I had the opportunity to do an internship at IIT Roorkee, and I also spent a few days at IIT Kanpur and one day at IIT Delhi. When you look at the older IITs, they have many departments, schools, and research centers, and each of them often works independently, as they should. But the challenge is that, with the sheer number and diversity of these units, it can sometimes become difficult to achieve a truly holistic approach.

In contrast, for newer IITs like IIT Hyderabad, if someone unfamiliar with the institute looks at its website, they may notice that the number of faculties, centers, and departments is relatively smaller. The facilities might seem fewer compared to the older, more established IITs. In light of this, what is your opinion on this situation? How do you think the newer IITs manage to stay competitive and successful despite these differences?

CSS: From my own experience at IIT Hyderabad, I can confidently say that being a new institution, we definitely have certain advantages. For example, at IIT Hyderabad, we've introduced several innovations in both academics and research. Let me share a few examples.

In academics, we don't follow the regular semester system. Instead, we've divided the semester into three segments, and most of our courses are not semester-long. We call this approach *fractal academics*. The idea behind it is to introduce emerging areas of study to students, especially in the B.Tech program, without the limitations of traditional credit systems. For instance, we break down certain

courses into smaller modules, which allows us to free up credits for more advanced courses.

In the traditional system, there are core courses like electrical engineering or computer science, which might not be as relevant today. We minimized these courses and introduced more new, interdisciplinary ones. Additionally, we give students the flexibility to dive deeper into subjects of their interest, something not typically possible under conventional semester systems.

This approach helped us revamp our curriculum, addressing new challenges while providing students with greater flexibility in choosing their courses based on their interests.

We've also introduced several new initiatives focused on interdisciplinary research. For example, in our PhD program, we have an interdisciplinary track where two faculty members from different departments collaborate on a project. The students join a center for interdisciplinary programs and work under the joint supervision of two professors. These students are not bound to any specific department, which promotes more collaboration across disciplines. This model is different from the traditional co-supervision approach, where one professor is primarily responsible. Both faculty members are equally responsible for guiding the student.

Such initiatives would have been challenging to implement in older IITs due to their more rigid systems. Being a new institution without legacy constraints has allowed us to experiment with innovative ideas in both academics and research.

SS: Sir, you are saying that the IIT Hyderabad design is meant mainly for the manufacturing industry. So, should we term that as core subject or non-core?

CSS: It's a B.Tech program, a complete B.Tech program in Computer Engineering.

SS: When I was about to join an institute, we were giving JEE Mains, JEE Advanced, and NEET exams. During that time, we were asked mainly which subjects we were interested in. Given the variety of subjects, the first screening often came down to whether the subject was considered 'core' or 'non-core.' To me, core subjects meant electrical, mechanical, and civil engineering, while the rest were seen as non-core. Some people believed core subjects would



Fig 3: Prof. Sharma was a visiting research scholar at the UC Irvine

always have a lot of job opportunities because they're foundational, while others argued that those are outdated, relics of the past.

In today's world, people often say that yesterday belonged to Electrical Engineering and today belongs to fields like Quantum Computing and Artificial Intelligence. Considering this shift, IIT Hyderabad is introducing a program aimed at the manufacturing industry and is ranked third in innovation. This challenges the traditional view that everything is shifting to electronics or online industries. From that perspective, how do you see the future of core vs. non-core subjects? Do you think the boundaries between them are becoming more blurred, or is there still a clear distinction?

CSS: I think saying that everything will be online or AI-based is not entirely accurate. In my opinion, there are core areas like the manufacturing industry that cannot be overlooked. The Government of India's vision to make India a 'Viksit Bharat' by 2047 is built around this idea. If we look at any developed country—like the US, Germany, or Japan—they all have strong manufacturing industries at their core. No country can truly develop without focusing on this sector.

With all due respect to the IT sector, we cannot become a superpower or a developed nation just because of it. The manufacturing industry needs to grow. Initiatives like 'Make in India,' 'Digital India,' and others are focused on this very sector. For example, the government has already launched the Semiconductor Mission, with plans to manufacture semiconductor chips in India within the next few years. But here's the question: where do we have the skilled manpower for this?

This brings me to IIT Hyderabad's perspective. Two years ago, we started a B.Tech program in IC Design and Manufacturing. We're the only IIT to have introduced this program, with a view to meeting the future demands of the semiconductor industry. I'm happy to share that the All India Council for Technical Education (AICTE) has recognized our initiative and adopted our curriculum for this program. As a result, last year, over 100 engineering colleges across India began offering similar B.Tech programs.

So, if we aim to develop the semiconductor manufacturing industry, we need to prepare our engineers accordingly. Right now, we lack skilled professionals in this domain. This is why we introduced this specialized B.Tech program in semiconductors.

SS: Now the question comes that the manufacturing industry needs experts that the UG course is making. Now the fact is that, if we come out of academics, India is a country whose borders are very fine with very good neighbors (smiling!!). So we have to spend a good amount on defense. India is a country which has a huge number of stomachs to fill. So we need agriculture and then agriculture based industries. India is a country to feed, we have to export. So there has to be stuff that has to be exported. Now, are those students capable enough to go to any industry that requires them or still they are tailored for some specific?

CSS: When we talk about this B.Tech program in computational engineering or the manufacturing industry, it's not limited to a specific sector. It can cater to multiple sectors like defense, healthcare, and agriculture, which are crucial today. With the rise of AI, it's important to understand that AI is a tool, but it needs to be applied with subject knowledge. For instance, to apply AI in healthcare, you must have a background in healthcare, or in agriculture, a basic understanding of agriculture is essential.

B.Tech programs in computer science provide knowledge in software, hardware, and programming, but they often lack the depth in core subjects. This program, which combines core subject knowledge with computational and AI tools, offers a much stronger foundation for future jobs, especially in the manufacturing industry.

At IIT Hyderabad, we recognized the importance of AI early on. We were the first institute in India to introduce a B.Tech in AI and, globally, we were the third after Carnegie Mellon and Stanford. Our vision is broader, and that's why, alongside the B.Tech in semiconductors and computational engineering, we also introduced the B.Tech program in AI.

SS: My next question may not come across positively, but given the global scenario and specifically the current situation in India, we've been hearing that IIT Bombay is considered the most coveted institute, followed by IIT Kanpur, IIT Kharagpur, and IIT Delhi. In recent years, it's been observed that about 70-80% of students are getting selected for IIT Bombay, while the rest are not, which seems very concerning. This situation feels unacceptable in our society. While it's understood that not everything can be 100% distributed, the fact that IITs have always been seen as paragons of excellence, and are now seeming to fall short, raises a question.

Do you think this decline is due to the changing global landscape, or is it that the brightest minds are no longer choosing to stay in India? Or, is it that IITs themselves are not producing the best anymore? How do you interpret this situation? It's not something that's viewed positively, whether at the government level, among students, peers, or industry.

CSS: See, I think we need to look at this scenario from a broader perspective. When we talk about placements, the 70-80% you mentioned doesn't mean that the remaining 20% aren't doing anything. Over the past 5 to 10 years, there has been a significant rise in startups, many of which are led by our youth, including B.Tech students. At IIT Hyderabad, for example, there are students in their second or third years running their own startups and even employing others. This highlights that not all students who don't get placed in traditional jobs are without opportunities.

The landscape has shifted. Many students are now pursuing entrepreneurship, higher studies, or unique career paths that don't always fit the traditional placement model. While the number of students opting for higher studies has reduced over the years, it's a positive shift, especially after addressing the brain drain concerns.



Fig 4: Prof. Chandra Shekhar Sharma's Carbon Laboratory, IIT Hyderabad

The focus is no longer just on finding a job after B.Tech or pursuing higher studies.

Even for those completing a Ph.D., the mindset has evolved. It's no longer just about joining academia; there are opportunities in R&D, science administration, science communication, and science journalism, which are becoming more attractive career paths.

So, if we look at this from a broader perspective, I believe no IIT graduate is without a career path. The options are more diverse than ever before.

SS: So you have been in academic administration. The fact is that being a professor just with his students and lab and being in the administration, how do the two chairs differ?

CSS: I believe there's a difference of opinion regarding the timing of transitioning into science administration. Some say one should focus on research early on and move to administration later in their career. However, my perspective is different. Through my experience with INYAS, I've realized that young scientists often face challenges that are best understood and handled by their peers. If you identify issues that you feel strongly about, I believe you should step into administration, rather than blame the system or the seniors. By doing so, you can make a positive contribution and help bring about change.

When I became a professor, my director asked me to take on the role of Dean of R&D at IIT Hyderabad. At the time, we had over 2,000 projects, and this number has grown to nearly 4,000. Managing this growth came with significant challenges, especially given the changing policies and funding sources. For me, administration became a full-time job, but it didn't negatively impact my research. In fact, I published more papers than I had in previous years, largely due to the 14 years I spent in the lab earlier in my career.

I had support from postdocs and senior PhD students, which helped balance both roles. I prioritized administration during weekdays but dedicated weekends and evenings to my research. My students were supportive, knowing the demands of my administration role, which I greatly appreciated.

Being involved in administration, especially as Chair of INYAS during



Fig 5: Meeting with ISRO chairman Dr. Somanath to strengthen the research cooperation between IIT Hyderabad & ISRO, with Prof. Chandra Shekhar Sharma

the pandemic, gave me a broader perspective, which in turn made me a better researcher. Even as a researcher, you need leadership skills to manage diverse teams. My experience in administration helped me develop those skills. While you must prioritize one role over the other at times, I believe these two aspects—research and administration—are complementary, and being involved in both can make you a more well-rounded professional.

SS: And now, I will give you a small problem to solve. What you told me is two months, two and a half months long.

Let's imagine a scenario: A student from Central University of South Bihar gets an opportunity to work at IIT Hyderabad. He dedicates around two and a half months, working diligently on computational tasks and basic research, while also continuing his studies back at the university. By the end of August, he completes his work, and by December, a paper is fully ready for submission. By God's grace, he gets the chance to present this paper at a conference in Germany.

However, there's a catch. The university, being less lucrative compared to IITs, might not have the funds to support his travel. Moreover, since he is an undergraduate, he is not eligible for SERB or similar research funding programs.

Given that he is not an IIT student, how can he secure the money required to travel?

CSS: Yeah, I think you have a very valid point. And I totally support this, that we should have a more structured way of supporting those students.

And this number is not very big, but I think this is very important. So, I mean, thanks for bringing this point, highlighting this point. And I totally agree with that.

And well, right now, I am not in that. But yes, I think whenever I will get an opportunity to look into this matter from the institute point of view, or maybe at the national level, where I am part of some committees, I will definitely try to come up with some structured policy. Or maybe something like from the science academies, where we can have some kind of financial allotment for such students, undergraduate students to present their work, because you are right, that there are structured programs for the opportunities for the PhD students, but not for the undergraduate students.

So, but I agree, I mean, this has to be looked into. And it is more like a policy matter. But given the kind of discussions and given the kind of focus these days on undergraduate research, I am sure very soon we should be having this thing in place, at least at an institute level. So, that is what I can say right now.

SS: Can you please explain briefly what INYAS and GYA are?

CSS: See, INYAS, it stands for Indian National Academy of Sciences. It was established in 2014 by the senior academy, Indian National Science Academy, which is one of the oldest academies in the country. So, they came up with the idea in 2014 that young scientists should be having a separate exclusive platform where their voices can be heard, where they can also get some chances to network among the young scientists and also importantly contribute towards the science outreach, science promotion.

This is how this young academy was established in 2014 and I am here in Kolkata to celebrate its 10th year. In these 10 years, from

2014 to 2024, INYAS activities, if you see, I think we have done exceedingly well.

Coming to the Global Young Academy, this is also like another young academy, but it is having a global nature. It is connected with more than 100 countries and it is headquartered in Germany. It is supported by the German Academy of Sciences, Leopoldina, administratively and partially financially as well.

And as I said, Global Young Academy has representatives or membership from more than 100 countries. So, obviously, the perspective of the issues of young scientists in the Global Young Academy is much broader.

SS: As a professor or scientific administrator, do you think the problems I've presented can be controlled, partially addressed, or alleviated within the academic system? Specifically, if we focus on the "young" demographic, including undergraduate students (and even postgraduate students or PhDs), who often face challenges despite some funding opportunities—how can we address these issues? Is there a way to encapsulate or reform these community-based systems to better support them?

CSS: Especially when you look at the Indian National Academy of Sciences (INSA) during my tenure as chair from 2020 to 2022, my major focus was to expand the Academy's activities in Yash to encompass a broader understanding of young scientists. We started this initiative in 2014, and at that time, the focus was primarily on school students. However, we gradually expanded the scope of our activities.

If you look at today's situation, we have several flagship events that cater to different segments. We are focusing on school students, rural teachers, and training those teachers to further educate their students. We also have programs for PhD students, postdocs, and early career researchers—what we often refer to as "young scientists". Additionally, we've introduced separate flagship events specifically for women scientists, covering various stages of their careers, from college to PhD to postdocs.

Over the past five to six years, we've significantly expanded our activities. As I've mentioned, there's still a lot more to be done. I'm confident that in the coming years, we will continue to grow and become a strong voice for young scientists. When I say "young scientists", I'm referring to everyone from school students to independent early career researchers.

With such a wide target audience, our initiatives have been impactful, but of course, there's always room for improvement. These academies are dedicated to supporting young scientists, and yes, there is an age limit for participation, but we are continuously working to ensure inclusivity and broader representation.

SS: Apart from these in the very basic nature or the mode of operation, how does the Indian Academy of Science, Indian National Science Academy and the third National Science Academy, the three in Delhi, Allahabad and Bangalore are different from INYAS ?

CSS: As I mentioned earlier, our mandate primarily focuses on young scientists, which, for us, includes everyone from school students to college students, to PhDs, postdocs, and early career researchers. In contrast, INSA (Indian National Science Academy) in Delhi has a mandate that is more centered on the international representation of Indian scientists on the global stage. We also have the National

Academy of Sciences, which focuses primarily on science outreach, especially in schools. The Indian Academy of Sciences, on the other hand, operates more as a publication space.

When we look at these three academies, what was missing was a dedicated focus on young scientists. This is where INYAS came in and bridge that gap. When we started, we were advised by senior academics not to overlap with their programs, which was completely fine. I believe there was enough room and sector for us to work in, and we've been able to effectively address the needs of this space.

This is where INYAS stands out. When we talk about the fellowships from these other academies, they typically go to very senior scientists—50+ years old, I'd say. Of course, they bring invaluable experience and wisdom, but to execute visions and turn them into reality, you need energy, you need enthusiasm. And that's where young scientists come in. This is the distinct difference that INYAS brings compared to the other academies.

SS: Okay. So, I will come out of the jargon and basic question, why did you become a scientist? You could have become something else.

CSS: Yes, you're right. If I look back, I can say that throughout my life, I always had an inclination toward academics. By academics, I mean being a scientist or a professor. That's what I wanted to pursue. I had a deep interest in chemistry during my +2, as many students do, and like most of them, I thought that chemistry and chemical engineering were quite similar fields. But, as I later learned, that's not quite true!

When I was doing my +2 at Aligarh Muslim University (AMU), I would pass by the chemical engineering department, and it was like a dream to study in that department. That's when I decided to pursue chemical engineering at the B.Tech level in AMU. At the time, my parents weren't very supportive, as chemical engineering wasn't considered as prestigious as mechanical or electrical engineering. I had the option to switch to mechanical or electrical, but I decided to stick with chemical engineering, and I think it was the best decision I made. When you make your own decisions, you put in extra effort to make them work.

It was during my time in chemical engineering that I found my true interest in academics. After completing my B.Tech, I was clear that I wanted to pursue a PhD, so I didn't go for a master's. When I got the opportunity to work at the CSIR lab in the National Metallurgical Laboratory (NML), I thought it would be great exposure to research, which would complement my PhD aspirations.



Fig 6: Prof. Sharma did his B.Tech in Chemical Engineering at Aligarh Muslim University (AMU)



Fig 7: Post-INYAS's Mid Year Meeting (MYM-2024) at IISER Kolkata

Once I was in the PhD program, I was still focused on academia. However, I never imagined at that time that I would be joining the academic staff at an IIT. By the time I was 30 or 40, I started looking into post-PhD opportunities. Working at IITs showed me that academics and research are deeply interconnected. Although my primary interest was always in teaching, I developed a strong interest in research as well. I believe IITs are the best place where one can balance both academic teaching and research. I got the opportunity to do this for three years, and it was a very fulfilling experience.

SS: You mentioned that your goal was always to pursue academics. However, in India, a long-term career in academics is often not considered very lucrative. What made you choose it? What were the consequences of that choice for you?

CSS: Yes, absolutely. You're right. When I completed my B.Tech and shared that I wanted to pursue a PhD, my family wasn't very supportive, to be honest. Especially, as you mentioned, coming from UP, the typical expectation after completing BTech was to get a job. And that's what most of my BTech friends did. I graduated in 2003, and it was the time when the IT sector was booming. Companies like Infosys would come to campus for mass recruitment drives. It was the perfect time to secure a job, but I never attended any placement sessions in my life.

Looking back, one thing that truly shaped my career is that I started making my own decisions about my future right after 10th grade. I was very clear about my path. After 10th, I was in the state board, and then I joined Aligarh Muslim University. There, I had to choose between mathematics and biology. I was sure I wanted to go for mathematics because I had a strong interest in it.

In +2, my inclination towards chemistry became even stronger, and that's why I decided to pursue chemical engineering. While my parents weren't supportive of chemical engineering—mainly because it wasn't as well recognized for job prospects—I stood firm in my decision. Again, I took ownership of my choice and committed to it, despite the challenges. Similarly, when I decided to pursue a PhD, my parents weren't in favor of it either. Yes, there was resistance, but I knew I could handle it because I was confident in my decision. Clarity of thought, especially at an early stage, is crucial. It's something that's been incredibly helpful to me in my career.

SS: And you had the occasion of being a teacher, at least getting appointed before you got the PhD degree in hand. So, that was some kind of answer to anyone who is questioning you.

CSS: Well, I wouldn't say it was wrong, because when I look at it from a family perspective, I can now relate as a father of three daughters myself. Parents are always looking for the safest and least risky path for their children. In that sense, they are right from their perspective, just as I was right from mine. It's a matter of how you convince them, and before you can do that, you need to convince yourself first.

That's where clarity of thought and self-confidence become crucial. If you're not clear about your decision, you won't be able to convince others. I was able to convince my family, though it took time. Eventually, they were fine with it, but yes, there was initial backlash.

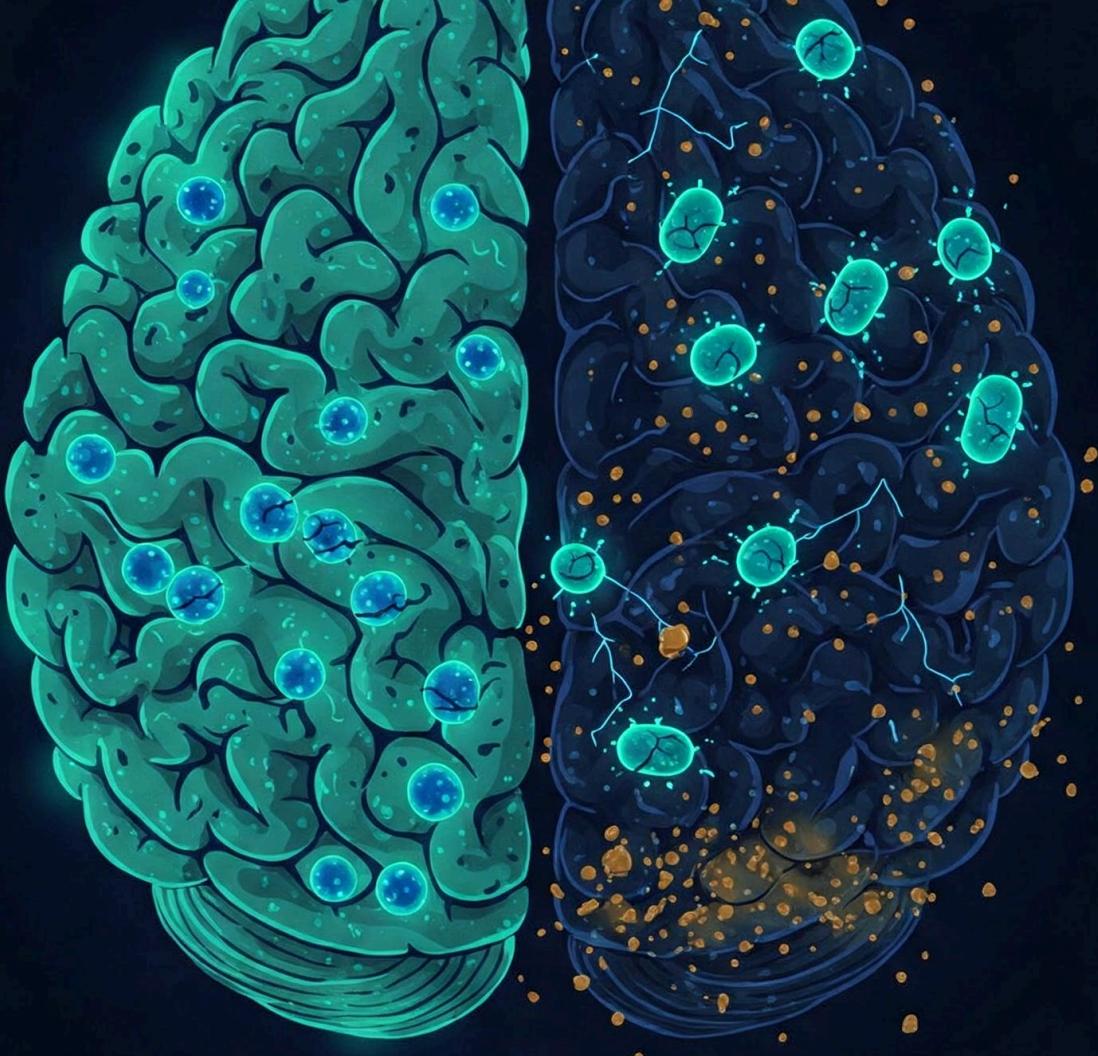
SS: Okay, so, last question, any final comments for the students and readers?

CSS: See, based on my own experience, my own journey, I must say that two things, one is *follow your dreams*, follow your passion. And secondly, have the clarity of thoughts in mind as early as possible because if you are confused, you will not be able to give your 100%. So, and to bring that clarity, you have to be aware of your surroundings. Like what is going on? What are the career options?

And these days, there are so many non-conventional career options that are emerging. And if you follow your passion, if you follow your dreams in that line, I think you will do much better. So, I think the first thing is to have clarity. Second, once you have clarity, follow it, follow your passion, follow your dreams. At a certain point of time, you may have to go against your peers, your parents, so be it. I am sure that if you follow and you are successful in that, I am sure of the chances and obviously the parents and others will also be in line with that. So, that is what I would say.

SS: Thank you, sir. It was nice talking to you.

CSS: Thank you.



Brain on Overload: Unlocking Hope for Rare Diseases Through Cellular Cleanup

Tisha Dash (Department of Biological Sciences, IISER Kolkata)

In Mucopolysaccharidosis VII, missing a key enzyme wrecks the cell's ability to clear out damage, draining energy and killing neurons. New research in fruit flies shows that resveratrol, a natural compound, can restore this vital process and protect brain cells, offering fresh hope against this devastating disease.

REVIEWED BY
Archita S

SUBMITTED
Jan' 09, 2025

CATEGORY
Biology

When

you think of waste management, the last thing that comes to mind is the human brain. Yet, deep within our cells, an intricate system works tirelessly to clear out damaged or unnecessary components, ensuring the smooth functioning of critical processes. But what happens when this cleanup system breaks down? For individuals with Mucopolysaccharidosis VII (MPS VII), a rare genetic disorder? This failure triggers a cascade of devastating events, culminating in severe brain damage and early death. In a landmark study, a team of scientists led by Professor Rupak Datta, from the Indian Institute of Science Education and Research Kolkata, has uncovered a crucial link between cellular waste accumulation and brain cell death in MPS VII[1].

When the Cell's Janitors Go on Strike: Understanding MPS VII

Imagine a city where the waste disposal system suddenly breaks down. Trash piles up in the streets, clogging the pathways, polluting the air, and slowly choking life itself. This, in many ways, is what happens inside the bodies of people with Mucopolysaccharidosis VII (MPS VII), also known as Sly syndrome, a rare but profoundly impactful genetic disorder, affecting roughly 1 in 300,000 live births [3].

MPS VII is caused by mutations in the GUSB gene, which encodes β -glucuronidase (β -GUS), a crucial enzyme that helps break down large sugar molecules called glycosaminoglycans (GAGs) [4][5]. Without enough β -GUS, these GAGs build up inside cellular recycling centers known as lysosomes, leading to widespread cellular dysfunction and multi-systemic manifestations.

Children and adults with MPS VII often face skeletal deformities, enlarged liver and spleen (hepatosplenomegaly), heart problems, and, most heartbreakingly, progressive brain degeneration [6]. Neurological symptoms like cognitive decline, motor difficulties,

and sensory deficits are stark reminders of how essential healthy lysosomal function is for maintaining brain health [7][8].

Today, enzyme replacement therapy (ERT) using vestronidase alfa offers hope by providing a functional version of the missing enzyme. However, there's a catch: the brain remains largely out of reach. Like an impenetrable fortress, the blood-brain barrier prevents the therapeutic enzyme from entering, meaning neurological symptoms continue to worsen even under treatment [9][10]. Additionally, ERT is lifelong and extremely costly, posing serious challenges for patients and families.

Recognizing these limitations, scientists have turned their attention deeper into the cell, looking for the root causes of brain cell death. Emerging research points toward disruptions in autophagy and mitophagy, the cell's internal clean-up and recycling systems [10][11][12]. In healthy neurons, autophagy clears out damaged proteins, while mitophagy removes broken mitochondria (the energy powerhouses). When lysosomes fail, as in MPS VII, these processes are disrupted. Damaged mitochondria accumulate, producing excessive reactive oxygen species (ROS), draining cellular energy

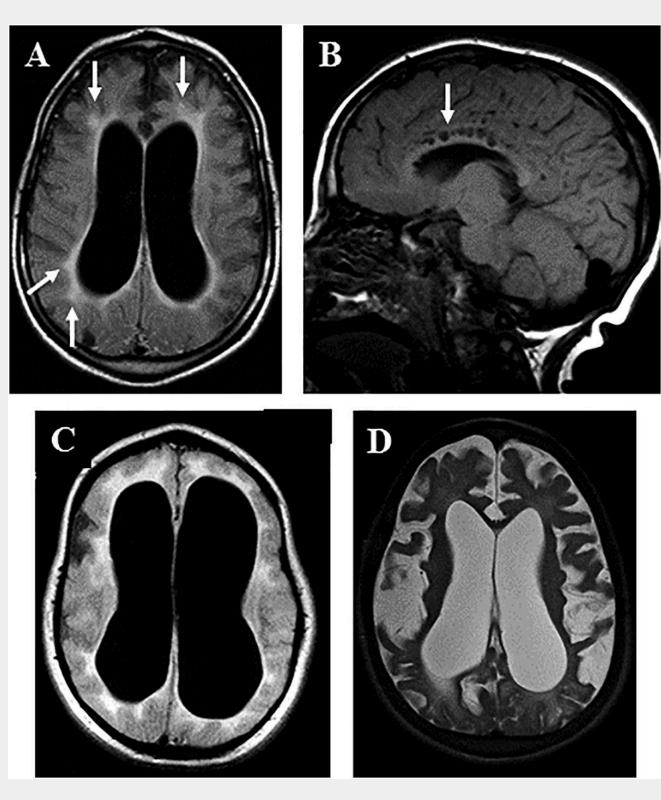


Fig 2: Structural Changes in the Brain of MPS VII Patients. This figure shows key anatomical changes observed in the brains of individuals affected by Mucopolysaccharidosis type VII (MPS VII), a rare genetic disorder [2]: (A) Moderate damage (lesions) in the white matter areas near the brain's ventricles (fluid-filled spaces), along with moderate enlargement of these ventricles (ventriculomegaly), which can affect brain pressure and function. (B) Noticeable widening of spaces around blood vessels in the corpus callosum (the large nerve fiber bundle connecting the two brain hemispheres), shown by arrows. (C) Development of hydrocephalus, a condition where excess cerebrospinal fluid builds up in the brain, leading to increased pressure and swelling. (D) Evidence of brain atrophy, meaning a loss or shrinkage of brain tissue, which can impair brain function.

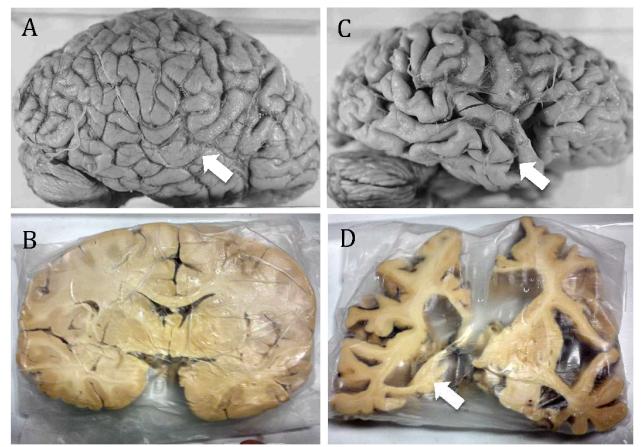


Fig 1: Neuroanatomical comparison of normal brain and diseased brain undergoing neurodegeneration. A,B) Normal Brain. C,D) Brain with pathology of MPS VII and Alzheimer's disease. B) Prominent atrophy seen in fronto-temporal areas involved with association functions (arrows). B, D) Coronal sections of A) and C) respectively. Where observe an enlargement of the ventricles and selective hippocampal atrophy (arrows) [15]

(ATP), and eventually leading to neuronal death, the true driving force behind the devastating brain symptoms [13][14].

Understanding these hidden cellular struggles opens the door to new therapeutic strategies, approaches that go beyond enzyme replacement to restore the brain's self-cleaning systems and protect neurons from dying. It's a shift from simply treating symptoms to targeting the core of the disease. For families facing MPS VII, each discovery brings a little more hope: hope that one day, the walls of the blood-brain barrier will be breached, and that both body and mind can be protected from the silent storms brewing within.

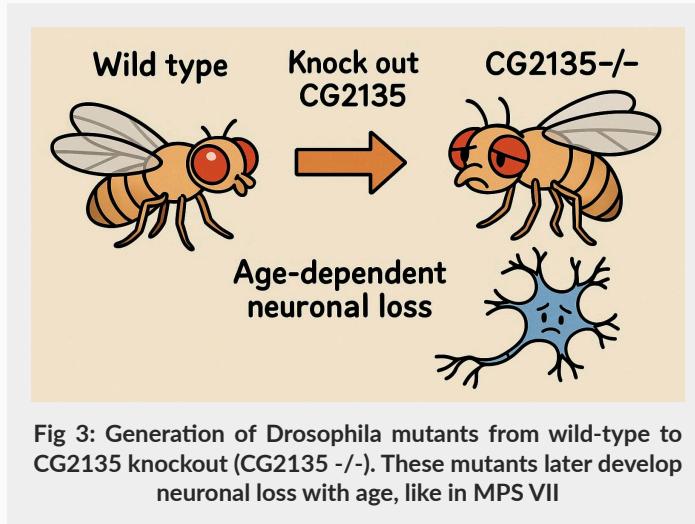
A Fly's Eye View: Modelling MPS VII Neurodegeneration in Drosophila

Sometimes, big insights come from small wings. In the search for better ways to understand and treat brain degeneration in Mucopolysaccharidosis VII (MPS VII), researchers have turned to an unexpected model: the fruit fly, *Drosophila melanogaster*. It may seem like a leap, but the choice is far from arbitrary.

Drosophila offers a uniquely efficient and genetically powerful system for modeling human disease. Its dopaminergic neurons, brain cells responsible for movement and emotional regulation, are well-characterized and display many features seen in human neurodegenerative conditions. In this study, scientists knocked out the CG2135 gene, the fly equivalent of β -glucuronidase (β -GUS), which is defective in MPS VII. As a result, these mutant flies (CG2135^{-/-}) exhibited age-dependent neuronal loss, mimicking the neurodegenerative decline observed in disorders like Parkinson's disease.

Closer inspection revealed widespread mitochondrial damage, a known consequence of lysosomal dysfunction. These failing mitochondria were unable to be cleared effectively - a failure of mitophagy, the cell's system for removing defective energy producers. Without it, oxidative stress increased, energy levels dropped, and neurons began to degenerate.

The strength of this model lies in its ability to recapitulate key disease features quickly and with genetic precision. But the very speed that makes *Drosophila* ideal for mechanistic insights also raises questions. Could its accelerated timeline of degeneration reflect the slow, complex pathology of human disease? Perhaps not exactly. Still, the conserved nature of autophagy, mitophagy, and mitochondrial regulation between flies and mammals provides a compelling reason to trust what we learn from these models.



By spotlighting how impaired lysosomal clearance and mitochondrial stress drive neuronal loss, this study lays the groundwork for future intervention - not just in flies, but potentially in humans as well.

The Mitochondrial Cleanup Crisis: How Impaired Mitophagy is Fueling Neurodegeneration

In the world of our cells, there's an unsung hero—autophagy. Think of it as the cell's janitorial service, working around the clock to clean up, recycle, and remove any unwanted materials, including damaged organelles. It's a process that ensures cells stay healthy and functional, a vital part of maintaining cellular balance. But what happens when this cleanup crew goes on strike?

This question lies at the heart of a fascinating new study investigating MPS VII, a rare lysosomal storage disorder. MPS VII is marked by defective cellular recycling mechanisms, and the study reveals that the brain suffers significantly as a result. The culprit? Impaired mitophagy - the specialized form of autophagy that targets and clears damaged mitochondria, the powerhouse of the cell.

Imagine your body's energy factories suddenly going dark. This is what happens in the MPS VII model, where defective mitochondria pile up in neurons, causing a dangerous ATP (energy) crisis. With energy running low, the neurons, unable to function properly, begin to die off in a process known as apoptosis. The result? Neurodegeneration, the kind of brain cell loss seen in Parkinson's and Alzheimer's diseases.

It's a grim scenario, but there's a hopeful twist. The researchers found that by enhancing mitophagy with resveratrol, a compound

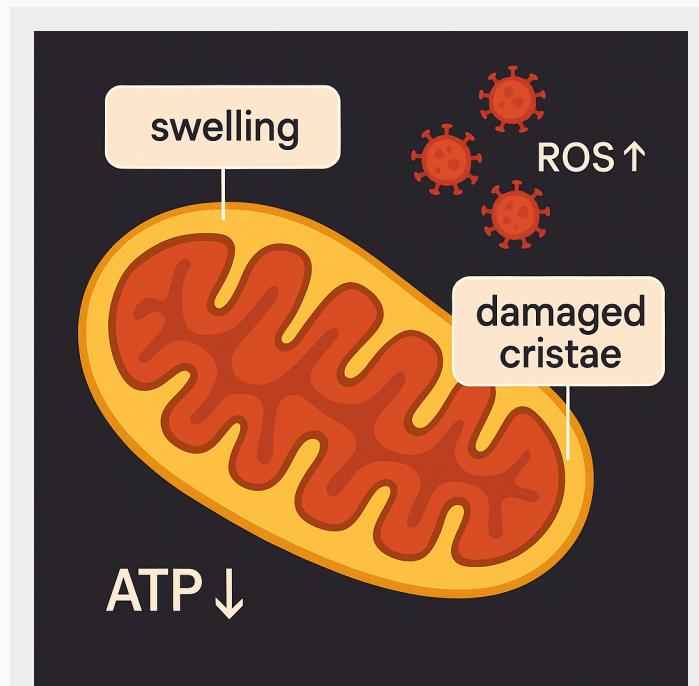


Fig 4: Visualization of mitochondrial damage in neurodegeneration. The swollen mitochondria with disrupted cristae indicate compromised mitochondrial function. Elevated reactive oxygen species (ROS) and decreased ATP levels highlight the cellular stress, contributing to neuronal degeneration.

known for activating the SIRT1 pathway, mitochondrial clearance improved, and dopaminergic neurons were rescued from degeneration. This opens up a fascinating possibility: could we harness this approach to stop or slow down neurodegeneration in diseases like Parkinson's and Alzheimer's?

Resveratrol and Autophagy Enhancement: More Than a Simple Fix

However, as promising as resveratrol seems, it's important not to oversimplify the complexity of autophagy modulation. Resveratrol, a well-known SIRT1 activator, has been identified as a potential therapeutic agent for modulating autophagic flux and enhancing mitophagy. The study showed that resveratrol improved mitochondrial function and neuroprotection in *Drosophila* (fruit flies), a model organism for neurodegenerative diseases. Yet, while the results are promising, there's a critical point to consider: could resveratrol alone be enough?

The research pointed out that while resveratrol enhanced mitochondrial clearance and improved neuronal survival, lysosomal function remained compromised. This suggests that enhancing autophagy through resveratrol alone might not fully address the underlying cause of MPS VII, which is rooted in enzyme deficiencies affecting lysosomal function. This raises an intriguing question: What if resveratrol's effects could be amplified by targeting other epigenetic regulators or combining it with other treatments?

Could targeting additional sirtuins or histone deacetylase (HDAC) inhibitors offer better outcomes? Moreover, a dual-pronged approach might be more effective. If autophagy can be enhanced

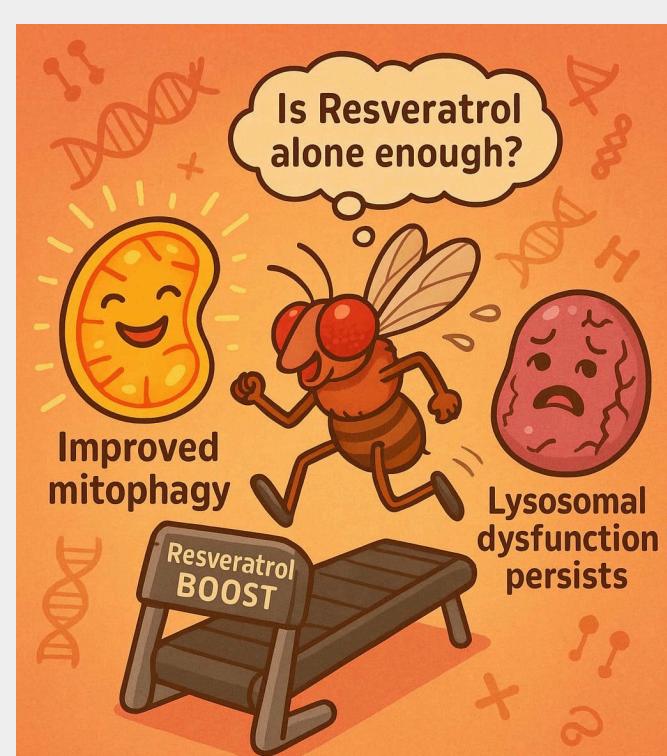


Fig 5: Resveratrol: A Partial Boost for Cellular Cleanup. Resveratrol enhances mitochondrial quality control by improving mitophagy in neurodegenerative disease models like *Drosophila*. However, lysosomal dysfunction persists, suggesting that while resveratrol gives a beneficial boost to cellular health, it's not a complete cure.

while simultaneously restoring lysosomal function, perhaps through enzyme replacement therapies - this could offer a more comprehensive treatment strategy.

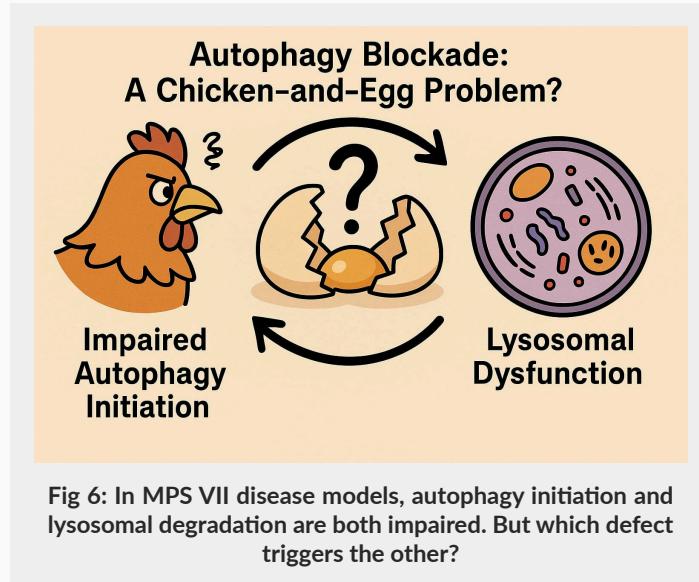
Autophagy Blockade: A Chicken-and-Egg Problem?

The downregulation of Atg1 (the *Drosophila* homolog of ULK1 in mammals) in the MPSVII model presents an intriguing paradox. Atg1 is crucial for initiating autophagy, and its reduced expression in this study suggests that lysosomal dysfunction might impair the initiation of autophagy. This raises the fundamental question: is the autophagy defect in MPSVII primarily due to lysosomal dysfunction, or is the failure of autophagy initiation contributing to the lysosomal burden? In other words, is this a feedback loop where one defect exacerbates the other?

The research provides compelling evidence that defective autophagic flux contributes to the accumulation of damaged mitochondria, but it does not yet answer the question of whether lysosomal dysfunction precedes or follows the autophagic defect. This "chicken-and-egg" scenario presents a fascinating puzzle for future research. Unraveling whether lysosomal dysfunction precedes autophagy impairment, or vice versa, could have profound implications for therapeutic approaches. For instance, if lysosomal dysfunction is the primary driver, then therapies focused on restoring lysosomal enzyme activity might alleviate both the lysosomal burden and the subsequent autophagic block. Alternatively, if autophagy defects are primary, then interventions aimed at restoring autophagic initiation could provide therapeutic benefit. Dissecting this feedback loop in greater detail is essential for developing more targeted therapeutic strategies for lysosomal storage diseases (LSDs) and other neurodegenerative diseases.

The Bigger Picture: Enhancing Mitophagy and Beyond

From a personal perspective, I believe that this research is a game-changer. Not only could it lead to new treatments for lysosomal storage disorders like MPS VII, but it could also offer a novel strategy for tackling other neurodegenerative diseases. The idea of improving mitochondrial quality control to reduce the build-up of damaged mitochondria could be the key to preventing neuronal death. But



it's also clear that to make a real impact, we need to think beyond a single pathway or treatment.

The future of neuroprotection might not lie in a single fix, but in a combination of therapies that target both upstream and downstream causes of disease. For example, combining autophagy enhancers with lysosomal enzyme replacements could offer a more robust therapeutic outcome, addressing both the root cause and the consequences of mitochondrial dysfunction.

As we continue to explore this concept, the future of neuroprotection looks a little brighter. With targeted therapies focused on enhancing mitophagy, we can turn the tide in the battle against neurodegeneration. After all, when it comes to keeping our cells - and our brains - healthy, sometimes a little cleanup goes a long way.

Broader Implications: Connecting the Dots to Other Neurodegenerative Disorders

While the study centers on MPSVII, the findings have far-reaching implications for understanding neurodegenerative diseases more broadly. Conditions such as Parkinson's disease (PD), Alzheimer's disease (AD), and Amyotrophic lateral sclerosis (ALS) share a common theme of defective autophagy and lysosomal dysfunction, which contributes to the accumulation of cellular waste, including damaged mitochondria. The research demonstrated that both mitochondrial dysfunction and autophagic blockade play crucial roles in the pathophysiology of MPSVII, reinforcing the idea that these pathways are central to a wide range of neurodegenerative disorders.

From my perspective, the study underscores the importance of viewing LSDs not in isolation, but as models for understanding common mechanisms of neurodegeneration. By shifting the focus from disease-specific pathways to shared cellular dysfunctions, such as impaired autophagy-lysosome pathways, we open the door for cross-disease therapeutic strategies. For instance, therapies

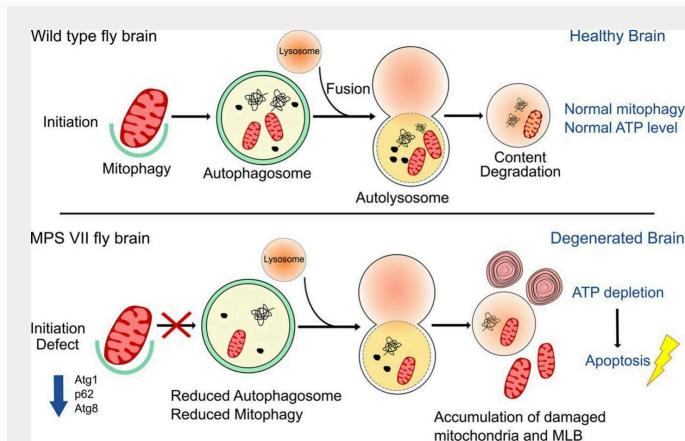


Fig 7: Schematic representation of the mechanism of neurodegeneration in the MPS VII fly. In the wild type (WT) fly brain, a healthy mitochondrial pool is maintained by the clearance of the damaged mitochondria through properly functioning mitophagy. This mitochondrial quality control helps maintain normal brain ATP levels. Autophagy deficiency in the MPS VII (CG2135^{-/-}) fly brain led to mitophagy defect, causing the accumulation of damaged mitochondria. This resulted in depleted ATP levels, triggering apoptotic cell death in the MPS VII fly brain. [1]

that enhance mitochondrial quality control could not only benefit LSD patients but could potentially serve as treatments for a range of other neurodegenerative diseases characterized by similar mitochondrial dysfunction.

Concluding Thoughts: A Roadmap for Future Research

In conclusion, this research provides critical insights into the role of mitophagy in MPSVII and its broader implications for neurodegenerative diseases. The study's results underscore the importance of defective autophagy and mitophagy in neuronal degeneration, showcasing both the value and the limitations of *Drosophila* as a model for human neurodegeneration. It raises important questions about the interplay between lysosomal dysfunction and autophagy initiation, as well as the potential for combination therapies that target both pathways. While *Drosophila* remains an invaluable tool in studying these processes, the next steps should be to validate these findings in mammalian models to better understand their translational potential.

Ultimately, the concept of enhancing cellular clearance mechanisms, whether through compounds like resveratrol or novel mitophagy-specific agents, holds promise for treating not only MPSVII but also a wide spectrum of neurodegenerative disorders. This study sets the stage for future research that could lead to more effective, targeted therapies for these devastating diseases.

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The Cora Ball - Protecting Millions of Ocean Acres by The Second

Sharanya Chatterjee (Second-year BS-MS student, IISER Kolkata)

Washing your blue shirt might seem harmless, but it can release microfibres that harm ocean life. Microfibre pollution—from textiles, hair, and pet fur—poses a growing threat to marine ecosystems. The Cora Ball, inspired by coral reefs, uses hydrodynamics to trap these fibres during laundry, reducing pollution by up to 31%. Praised by marine biologists and environmentalists, Sharanya Chatterjee takes you through the journey through her article showing a simple yet effective household solution to this global issue.

REVIEWED BY
Budhaditya B and Ishita B

SUBMITTED
Feb' 1, 2025

CATEGORY
Environmental Science

The Problem of Microfibers

The news flashes across the television screen one fine morning: The proportion of aquatic life affected due to microfiber pollution is currently at 100 million; the number rises everyday! You pause to look for a second with the laundry in your hand, maybe turn the volume up. As you load the clothes in the washing machine, turn the knobs, you shake your head at the state of the times, even telling your toddler that climate change should be fought against. However, do you pause as you chuck that blue shirt into the machine and wonder what the enemy looks like? Well you don't have to look that far. The blue shirt and millions like it, or in other words, any kind of textile and fibre are one of the primary reasons for *microfiber pollution*.

Synthetic textiles, which are made up of polyester, nylon, acrylic and other fibres, almost singly contribute to **engineered micro-plastics** in the ocean, accounting for 35 percent of the total volume. These microfibers are released from fabric, which can be as small as three microns, a thirteenth the width of a single strand of your hair, are too small for water treatment plants to remove. These invisible minions make their way into the ocean at large scale, allow organic pollutants like DDT and PBTs to attach, and **accumulate in the bodies** of the aquatic life like fish, and its consumers like birds and humans, becoming more and more toxic with increasing concentrations. According to a researcher at the University of Plymouth, up to 700,000 micro-fibres can shed from a 6 kg household load of textiles. And thus every time you chuck that skirt in for a wash, you plot for death of aquatic life across an acre of ocean.

Rachel Miller and The Cora Ball

So what is the way out? Should we go back to the Stone-Age and live off bark skin and leaves and discard textiles totally? Well that might be a nice way to spend a summer afternoon but definitely isn't practical enough for today's life. However, a certain **Rachel Miller** wasn't ready to sit with her hands on her lap. A marine archaeologist and a windsurfing instructor went to help clean up an island off the coast of Maine in the north-east of the US in 2009. There had been a heavy storm, and she found the beach covered in debris, most of which was washed-up fishing gear. And that made the film-roll click into place and Rachel made up her mind to make a difference – prevent plastics from ever reaching the ocean. And that brings us to Miller's big reveal – the **Cora ball**. While it looks something you will buy to your kid from a toy shop, it does more than it shows. Cora Ball's surface is made up of coral-like stalks



Fig 1: Coral Structures in the ocean. Miller's team found inspiration in nature, specifically the structure of coral, to design Cora Ball, which captures microfibers while allowing water to flow through. Coral's unique anatomy guided their design. [Photo by Francesco Ungaro]



Fig 2: Cora Ball prevents fiber shedding from clothes, extending their lifespan and reducing microplastic pollution in our waterways. The Cora Ball's hydrodynamics are inspired from the motion of Coral Reefs to trap food particles from the ocean water

which trap microfibers while water flows through it. Coral reefs and sea anemones have tentacles with surface adhesion properties on the surface, mechanical motion of which helps to filter and trap food particles from ocean water. Inspired from the same, the Cora Ball's stalks deploy turbulence and speed fluctuation hydrodynamics which makes the circulating water **filter out the microfibers**.

The Cora Ball is easy to use as well. You have to put it into the washing machine along with the laundry and as your clothes get washed the Cora Ball **traps the microfiber** breaking off from the textiles as well as hair stuck to the clothes from the circulating water and stores it in its complex branching morphology. And as you open the lid, you take the Cora Ball out with the pollutants including textile fibre and shed fur and hair stuck to it .

Impact

The Cora Ball can be easily cleaned by parting the stalks and removing the fibre mass and discarding it into the trash. The Cora



Fig 3: Rachel Miller – A visionary environmentalist driven by a passion for ocean conservation. She has a bachelor of arts in anthropology (underwater archaeology) from Brown University 1993 and is a USCG Captain with an endorsement for auxiliary sail.



Fig 4: The Cora Ball team, from the left: Brooke Winslow, James R. Lyne and Rachel Miller. Rachael, James and technical designer Brooke Winslow joined together to create Cora Ball and launched on Kickstarter in 2017

Ball also doesn't have to be cleaned every day. The fibres need to be removed only when it becomes a sizeable mass. With the Cora Ball you ensure that microfibers do not get carried to water bodies and prevent harm to the aquatic life and the ecosystem as a whole. Later the Cora Ball is to be cleaned and becomes ready for future use again. Miller claims that even if **just 10% of US households** used the Cora Ball it would prevent an equivalent of 30 million water bottles from washing into public water bodies every year. It reduces microfiber pollution by 31% as the numbers suggest. Although it is not yet available in every country including India but Miller and her team aspire to soon turn over this fact and make Cora Ball available to combat micro-fibre pollution globally.

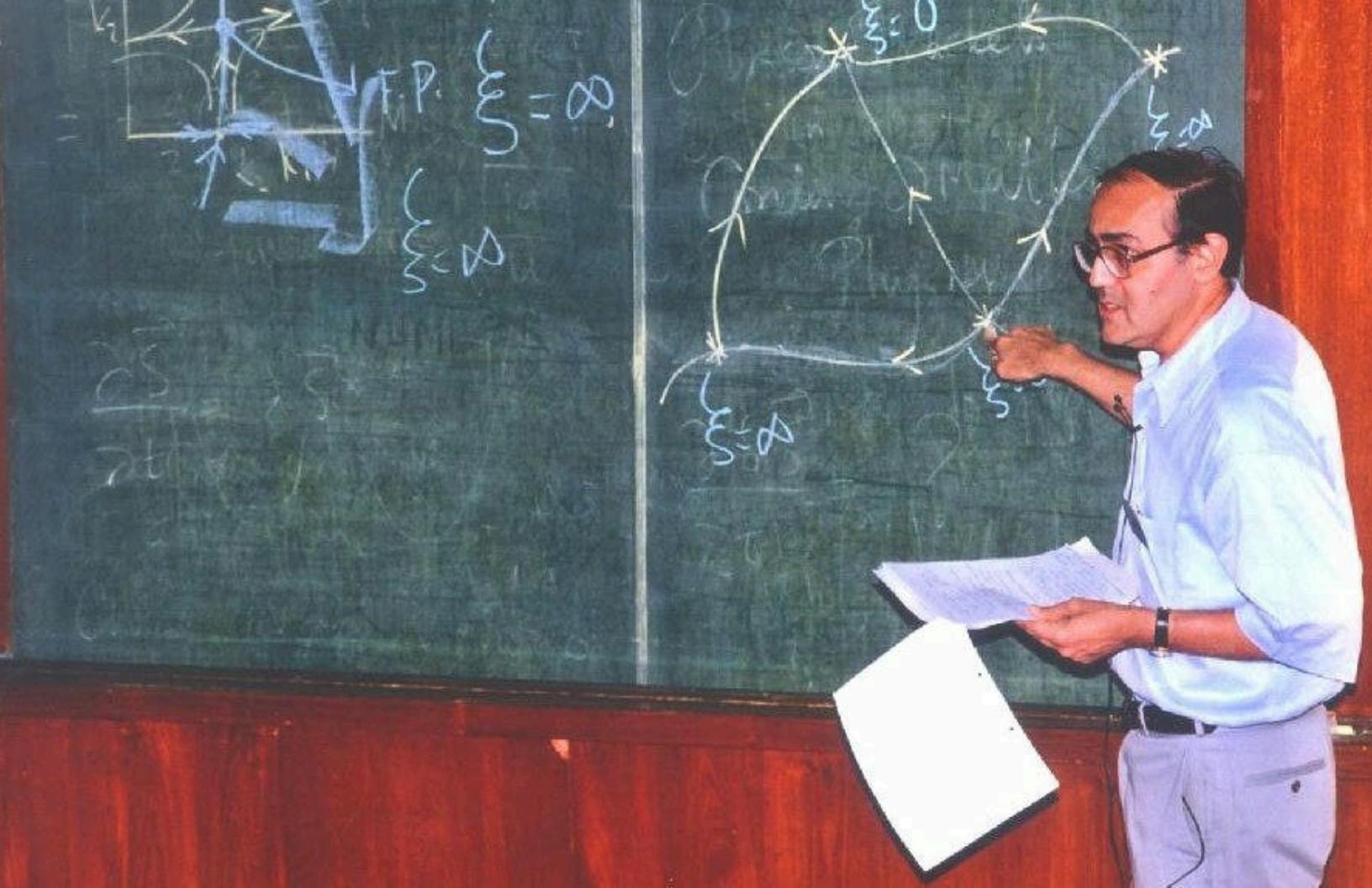
Be it London's Imperial College or Miller's own Rozalia Project, people miles apart work in unison to reduce microfibers from entering the sea. This blue ball which works wonders shows how ingeniously one can make a small difference every day, through the simplest of mechanics. What started as a one-room project is in the BBC news today, with a potential of saving millions of lives. And with this words of Fullerene come to mind, "The only way to predict your future is to design it." Happy wondering!

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In Conversation with Prof. Mustansir Barma

Swarnendu Saha, Manish Behera (IISER Kolkata)

What sparks a lifelong passion for physics—and what does it take to lead one of India's premier scientific institutions? In this rich and wide-ranging conversation, Prof. Mustansir Barma opens up about his journey from a curious schoolboy writing letters to textbook authors to becoming a celebrated physicist and the founding director of TIFR Hyderabad. He reflects on the essence of randomness, the beauty of phase transitions, the art of asking questions, and the quiet power of effective leadership.



SS:

Good morning sir. I am Swarnandu Saha from InSight. First things first, are you from Bombay?

MB: Yeah, I was born in Bombay. For the last 9 years or so, I have been at TIFR Hyderabad.

SS: You studied at St. Xavier's College, Mumbai, if I am not wrong, after which you went to the United States.

MB: Yeah, I went to the State University of New York at Stony Brook.

SS: I would like to know how you reached the position you are today, in the academic sphere. Were you inspired by your family, or was it more of an accident?

MB: Yeah, so it's like this. I had an interest in physics. I want to tell you about my school days because I will tell you about an incident from my school days.

What happened is that we had a textbook on light and there was a statement there that if you have two parallel mirrors and a candle in between, you will get an infinite number of images. Now, I sort of found that not quite right in that light has a finite speed of propagation. So, if we put the candle there, there would be reflection from one mirror to the other and soon.

So, the number of images will keep increasing in time but in a very short time, there will be no image because the light has not gone and come back. I wrote to the author. At that time we were in the 1950s, this was an English book. So, this person was in England. I wrote to him and he wrote back a nice letter saying that he is glad that I read my books and think about what is written and he sort of agreed with me that in a finite time, you won't have an infinite number of images.

So, that incident sort of sparked my confidence and then there were many other things in school and college. So, I really wanted to take up physics. Now, when I told this to my parents, my father was actually quite supportive for various reasons. When he was young, he had done engineering but he was asked to step into the family business because his father passed away. So, he had a sympathy for people who wanted to do academics. So, that is how I have done it.

SS: Now, coming to science, you work in statistical physics. When I as a layperson hear the word random, I do have some idea of what that means. But to a practising physicist such as you, what does randomness really mean?

MB: Randomness means to me the same thing that it means to everybody else. Something that is not predictable because it could be this way or that way. There are options and there might be different probabilities or different options so that you cannot be sure which one will happen.

So, that is what I would say is the characteristic of randomness. You are not sure of what will happen in time.

Randomness in space, we all have an intuitive idea - things are scattered without any pattern or arrangement, you know. So, my idea of randomness is the same as anybody else's, I think.

SS: So, if we could find out a mechanism to determine which one is going to be picked, then do you think this concept of randomness will become redundant?

MB: Not in such a sweeping sense but it is also true. See, there could be some things that are intrinsically random like nuclear decay which involves beta particle emission - from one emission to the next, it is truly random. There are other things which are effectively so random that you, I mean, well, which are effectively very well described as random.

For instance, when you toss a coin, you know it will end up as heads or tails and the question is why do we think of it as equally probable? Well, that is because actually as we know the laws of physics including, I mean, involving classical mechanics should determine exactly what the outcome would be - either heads or tails. But it is complicated enough that effectively indeed it is a random process.

So, what I am trying to say is that things that are complicated though intrinsically described by deterministic equations will effectively be random. People should use effective descriptions and the reason is very simple - because they are simpler. Any description that is simpler is good and useful and certainly, effective randomness is an example.

SS: I understand. My next question relates to how we traditionally learn about phase transitions in school. We are taught that given a temperature and pressure, ice changes to water, and water changes to vapor as temperature increases. However, we often overlook the role of pressure. While temperature is the primary factor we focus on, a slight change in pressure near the triple point—even while keeping the temperature constant—can prevent a phase transition from occurring. The fundamental idea remains that once a certain boundary is crossed, a phase transition takes place.

MB: That's an interesting point. When we talk about phase boundaries, particularly the transition between liquid and vapor, we see that this boundary terminates at a critical point. However, the solid-liquid boundary behaves differently—it does not end at a critical point but rather continues indefinitely. The reason lies in symmetry considerations.

Liquid and vapor phases share the same symmetry—both are homogeneous and isotropic. This allows for the existence of a critical



Fig 1: Mustansir Barma accepting the INSA (Indian National Science Academy) medal for Young Scientists in 1980. [Source TIFR H]

point where the phase boundary terminates. However, the solid phase has a fundamentally different symmetry. In a solid, atoms are arranged in a structured manner, meaning it breaks continuous translational symmetry. This broken symmetry prevents the solid-liquid transition from terminating at a critical point because, if it did, one could theoretically move around the phase diagram and bypass the phase transition entirely, which is not physically possible.

A particularly fascinating case is water under high pressure. Unlike many other substances, water exhibits multiple solid phases, meaning that at very high pressures, the phase diagram becomes highly complex, with over 10–11 different solid phases discovered so far. Each phase is separated by its own phase boundary, creating a web of phase transitions rather than a simple linear boundary.

This concept of symmetry-driven phase behavior is fundamental in statistical physics and quantum mechanics, and it was originally formulated by Lev Landau. His argument explains why phase boundaries can terminate at a critical point only if the phases involved share the same symmetry—as seen in the liquid-vapor transition. However, for solid-liquid transitions, where symmetry fundamentally differs, such a termination is not possible.

SS: Let me try to understand this from a different angle. You mentioned earlier that in theory, for a very short time interval after I place the candle, there is no image of it on the mirror. In the same way, if I consider the system over a very short time interval, there will be a region where the phase is morphing. Can you please explain or help me visualize what exactly is happening there?

MB: Well, the first thing is that you must understand what is meant by this temperature, pressure phase diagram and what it is referring to is phases which have reached equilibrium. So, the diagram with pressure and temperature and so on applies only to equilibrium phases of matter. Now, equilibrium is a state which is reached in principle if you wait very very long - you have to wait really long for a system to reach equilibrium and for example, if you change the temperature, it takes some time for the system to equilibrate.

So, the diagram, that phase diagram applies only to phases and systems which are actually in equilibrium. The moment you say that you do something and for a time, short or you know finite time, the system may or may not have reached equilibrium in that time, it probably would not, I mean it is a very short time and so this diagram on its own will not apply, but the fact is that as time goes by, you will indeed transit to the other phase. So, the question you

ask is actually very interesting and a matter of current research. How do you accomplish a phase transition, how does one phase change to another in time? The answers are also very nice and finally, very simple.

So, there are regions with phase 1 and regions of phase 2 and these are small if the time is low. As time passes, these regions grow, they are still not very very large, but they are bigger than they were and you can define if you like a typical droplet size. So, as time passes, that size increases.

When that size reaches the size of a container, you actually will finally reach equilibrium. So, that is the way one can imagine it.

SS: Thank you. My next question is about administration. You have served as the Director of Tata Institute of Fundamental Research (TIFR). How do you see the difference between a non-scientist administrative role with regular responsibilities and the role of a director, in a scientific institution?

MB: These two roles are very different, yet they are interconnected. As a director, my responsibilities extended across various aspects of the institute.

First and foremost, there is a responsibility towards the faculty, as well as the entire staff—administrative personnel, technical teams, gardening staff, and so on. The director oversees the well-being of everyone in the institute. Even small but meaningful changes, such as installing an air conditioner in a driver's cabin, can make a difference in creating a better working environment.

While these are administrative tasks, the director plays a crucial role in academics. The responsibility is not to dictate but to help define the direction the institute should take in research and education.

Personally, I found that the biggest support in this role came from two sources, i.e.,The Faculty – They are central to the institution, and their collaboration is crucial for the institute's growth and The Council of the Institute – In the case of TIFR, the council was chaired by Ratan Tata (which, though incidental, is notable). The council played a key role in providing critical oversight and guidance. It met four times a year and functioned similarly to a Board of Governors (BOG) in other institutions.

The director also has an external-facing role—securing funding and engaging with government bodies. Since TIFR operates under the Department of Atomic Energy, I had many interactions with government officials and funding agencies.

This is very different from the role of a researcher. As a researcher, I would be happy to teach, mentor a small group of students, and work on problems at a blackboard with chalk in hand. That is where my personal comfort lies. But a director's job is different.

One of the biggest challenges in leading an academic institution is managing highly talented, independent-minded individuals. Academics are known for their strong opinions, and everyone believes they are right—and often, they are, in different ways. The challenge for a director is to bring these different viewpoints together to shape a collective vision for the institution.

So yes, being a director is a very different experience, but fortunately, it is also a fulfilling one.

SS: How do you evaluate the present condition of academia in



Fig 2: The then Prime Minister of India, Dr. Manmohan Singh, unveiled the foundation stone of the new TIFR Hyderabad campus in October 2010. [Credit: Mohd. Yousuf, The Hindu]

various countries - for science in general and research in particular? I don't have a more specific question regarding this, so I would just like to hear your thoughts on this.

MB: To assess the current situation, we must compare it with the past. So, I'll share my perspective by comparing today's scenario with the time when I returned to India from the United States.

I came back in 1976 and joined TIFR, first as a postdoc and later as a permanent faculty member. If I focus on physics, particularly condensed matter physics, the research environment back then was very different from what it is today. At that time, there were very few active research groups in India. It is difficult to imagine today, but back then, you could count all the major groups on your fingers—probably no more than ten. It was a challenging time, but also exciting in its own way. The DAE Solid State Physics Meeting was one of the very few academic gatherings in the country. Since there weren't many conferences, this meeting became the central hub where almost everyone working in condensed matter physics in India would come together. Travel was very different too. There were no frequent flights, so we relied on trains for travel. I remember collaborating with a researcher in Roorkee while I was in Bombay—and every interaction required significant logistical effort.

SS: Do you mean IIT Roorkee?

MB: There was no IIT in those days—it was the University of Roorkee. But yes, the same place.

Back then, travel was very different. To visit Roorkee, I would take the Dehradun Express, which slowly made its way through Delhi and reached Roorkee in about 36 hours. Today, that seems unimaginable—there were no direct flights, no quick alternatives, but we managed. We took trains all over the country, and that was just how things were.

Of course, that's not the main point. The real point is how different the academic landscape was. There were very few researchers, but it was still very enjoyable. We communicated by letters—no email, no instant messaging. And in some ways, that was actually a good thing. When you wrote a letter, you had time to think before responding. Today, emails create an expectation of immediate replies—within a couple of hours at most. But back then, you could take a week to reply, reflect on ideas, and engage more deeply. Compared to those days, things today are much faster and more interconnected. Collaborations are no longer limited by geography—they happen

online, across institutions, and even across continents.

If I focus on my field, statistical physics, the transformation has been incredible. Today, India has one of the largest statistical physics communities in the world. That didn't happen overnight—it took years of meetings, training, holding schools, and community-building efforts. One of the best examples of this is the Annual Community Meeting, organized by the International Centre for Theoretical Sciences (ICTS) in Bangalore. It is a completely open forum, where everyone—no matter how senior or junior—gets just 10 minutes to speak. The idea is to foster inclusivity and ensure that everyone contributes.

Another major initiative by ICTS is the Annual Summer School, where they bring in top international speakers. Around 80–90 students participate each year, getting exposure to some of the best minds in the field. It's not just about learning from experts—it's also about impressing them with the quality of Indian research. There's no doubt that the research scenario in India has evolved dramatically. Opportunities have multiplied, and the landscape is far richer than before.

I once wrote about this in an article titled "An Evolving Landscape" for the Indian Association of Physics Teachers magazine. But that's beside the point—I'm happy to share these thoughts again because the transformation of science in India is something worth celebrating.

SS: What do you make of the present scenario regarding research funds in India?

MB: Research funding has its challenges. Due to the budget cycle, sometimes funds are not released exactly on time, but such delays have not been severe enough to disrupt the entire system. It is not as though salaries are suddenly cut in half or research is completely halted.

The government has been generally supportive of science—sometimes more, sometimes less. All institutions have aspirations: they want to grow, expand into new areas, and accommodate more students. However, it is not always possible for the government to support everything at the desired scale.

That said, if I compare today with the 1970s, the situation has greatly improved. Back then, traveling abroad to attend conferences was not possible frequently—perhaps once in a few years, not every year as it is for many researchers today.

Research funding today is better than in the past, but a judicious allocation of resources across institutions and researchers would have a huge impact. In the grand scheme, the amount allocated to fundamental science is still minuscule, but it does not mean that simply increasing the budget is the solution.

If we can ensure that financial support is given in an effective and strategic manner, India can progress by leaps and bounds.

SS: Should we question everything, or should we only ask the right questions?

MB: Question everything. There is no such thing as questioning rightly or wrongly. How do you even know if a question is right or wrong until you define it and explore the answer?

In science, answers are not the main thing. The question is



Fig 3: STATPHYS – Kolkata IX (2016): Abhishek Dhar, Sanjib Sabhapandit, Mustansir Barma, Sakuntala Chatterjee, Shamik Gupta. [Source TIFR H]



Fig 4: Mustansir Barma delivering an invited talk at the International Institute of Physics, Brazil, on “Entropy, Order and Fluctuations”, in January of 2020. [Source IIP]

paramount. The true essence of science lies in asking the right questions, pushing boundaries, and challenging assumptions.

SS: Having completed a major portion of your academic life and having become an Emeritus Professor, what do you consider to be your biggest contribution to science, TIFR, and the students?

MB: One of my most significant contributions as a Director of TIFR was initiating and playing a key role in the formulation and partial execution of the new TIFR campus in Hyderabad. It is a very large campus, seven times the area of the TIFR campus in Mumbai. It holds enormous potential, and if it reaches its full realization, it will be a game changer—not just for TIFR, but for the entire country.

Progress is happening, though not at the speed we initially envisioned. Time has inflated, as is often the case with large-scale projects. But in the long run, this does not matter, because we hope that this institution will last for hundreds of years.

Seeing the plans I helped initiate now being executed is a source of immense satisfaction and pride for me.

SS: Thank you, sir. It was a pleasure speaking with you.

MB: Thank you very much.



Halder and Annagiri's study (contributed by TM) shows how competition for limited nesting sites during relocation imposes significant fitness costs on *Diacamma indicum* colonies. Larger colonies gain advantage through strategic aggression and recruitment.

InSight Digest

Fresh highlights from the frontiers of science

Dhiman Sankar Pal

New Functions for an Old Protein: How Does RAS Drive Migration in Human Cells?

Anusha Biswas

Recyclable Bio-based Polyethylene-like Materials: Synthesized via Acceptor-less Dehydrogenative Polymerization of Bio-derived Diols and Catalyst-enabled Closed-loop Recycling

Madhura Theng

The Neuron With Its Own Brain

Tanusree Mondal

Intraspecific competition for a nest and its implication for the fitness of relocating ant colonies

New Functions for an Old Protein: How Does RAS Drive Migration in Human Cells?

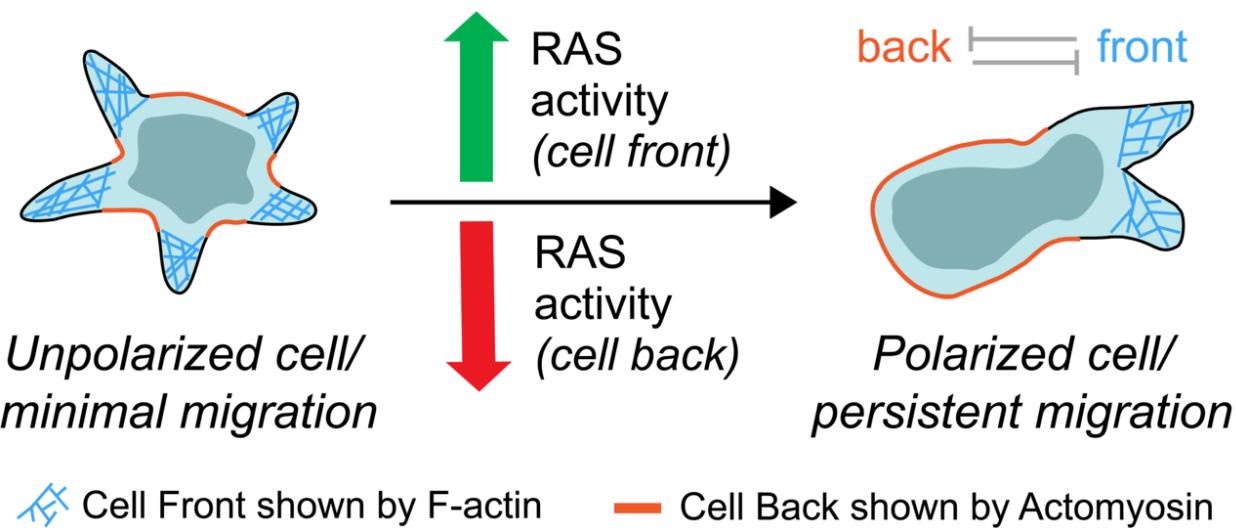
Pal, Dhiman Sankar et al. Developmental Cell, Volume 58, Issue 13, 1170 - 1188

Contributed by Dhiman Sankar Pal (Department of Cell Biology and Center for Cell Dynamics, School of Medicine, Johns Hopkins University, Baltimore, MD, USA)

In mammalian cells, directed migration is crucial for a multitude of physiological processes ranging from embryogenesis, cancer metastasis, to immune response. Although Ras and its downstream pathways are typically associated with longer-term growth control, our studies showed how the Ras-mTORC2-Akt growth-control axis steers leukocyte migration on a rapid timescale, independently of new gene or protein expression. To this end, we designed blue-light controlled, cryptochrome-based dimerizers to abruptly and locally perturb Ras or Akt activity in human neutrophils and macrophages, bypassing the chemoattractant-sensing receptor/G-protein network. Within seconds of global recruitment of CAAx-deleted version of constitutively active Ras isoforms or a RasGEF, RasGRP4, initially quiescent cells spread and migrated rapidly. Thus, Ras proteins directly promote random motility. Furthermore, by activating Ras at the cell rear, new F-actin rich protrusions emerged locally, thereby reversing pre-existing polarity and steering sustained migration towards the light source. Interestingly, locally recruiting the crucial Ras-mTORC2 effector, Akt1 or Akt2, had similar effects. Next, employing a RasGAP, RASAL3, we were interested to test the effects of reducing Ras

in migrating cells. Globally or locally dampening Ras activity at cell fronts could extinguish protrusions and abolish polarity or migration, as expected. However, surprisingly, an acute reduction in Ras activity specifically at the cell back increased both polarity and random motility. Further experimentation showed that cell polarity can be achieved by suppressing Ras activity at the cell rear resulting in locally increased actomyosin contractility. These unexpected outcomes of attenuating Ras activity naturally had strong, context-dependent consequences for chemotaxis. Our experimental results upended existing models of cell polarity, and a new computational model in which Ras levels control separate front and back feedback loops was proposed. Taken together, our unanticipated findings on cell polarity and migration have crucial implications for cancer treatment. While a target of intense interest for cancer therapy, Ras inhibition may not always be beneficial i.e., attempts to abrogate cell proliferation could force cells into a more polarized migratory state, thereby promoting metastasis. Minimally, our study suggests that a deeper understanding of the different roles of Ras activity is needed for developing therapeutic strategies.

How do Growth-Control Proteins Direct Cell Movement?



Within the human body, migrating cells need to have a stable front-back cytoskeletal polarity where actin polymerization (or F-actin; shown as a mesh of cyan lines) takes place at the cell front and actomyosin-driven contractility (shown as a heavy orange line) occurs at the back of the cell. Our optogenetic study showed that a front-back gradient of the activities of RAS and its downstream effectors of the growth-control signalling pathways on the plasma membrane generates cytoskeletal polarity and steers motility. Thus, an increase in RAS-mTORC2-AKT activation at the front of cells directly promotes localized actin polymerization whereas its decrease at the cell back stimulates rear actomyosin-driven contractility. Importantly, these cytoskeletal and migratory effects are independent of new gene/protein expression of classical growth-control network components.

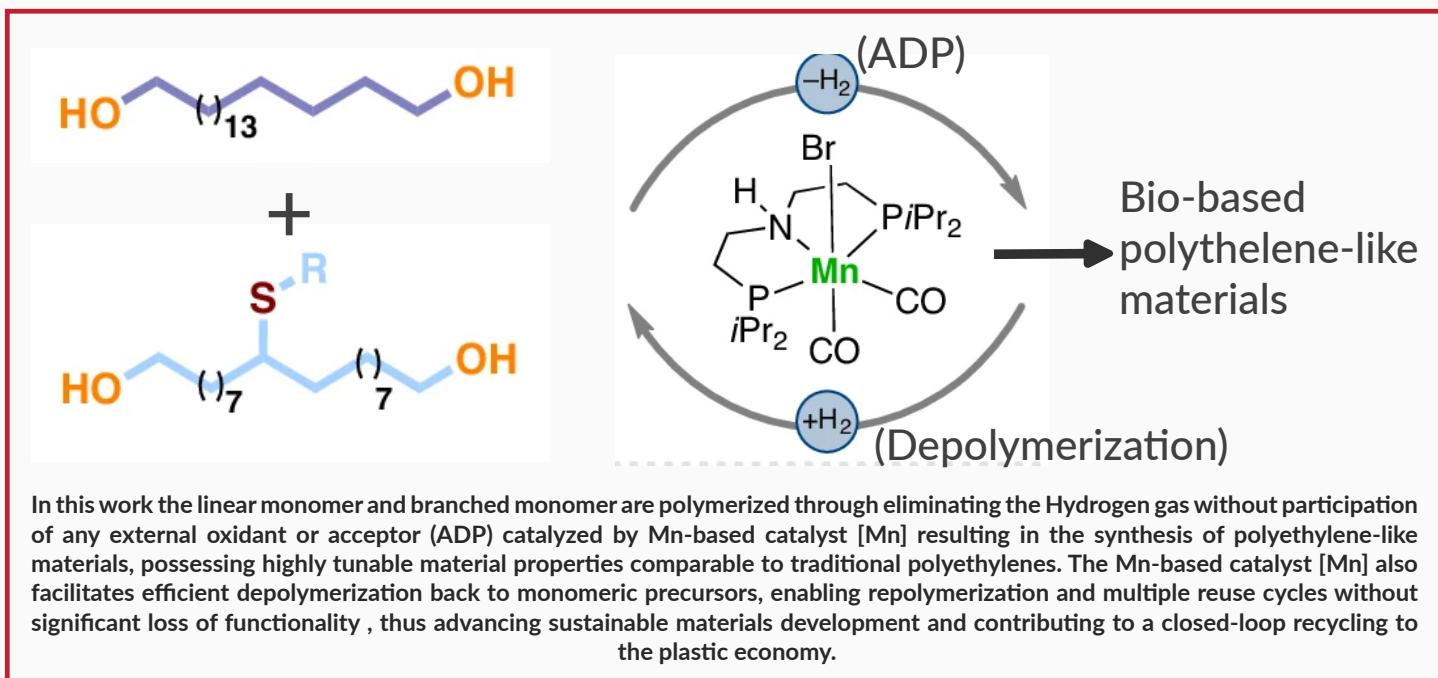
Recyclable Bio-based Polyethylene-like Materials: Synthesized via Acceptor-less Dehydrogenative Polymerization of Bio-derived Diols and Catalyst-enabled Closed-loop Recycling

Liu, X., Hu, Z., Rettner, E.M. et al. Nat. Chem. 17, 500–506 (2025)

Contributed by Anusha Biswas (Graduated BS-MS Student (19MS))

The widespread applications of petroleum-derived polyolefins can be attributed to their favorable physicochemical properties and economic viability. However, the environmental footprint of polyolefins is increasingly concerning, as their mass-production, single-use-nature, and slow decomposition contribute to long-term ecological pollution. Chemical recycling of polyolefins, conventionally involves processes-pyrolysis or steam cracking resulting in significantly lower yields of constituting monomers even under high temperatures($\sim 800^\circ\text{C}$) or harsh conditions. Effective resolution of this issue is contingent upon the development of polyethylene-like polymers that are both chemically recyclable and capable of replicating the key attributes of traditional polyolefins. Inclusion of ester or amide functionalities can operate as predetermined breaking sites within the polymer chain, enabling depolymerization at milder condition and yielding monomers suitable for re-polymerization. In the aforementioned paper, Miyake and co-workers had reported the synthesis of bio-based polyethylene-like polymer-materials from linear and branched diols via Acceptor-less Dehydrogenative Polymerization(ADP), which display efficient depolymerization too, catalyzed with earth-abundant Manganese complex and exhibit highly tunable material properties. The crystallizable saturated linear monomer and unsaturated monomer were derived from fatty acids (plant-based oils), contributing high melting temperature(T_m) and modulus with its long linear methylene chains. The thiol-ene reactions with thiols, yielding high efficiency, enables the synthesis of branched monomers influencing polymer morphologies and thermomechanical properties. The authors

had highlighted the manganese-based complex [Mn] as the most efficient catalyst for this Acceptor-less Dehydrogenative Polymerization and also depolymerization too, attaining high conversion and turnover number with the low catalyst loading and addition of suitable base. The synthesized thermoplastic polymers demonstrated thermal properties comparable to commercial polyethylenes, with decomposition temperature of 395°C and melting point(T_m). Increasing the content of branched comonomers reduced crystallinity and modulus, ultimately leading to elastomeric behavior, while all compositions maintained high tensile strength($\sigma_{UTS}=16-27 \text{ MPa}$) and toughness($UT=100-180 \text{ MJ m}^{-3}$), outstripping that of commercial plastics. Additionally these PE-like materials showed excellent environmental stability and incorporating thioether or sulfone groups in the copolymers exhibited excellent adhesion to various surfaces-including stainless steel, aluminum and so on. To overcome the traditional plastic recycling challenges, the authors introduced efficient chemical depolymerization of synthesized bio-based-PE-like polymers driven by hydrogen gas in the presence of mixed commercial plastics using the Mn-based catalyst[Mn], achieving high monomer recovery(91-99%), leaving other plastics impurities unaltered. The recovered monomers were successfully repolymerized through multiple cycles without loss of efficiency and stability, confirming the robustness of the closed-loop process. Furthermore, high-yield monomer recovery was achieved even in the presence of post-consumer plastics and at larger scales, highlighting the system's practical and scalable recycling potential and route to sustainability.



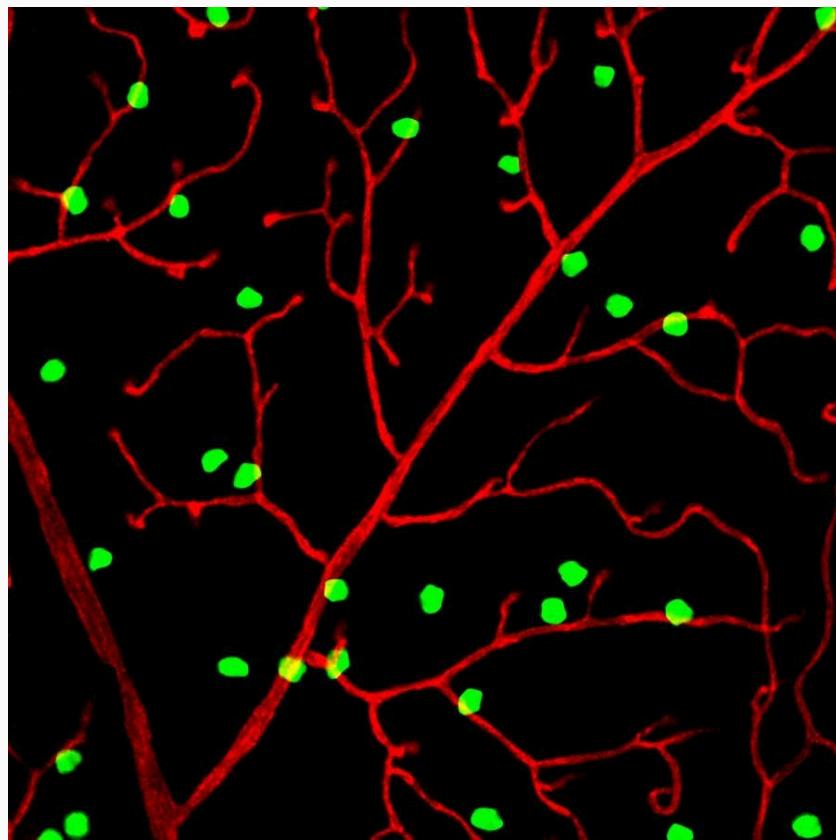
The Neuron With Its Own Brain

Toma K et al. Perivascular neurons instruct 3D vascular lattice formation via neurovascular contact. *Cell.* 2024 May 23.

Contributed by Madhura Theng (IISER Kolkata)

We all know that the human brain is filled with neurons that direct our dreams and administer our body's organ functions effectively. But that's not all. Recent studies have found that a specific type of neuron in the eye plays a crucial role in vision—almost as if it has its own "eye and brain." Fascinating, right? For years, scientists have known that a network of blood vessels nourishes the retina (the posterior part of the eye), where light refracted from the lens forms an image. However, how this intricate structure develops remained a mystery. Now, researchers at UC San Francisco have discovered that a specific subset of retinal neurons, called perivascular neurons, directs the formation of the retina's three-dimensional vascular lattice. These researchers worked with newborn mice, whose eyes require several weeks to fully develop. Then they labeled the retinal neurons closest to blood vessels with a protein that glows bright green under ultraviolet light, allowing them to observe the lattice as it formed. These neurons establish direct contact with developing blood vessels through perisomatic endfeet (specialized neuronal structures that extend from the cell bodies of certain neurons) physically connect with surrounding blood vessels. This interaction guides the precise 3D

lattice formation, which is essential for retinal health. Perivascular neurons produce a mechanosensitive ion channel protein called PIEZO2, which enables them to sense contact with other cells. Now the absence of PIEZO2 disrupts these neurovascular interactions, leading to disorganized vascular structures, reduced capillary perfusion, and increased susceptibility to something called ischemic damage (tissue damage caused by lack of blood flow, eventually leading to cell death). In mice that could not produce PIEZO2, perivascular neurons failed to maintain contact with blood vessels, causing the vascular network to grow in a tangled, disorganized manner that disrupted blood flow. As a result, the surrounding nerve cells became oxygen-starved, deteriorated and made the mice more vulnerable to stroke-like injuries. By collaborating with developmental biologists, researchers could confirm that perivascular neurons also exist in the human retina, suggesting their importance in human vascular health. This discovery paves the way for new therapeutic approaches aimed at repairing or reorganizing damaged blood vessel networks, offering potential treatments for glaucoma, diabetic retinopathy, and stroke. By exploring how neurons regulate vascular development



Neurons in the retina (green) making directing blood vessels to forms a complex, three-dimensional lattice as they grow. These lattices are helpful in understand the working of neurons on how these neurons establish direct contact with developing blood vessels. By restoring these lattices, scientist can develop targeted therapies to maintain healthy blood flow and even restore vision!

Intraspecific competition for a nest and its implication for the fitness of relocating ant colonies

Halder, E., Annagiri, S. Insect. Soc. 71, 431–440 (2024)

Contributed by Tanusree Mondal (DBS, IISER-K)

The study by Eshika Halder and Dr. S. Annagiri from Indian Institute of Science Education and Research Kolkata explores intraspecific competition in *Diacamma indicum* during colony relocation, a cooperative yet challenging process triggered by environmental stressors like habitat destruction, resource depletion, or predation. Unlike the commonly studied contexts of foraging and mating, this work focuses on competition for limited nesting sites, providing new insights into ant behavioral ecology and colony fitness.

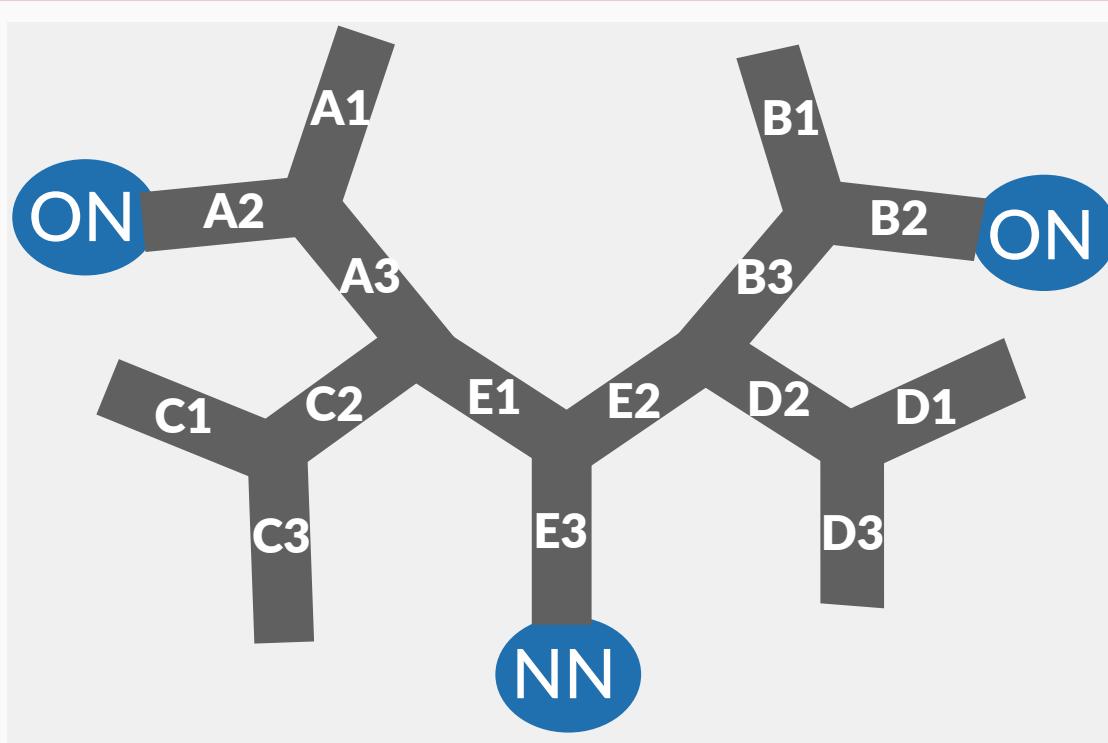
The authors investigate how colony size affects competitive success, the nature of aggression during relocation, and how these interactions impact colony fitness. The experiments used both comparable-sized (CS) and non-comparable-sized (NCS) colonies in a controlled lab setup, simulating natural relocation conditions with two old nests and a single new nest. Behavioral data such as aggression, brood theft, and recruitment via tandem running were observed and statistically analyzed. Control groups (colonies relocating without competition and non-relocating colonies) helped assess the baseline levels of mortality and relocation efficiency.

Results show that colony size significantly influences success. In CS trials, one colony successfully relocated in 13 of 17 cases. In NCS trials, larger colonies dominated in 11 of 14 instances due

to their numerical advantage in both aggression and recruitment. Smaller colonies struggled to manage both tasks simultaneously. Interestingly, colony mergers occurred in about 25% of trials facilitated by cross-colony tandem running. These often led to the death of one gamergate, typically from the smaller colony.

Aggression was concentrated around critical zones like old and new nests, especially during the recruitment phase. Winning colonies were more strategic, involving fewer individuals in aggressive acts and reserving more for relocation. Brood theft was a notable behavior, primarily by larger colonies in NCS setups, enabling workforce expansion without reproductive cost.

The study highlights the high fitness costs of competition during relocation. Losing colonies exhibited mortality rates three to five times higher than controls, while even winners experienced elevated losses. These findings underscore the ecological risks associated with relocation, particularly when multiple colonies compete for limited resources. Overall, this research offers valuable insights into how social insects respond to ecological stress and competition. It contributes to our understanding of behavioral strategies, colony dynamics and has implications for conservation especially under increasing environmental pressures.



The experimental setup consisted of a rectangular arena (122 cm × 92 cm) filled with water to confine the ants. A maze divided into five sections (A-E), each with three arms (15 cm each), was placed in the arena. Two old nests (ON) were positioned at arms A2 and B2, while a single new nest (NN) was located at the end of arm E3, serving as the common path for colony relocation.



CREDIT: NOIRLAB

Science Games

Science Quiz

Questions drawn from ideas of general science.

Themed Crossword

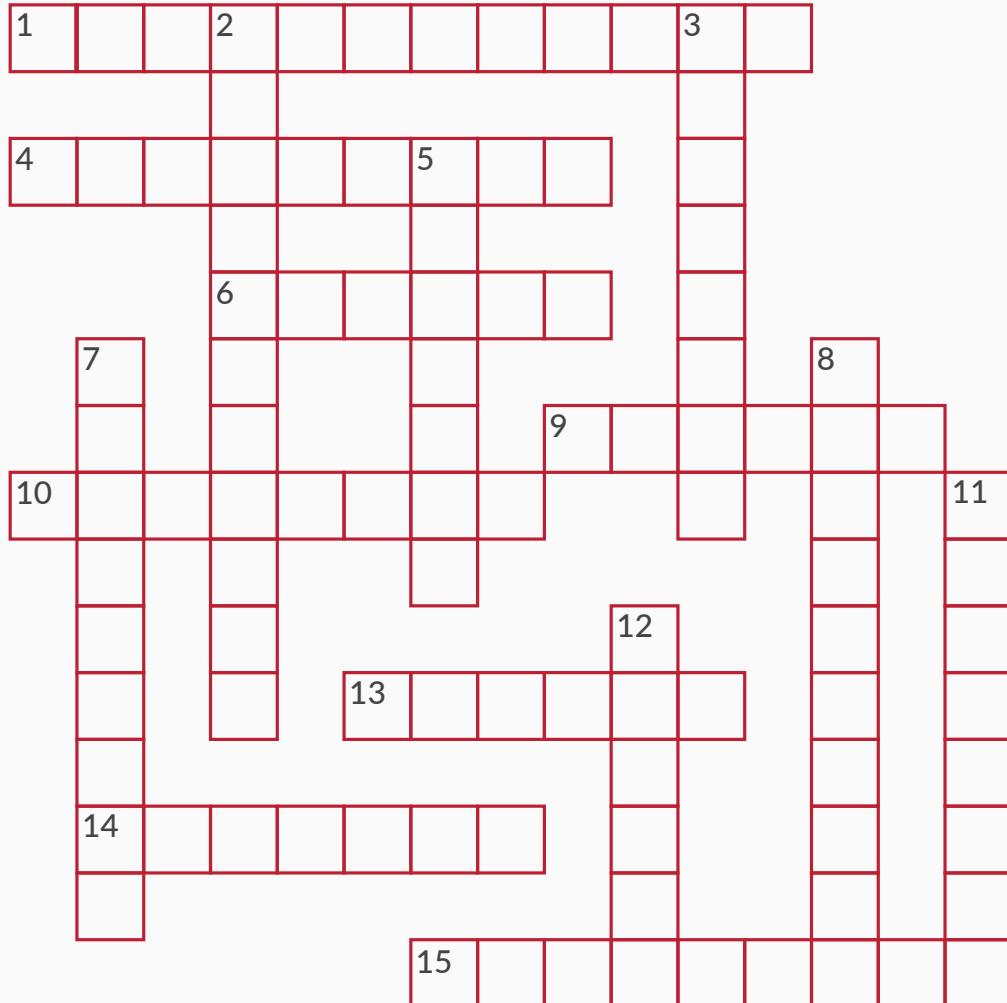
The theme for this issue is Astronomy and Astrophysics.

Linked List

Link each term with the next, and complete the science word chain!

Themed Crossword

This issue's crossword is based on evolutionary biology.



Across

- A scientific instrument that disperses light into a spectrum, allowing astronomers to analyze the composition of stars.(11)
- A spiral galaxy on a collision course with the Milky Way, visible to the naked eye from Earth.(9)
- A vast cloud of gas and dust in space, often the birthplace of stars or the remnants of dead ones.(6)
- An extremely bright and energetic object powered by a supermassive black hole at the center of a distant galaxy.(6)
- The point in a planetâ€™s elliptical orbit that is farthest from the Sun, resulting in lower solar intensity.(8)
- The brightest star in Earth's night sky, part of Canis Major, located just 8.6 light-years away.(6)
- A pair of NASA spaceprobes launched in 1977, now traveling through interstellar space carrying the Golden Record.(7)
- An ancient analog tool used for solving problems related to time and the position of the Sun and stars.(9)

Down

- A high-precision timekeeping device used historically in navigation to determine longitude at sea.(11)
- The apparent shift in position of a nearby star against the background of distant stars due to Earth's motion.(8)
- The two points in Earth's orbit when the Sun is directly above the equator, resulting in nearly equal day and night.(7)
- A cataclysmic explosion marking the violent death of a massive star, often leaving behind a neutron star or black hole.(9)
- A distinctive W-shaped constellation named after a vain queen in Greek mythology.(10)
- The moment when the Sun reaches its highest or lowest point in the sky at noon, marking the longest or shortest day.(8)
- A highly magnetized, rotating neutron star that emits beams of electromagnetic radiation from its magnetic poles.(6)

Answers can be found near the end of the issue. For an interactive version, check out our [website](#).

Linked List

Linked List is a general science-based word game. The rules are straightforward:

1. The goal is to guess eleven words that have been drawn from science.
2. The first word (the seed) will be provided to you, and hints and number of letters will be provided for the remaining words.
3. You are also informed that the first letter of any word is the last letter of the previous word. So the first letter of the second word will be the last letter of the seed word, the first letter of the third word is the last letter of the second word, and so on.
4. This property goes all the way, so that the last letter of the last (eleventh) word is also the first letter of the seed word.

Find all the words!

Today's seed: **SEMICONDUCTOR**

1. A radioactive element discovered by Marie and Pierre Curie, once used in medicine but later found to be hazardous to health. (6)

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2. A physical force resulting from moving electric charges, responsible for the attraction or repulsion between materials such as iron. (9)

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3. A conserved quantity in physics, defined as mass times velocity, representing how difficult it is to stop a moving object. (8)

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4. A group of two or more atoms chemically bonded together, forming the smallest unit of a compound with specific properties. (8)

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5. A measure of disorder or randomness in a system; in thermodynamics, it naturally increases over time. (7)

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6. A silvery metal with atomic number 39, used in LEDs, lasers, and superconductors, commonly found in rare-earth minerals. (7)

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7. A subatomic particle made of a quark and an antiquark, playing a key role in the strong nuclear force between nucleons. (5)

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8. The process of forming new atomic nuclei from protons and neutrons, occurring in stars and during the Big Bang. (15)

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9. A state in which a material can conduct electricity without resistance, occurring below a certain critical temperature. (17)

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10. A measure of a material's stiffness, representing how much it deforms under stress within its elastic range. (13)

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Answers can be found at the end of the issue. For an interactive version of this as well as the other games, check out our [website](#).