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National Centre for Biological Sciences
Tata Institute of Fundamental Research

Annual Report 2021-2022

NATIONAL CENTRE FOR BIOLOGICAL SCIENCES
ANNUAL REPORT 2021-2022

Design: www.superpixel.in
Faculty sketches: Alissa Barnes

Contents

DIRECTOR'S REPORT

The Tenth Edition

Satyajit Mayor
Director, NCBS

This year started with the trepidations of an uncertain COVID-laden future. Fortunately, with the systems we had put in place last year, systematic and deliberate restrictions on crowding and social interactions in closed rooms, and calibrated loosening of such restrictions as advised by our in-house saliva-based screening strategy, we were able to move to a fully functional campus with little or no restrictions by late July. Now we have returned to a pre-COVID state where on-campus meetings and travel for in-person meetings are becoming the norm. The zombie days are over, but I hope we will revert to a more carbon footprint friendly state with a reasonable mix of online and in-person activities. While it will take us years to get over the trauma imposed by social isolation, and repair the fissures in mind and body politic created by the pandemic, it is very important that we engage fully with a wonderful set of new colleagues in the faculty and as Early Career Researchers who joined us last year. Our campus culture is also about building deep social bonds as we pursue our science and help shape the campus.

Here I would like to hail the establishment of the BLiSC Early Career Researcher Council (BLiSC ECRC) and welcome Abrar and Simran as the founding members of this Council, leading over 20 members who now represent every nook early career researchers may inhabit. Their work has already started making an impact for the better; Happy Fridays are back again! They are helping to address issues that will ensure a more inclusive campus by creating a more collegial and involved campus. They also have a space in this annual report to talk about their activities *(see page 108)*. In fact, this issue is dedicated to the life and times of our ECRs on our campus. This report is also the maiden effort of our new Communication officer, Sonal Katyal, with great support from Uma Ramakrishnan, our Head of Communications, Outreach and Development. I heartily welcome Sonal to the campus to create new ways of generating more momentum on our scientific communication channels and public engagement and wish her all success.

I would also like to extend a warm welcome to GN Devy *(https://news.ncbs.res.in/spotlight/bringing-science-history-social-sciences-one-table),* the current Obaid Siddiqi Chair in the History and Culture of Science *(https://archives.ncbs.res.in/OS)*, at the Archives@NCBS, and simultaneously bid farewell to MD Madhusudhan our first Chair. Madhu provided a wonderful start as the inaugural Chair, made possible by generous support from TNQ Technologies Pvt Ltd (TNQ). I remain grateful to Mariam Ram (Chairperson, TNQ) for her tremendous support for science and also for believing in keeping the vision of Obaid alive and vital in these trying times. Almost as an endorsement of our faith in the archives, and the tireless efforts of the Head Archivist, Venkat Srinivasan, Arcadia Foundation has also generously supported a program on documenting the Contemporary History of Science in India, ensuring the stability of our archives for some time.

Adding to the wide gamut of science that is our bread and butter *(see Report of Scientific Research, page 19)* over the past year, NCBS has also spearheaded many efforts that reflect our capacity to pivot towards a more translational direction where indicated. NCBS continues as a member of the Biodiversity Collaborative *(https://www.biodiversitycollaborative.org/)*, a collective of like-minded institutions working towards a National Mission on Biodiversity and human wellbeing. Thanks to the effort of Jayashree Ratnam, we now anchor a new consortium dedicated towards Wildlife and Conservation, this consists of Nature Conservation Fund (NCF), Wildlife Conservation Society (WCS) - India as main partners and the Habitats Trust as well as the Wildlife Conservation Trust as supporters. A renewed alliance with the WCS-New York is also helping us with our Wildlife Biology and Conservation Master's program, and we are grateful for this support. Our long experience (since 2004) with this program has given us a model for creating future Master's initiatives that we at NCBS can uniquely offer, drawing on our practice of life science at the frontiers of this discipline. NCBS is a founding member of the Bengaluru Science and Technology (BeST) Cluster, a new initiative of the Principal Scientific Advisor's office to link all geographically localized S&T centres to enhance their ability to solve societal problems with the application of deep S&T.

I would like to report a series of changes at the Bangalore Life Science Cluster (BLiSC). We are delighted that the Tata Institute of Genetics and Society (TIGS; led by Rakesh Mishra), an initiative of the Tata Trusts, has become the newest member of our cluster. At inStem, the current director Apurva Sarin has superannuated, and we now welcome its new director, Maneesha Inamdar, who is no stranger to our campus and joins us from across the street from the Jawaharlal Nehru Centre for Advanced Scientific Research. I wish her all success. Once again, with the growing attractiveness of this life science ecosystem that strives for excellence in basic and discovery science *(NCBS, inStem)*, creating a translational ecosystem (inStem, TIGS) that fosters innovation and entrepreneurship (C-CAMP), there is a lot celebrate for the future.

As India turned 75 this last year and considering the atmosphere of divisiveness that is pervading our country, I feel that we have been able to chart an alternative path in embracing our diversity. Diversity, both in our aims and aspirations of our institutions and in the individuals who work on this campus, characterizes our campus. This will help overcome the significant challenges that undoubtedly lie ahead institutionally, and enable, in a small corner of India, the kind of world in which we wish to live. Finally, this is my tenth and last note in these pages. So, as I bid adieu, I would like to welcome my successor, Professor LS Shashidhara. It has been my privilege to serve as the NCBS Director for all these years, and I hope my successor will also enjoy the extraordinarily strong support that I have relied on and received.

May we continue to strive for excellence in science and preserve a culture of creativity and inclusivity that our campus has always symbolized.

NCBS Awards

NCBS is host to a diverse set of faculty and NCBS researchers have, at every stage of their careers, received accolades in the last year for their work.

International

- **Prof. Uma Ramakrishnan** received the **Conservation Beacon Award** from the Society for Conservation Biology, USA for 2021, December 2021.
- **Dr. Hiyaa Ghosh,** faculty, has been selected as a **new member of the EMBO Global Investigator Network**, January 2022.
- **Prof. Padmanabhan Balaram,** DST Year of Science Chair Professor at NCBS, received the **R. Bruce Merrifield Award** for 2021, by the American Peptide Society, June 2022.

National

- **Dr. Anjana Badrinarayanan** received the **Intermediate-Career Fellowship** from DBT/Wellcome Trust - India Alliance, January 2022.
- **Dr. Poonam Mishra** (a post-doctoral fellow in Dr. Vatsala Thirumalai's group) received the **Early-Career Fellowship** from DBT/Wellcome Trust - India Alliance, January 2022.
- **Prof. Gaiti Hasan** was honoured with the **Sir M. Visvesvaraya Senior Scientist State Award** for the year 2019, instituted by the Government of Karnataka, March 2022.
- **Prof. Krushnamegh Kunte** was awarded the **Prof. T. N. Ananthakrishnan Senior Scientist Award** by the Prof. T. N. Ananthakrishnan Foundation, Chennai, August 2022.
- **Prof. PV Shivaprasad** was **elected to the National Academy of Sciences**, India, Nov 2022.

NOTE BY DEAN, FACULTY

Dean's Office

Sanjay Sane
Dean of Faculty

I took over the responsibilities as the Dean of Faculty from Prof Upi Bhalla in July 2021. Despite the disruptions due to the pandemic, Upi ensured that the baton was smoothly transferred. I thank him for his efforts in streamlining this office and providing a clear organizational profile for various tasks. It has largely been an enjoyable stint, helped on by the easing of COVID pandemic-related restrictions. I hope, above all, that this openness will foster easy interactions between faculty members. Nothing is more fun than a colleague walking in through your door unannounced, and engaging in a lively discussion. A major endeavour of the Dean's office will be to facilitate such collegiality.

The primary task of the office of Dean of Faculty is to ensure that the faculty composition of NCBS is carefully balanced and incorporates an optimal cross-section of Biological Sciences. An important *albeit* routine aspect of this job is to process tenure and promotion decisions up the faculty ladder. More challenging, however, is the task of calibrating the hiring process to help determine the direction of our scientific trajectory in the foreseeable future. Here, we are confronted with a paradox: on the one hand, we must maximize the diversity of scientists in various sub-fields of biology and fill the gaps in the underrepresented areas. On the other hand, within each subfield, we must build strength and depth, which means ensuring a critical mass of scientists in specific areas.

In all its years of existence, NCBS followed the policy of not pre-determining the areas of hiring, but rather finding the very best applicants whose science was exciting and who enhanced the intellectual effervescence of the campus. Then, in 2019/20, the scientific review committee chaired by Prof Iain Mattaj conducted an extensive research review of NCBS and identified three major initiatives: *a brain initiative* focusing on human brain disorders, diseases and related therapeutics, *a biodiversity, ecology and evolution initiative* to make NCBS the hub of biodiversity research and conservation activity in India, and *a computational and theoretical biology initiative* to develop the role of theoretical and computational methods in tackling large-scale quantitative data. As we emerged from under the dark COVID clouds, the need for greater strength in areas such as immunology and infectious diseases also became apparent. There is also a need to develop strength in plant sciences and climate-change-related studies.

I am happy to report that we are steadily fulfilling this mandate. We welcome two new faculty members – neurophysiologist Dr Sufyan Ashhad, who studies the neural circuits that set up respiratory rhythmogenesis using transgenic mice as a model system, and plant/fungus molecular biologist Dr Amey Redkar who studies the mechanisms underlying pathogenic plant-fungal interactions. It has been an extraordinarily busy time at the Dean's office which, since July 2021, has processed 6 tenure cases, 4 promotion cases, and 14 virtual or in-person interviews of faculty candidates, in addition to numerous routine tasks. In collaboration with our InStem counterparts, a Research Ethics and Integrity Office was set up to ensure that the highest standards of data and publication integrity are met. Lastly, the office oversees the functioning of all statutory committees on the BLiSC campus.

My sincerest thanks to Ms Ambili Dinesh who manages the Dean's office, to Ms Mouna Nagaraju who manages the statutory committees, and to Mr Sabuj Bhattacharyya and Mr Biswa Bhushan Mahapatra who run the pan-campus Research Ethics and Integrity office.

Working with Drosophila.
Photo credit: Sonal Katyal

Students and Alumni

The Multiple Facets of Life on Campus

Journal Clubs at NCBS

Alumni Voices

Avantika Lal, Arjun Guha, Divya Vasudev, Trayambak Pathak

***Howzzat!* Cricket tournament on campus.**
Photo credit: Sonal Katyal

STUDENTS AND ALUMNI

The Multiple Facets of Life on Campus

Students in the BLiSC campus come together as part of many campus clubs like *dance, theatre, music, sporting groups* and *book clubs.* These clubs organise events where students showcase their talents, and forge friendships outside their labs. For many, these initiatives have helped navigate the ups and downs of the PhD journey.

Hrishikesh Nambisan
Dance Club

Over the years, **the dance club** has become a means for dance lovers to express themselves and an escape from the grind of daily lab life. It also provides an opportunity for the campus community to engage with and enjoy the shows performed in Dasheri. From *'Navrasa'*, to story format *'Chali Kahani'* and to a radio show format *'Jashn-e-funkaar',* the club has performed shows that have tested our creative limits in trying to provide something new and exciting to the campus every time.

Chinmayee LM
Music Club

To uncover the musical talents on our campus, **the music club** organises *classical, folk* and *fusion* music events. These cultural events bring out hidden facets of co-workers and give a sense of belonging in larger social circles independent of academic success. Students, faculty and campus staff participate in these events amidst experiments, meetings and deadlines to make this a happy retreat from academic stress.

Manal Shakeel
Theatre Club

It's been more than 5 years since **StageCraft** was established. Through StageCraft, students and researchers passionate about the art of theatre come together and bring stories to stage. After a painful hiatus due to the pandemic, we performed this year at Dasheri. Stay tuned for future shows!

Nandita Chaturvedi
Book Club

The **book club** on campus is a forum to share and discuss ideas. It emerged with the idea of engaging with knowledge and history to make sense of the present world. An essay or a chapter from a novel is selected. Students meet and engage in discussion around the topic. The club also organizes screening of important documentaries and debates.

Sweety Meel
Sports Committee

The campus changes when the sun goes down. People come pouring out of their offices and labs, into the lawns and into the sports complex. From **indoor sports** to **outdoor sports**, from solo sports to team sports, we hone our sportsmanship through regular tournaments. Sports like *cricket, badminton, frisbee, football* and *volleyball* bring together the whole BLiSC community including PIs, students and staff. *Basketball, squash* and *tennis* on campus offer some good physical exercise while games like *foosball, carrom, darts, chess,* etc., are great stress-busters for students. The gym and swimming pool facility help students stay in shape. Sports on campus back up the much needed mental well being of students along with the other clubs available on campus.

Journal Clubs at NCBS

The Ecology and Evolution Journal Club

The Ecology and Evolution Journal Club (EEJC) was started in 2019 to create a forum to discuss and engage in interesting and useful discussions under the very broad umbrella of ecology and evolutionary biology. Since its inception, more than 50 sessions have taken place, both offline and online, from PowerPoint presentations and chalk talks to discussion forums, with both off-campus and in-house speakers. Following a monthly theme model and having discussions, facilitators made sure that a comprehensive range of topics were thoroughly discussed.

Development and Behaviour Journal Club

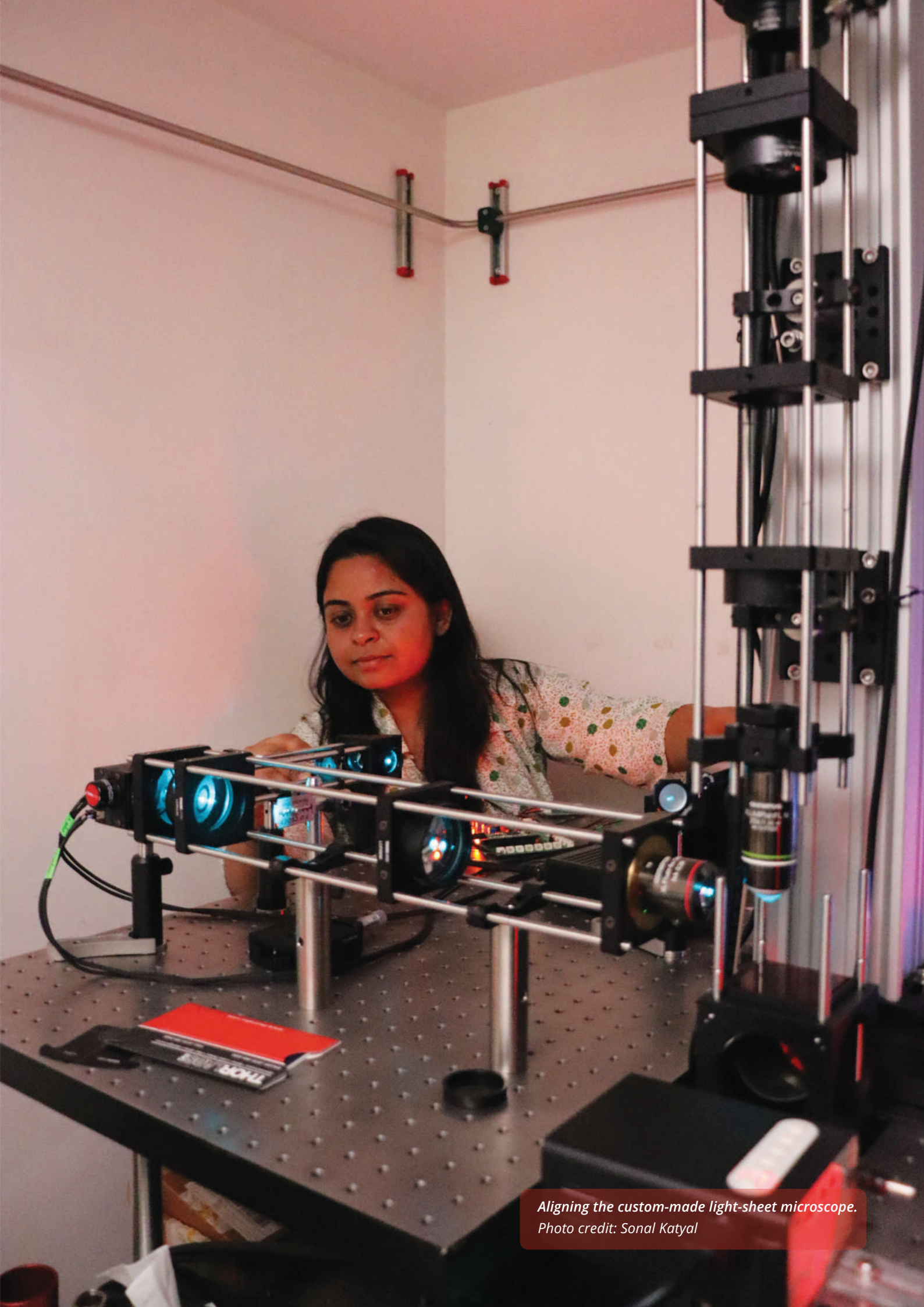
It's easy to get caught up in the frustrations of failed experiments and codes that stop working without warning. So, it's important to find ways of reconnecting with the thrill of science and research as a reminder of what drew us to this world in the first place. So we, the co-conspirators of the DevBio and Behaviour Journal Club, decided to put together a forum where willing participants – faculty and students alike- took turns presenting a paper from the field of Developmental biology, Evo-Devo and behaviour. Keeping a rather open mind about what constitutes "development" and "behaviour", we loosely structured the theme of our journal club on Tinbergen's Four Questions: to adequately explain a behaviour, one must ask questions on its function, its evolution, its causation, and its development.

And so it was that members of the BLiSC community and DevBio nerds across institutes in the country met once a week with one person leading the discussion while all of us thought critically about the question at hand, and the approach taken in addressing it. We often invited authors of these papers to walk us through the train of thought that went into their work. We punctuated these sessions with a quiz. The response within the community was overwhelming, and we hope to make this an annual event!

We hope to come back next year with more ways of keeping this fun!

Neurobiology Journal Club

For research scholars, it is as important to read deep as it is to read broad. Neurobiology Journal Club (NBJC) is an opportunity for neurobiologists across the campus to get together and broaden their horizons. We discuss recent literature ranging from the mechanisms of action potentials to memory formations and behaviour. This helps us keep up with the latest research in neurobiology.



Aligning the custom-made light-sheet microscope.
Photo credit: Sonal Katyal

Alumni Voices

Avantika Lal
Insitro, USA

I completed my PhD from Dr Aswin Sai Narain Seshasayee's group at NCBS in 2016. Toward the end of my PhD, I became interested in machine learning, a computational approach which was revolutionizing fields like computer vision and text analysis. I wondered whether the same techniques could be adapted to better understand the human genome. Although this was a new field for me, training at NCBS had given me the rigour and broad scientific base to adapt to any problem.

I went on to do a postdoc at Stanford University, where I developed computational models to predict how cancer patients would respond to treatment. After this, I joined NVIDIA, a multinational technology company, where I researched new ways in which deep learning could be applied to the human genome. Presently, I work as a Senior Data Scientist in Insitro, a startup aiming to discover new drugs for life-threatening diseases using machine learning.

I have found research in industry to be a deeply satisfying career path. It allows me to do rigorous science using cutting-edge methods, in a team-oriented environment. The biotechnology sector is growing rapidly worldwide and there are many opportunities for both experimental and computational biologists.

Arjun Guha
inStem, India

As a graduate student in Satyajit Mayor's laboratory at the NCBS, I glimpsed the vast potential for making new discoveries when studying cells. However, it was obvious even then that these explorations would be most exciting in the context of the intact organism as it develops over time. So, after a highly instructive experience as a graduate student exploring mechanisms of endocytosis in cultured cells, I moved to studying a novel and unusual developmental program that generates the adult tracheal system in Drosophila for my postdoc. I joined Tom Kornberg's lab at UCSF, where he was exploring the origin of the cells that generate the adult thoracic tracheal system. My co-workers and I found that the same cells that comprise the larval thoracic tracheal system are reprogrammed to proliferate and generate the adult tracheal system. Such a developmental program was unprecedented in Drosophila, and this was the beginning of my interest in the phenomenon of cellular plasticity during development and homeostasis. I realised that the murine lung would be a better system to study this phenomenon since it had better markers for lineage commitment along with other features. I moved to Wellington Cardoso's lab at Boston University to acquaint myself with the mouse lung, and soon started my own laboratory as an Assistant Professor. The work at BU set a solid precedent for studies on the regulation of cellular plasticity in the lung, and how plasticity contributes towards lung homeostasis. The lines of enquiry, in both systems, continue in my laboratory at inStem today. Be plastic.

Divya Vasudev
Conservation Initiatives, India

My two years at NCBS doing my Master's in Wildlife Biology and Conservation set me on a journey that I have cherished. I completed my doctorate from the University of Florida, focussing on species behaviour, dispersal and conservation in large complex landscapes. I did my field work in Meghalaya, Northeast India, and I was smitten—I knew I would come back to this fabulous and challenging region. In 2017, I co-founded and continue to co-lead an NGO, Conservation Initiatives, dedicated to furthering science-based conservation in the relatively unexplored north-eastern states of our country. We now have

conservation programs in three states: in Assam, we look at how the Asian elephant, India's National Heritage Animal, survives, disperses across forests and interacts with people. In Meghalaya and Nagaland, we support communities who are conserving forests on their lands, with the western hoolock gibbon—India's only wild ape—as a flagship species.

For aspiring conservationists, I pass on what I realised early on in my career: there is nothing more rejuvenating that experiencing nature with all our senses, and nothing more fulfilling than knowing that one has contributed—even if just one drop in an ocean—to sustaining nature into the future.

Trayambak Pathak
University of Pittsburgh, USA

As a graduate student, I joined Dr Gaiti Hasan's lab and started working on store-operated calcium entry (SOCE) in Drosophila neurons. After completing my PhD in 2017, I joined Dr Mohamed Trebak's lab as a postdoctoral scholar at the University of Pittsburgh, USA. In Dr Trebak's lab, I am studying the role of SOCE in mammalian physiology, specifically mitochondrial metabolism, obesity, and cancer. I discovered that the SOCE and mitochondrial Ca2+ are interconnected and synergize to support transcription and metabolic reprogramming necessary for cancer progression. In my recent work, I aim to understand the molecular mechanism that regulates obesity, to develop a novel non-invasive therapeutic strategy for obesity. During my postdoctoral studies, I published multiple first-author and co-author research articles. I received the American Heart Association (AHA) postdoctoral grant in 2019, a career development award from the AHA in 2021, and K99/R00 award from NHLBI in 2022. The K99/R00 award is helping me transition from a postdoctoral fellow to a tenure-track assistant professor position.

My advice to all the upcoming PhD students and postdoctoral fellows is to choose your mentors wisely. In my opinion, one of the essential characteristics to look for is the supportiveness of the mentor toward their mentees.

Colours of Lab Life.
Photo credit: Sonal Katyal

Our Research Interests

Biophysics, Biochemistry, and Bioinformatics

- Aswin Seshasayee
- R Sowdhamini
- Vinothkumar K R
- Ranabir Das
- Arati Ramesh
- Sabarinathan R
- Tapomoy Bhattacharjee

Genetics and Development

- K VijayRaghavan
- P V Shivaprasad
- Raj Ladher
- Dimple Notani
- Soumyashree Das
- Gaiti Hasan

Cellular Organisation and Signalling

- Satyajit Mayor
- Raghu Padinjat
- Varadharajan Sundaramurthy
- Anjana Badrinarayanan
- Swadhin Jana

Theory, Simulation, and Modelling of Biological Systems

- Shachi Gosavi
- Mukund Thattai
- Sandeep Krishna
- Madan Rao
- Shashi Thutupalli
- Shruthi Viswanath
- Shaon Chakrabarti
- Archishman Raju

Neurobiology

- Upinder Bhalla
- Sanjay P Sane
- Sumantra Chattarji
- Vatsala Thirumalai
- Hiyaa Ghosh
- Abhishek Bhattacharya
- Sufyan Ashhad

Ecology and Evolution

- Mahesh Sankaran
- Uma Ramakrishnan
- Krushnamegh Kunte
- Shannon Olsson
- Deepa Agashe
- Axel Brockmann

Counting red flour beetles in a population.
Photo credit: Sonal Katyal

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Biophysics, Biochemistry, and Bioinformatics

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BIOPHYSICS, BIOCHEMISTRY, AND BIOINFORMATICS

Structure to Signalling: Insights into Biology through Natural and Engineered RNA Structures

We use biochemical/structural approaches to investigate how RNAs create the chemical complexity for sensing metabolites/proteins, how natural signal-sensing RNAs function, and how they may be exploited to develop RNA-based biosensors.

India faces challenges in prevention/diagnostics/treatment of infectious disease. We have established a robust pipeline for design and development of RNA-biosensors for ultrasensitive detection of infectious microbes including SARS-CoV-2 and Dengue viruses (Figure 1). Isothermal-amplification of a viral-RNA fragment coupled with activation of our biosensors leads to a conformational switch in the sensor, leading to translation of a reporter that is detected using color/luminescence. This assay is remarkably sensitive (attomolar RNA) and specific, producing color that is easily visualized by eye. Our RNA biosensors detect viral-RNA in patients, comparable with RT-qPCR tests, and are deployable in low-resource settings, making it potentially important for many parts of our country.

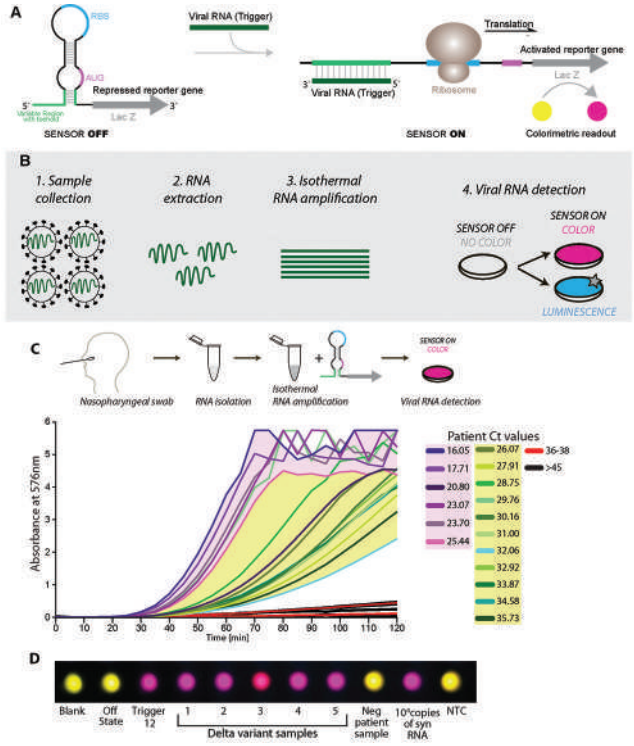

Figure 1: A-B) Toehold RNA based biosensors are designed to specifically sense SARS-CoV-2 RNA. Coupled RNA amplification and biosensor detection results in attomolar sensitivity.

C-D) Sensors report on COVID (and the prominent DELTA variant) in patient nasopharyngeal samples, with easily detectable color.

We are investigating mechanisms of RNA-mediated regulation that confer pesticide resistance in soil organisms. Organophosphate hydrolases (OPH), are enzymes from soil bacteria, that hydrolyze pesticides. Our findings establish a novel, multi-layered, iron responsive regulation that occurs via structured RNA elements, and is crucial for OPH expression. Our work implies links between the transport of siderophore-mediated iron uptake and pesticide break-down via OPH.

PUBLICATIONS

- Anirudh Chakravarthy, Anirudh K N, Geen George, Shyamsundar Ranganathan, Nishan Shettigar, Suchitta U, Dasaradhi Palakodeti, Akash Gulyani, Arati Ramesh. “Engineered RNA sensors for ultrasensitive SARSCoV2 detection in a simple color or luminescence assay” Life Science Alliance. 2021 Sep; 4 (12) e202101213; DOI: 10.26508/lsa.202101213.
- Dolly Mehta and Arati Ramesh. “Diversity and prevalence of ANTAR RNAs across actinobacteria” BMC Microbiology. 21, 159 (2021). DOI: 10.1186/s12866-021-02234-x.

Adaptation, the Bacterial Way!

Aswin Seshasayee
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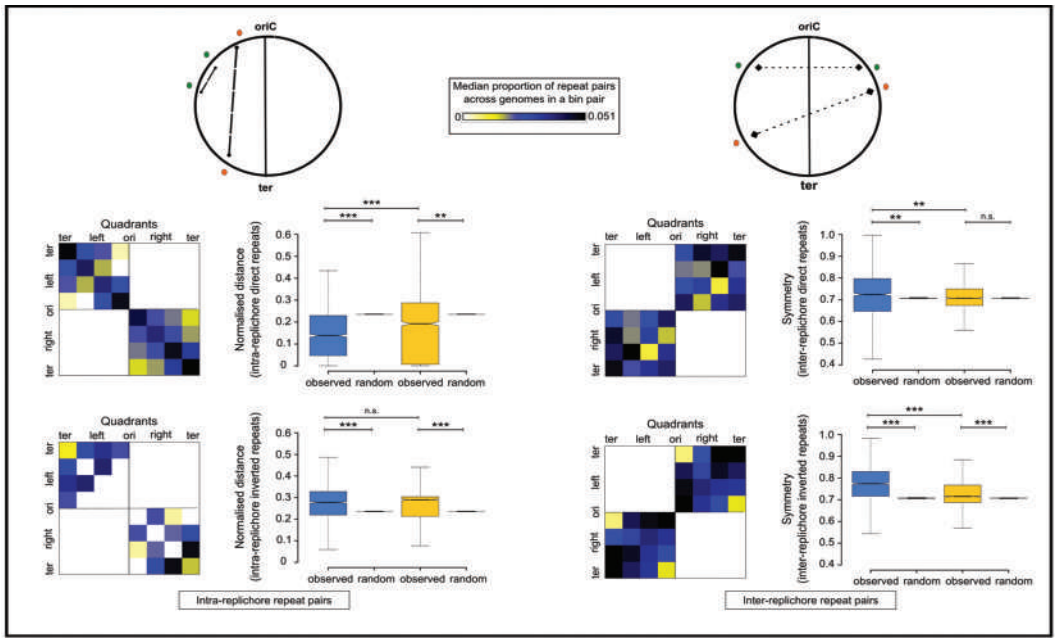
Bacterial adaptation is multipronged. Not only do bacteria regulate what molecules are produced when, they also adapt by changing their genotype. We ask how these phenomena operate using computation.

Circular bacterial genomes are organised around a single origin of replication, which establishes a gene dosage gradient that decreases from the origin to the diametrically opposite terminus of replication. These gradients are especially severe in fast-growing bacteria. Gene organisation is often such that it takes advantage of this dosage gradient. At the same time, rearrangements of segments of the chromosome are unavoidable and often mediated by repetitive DNA. We asked if there is selection operating on where such repetitive DNA, which are often acquired by horizontal gene transfer and may also have the ability to be mobile within a host chromosome, are positioned in bacterial chromosomes. We find that their positioning is such that it would reduce the chances of highly detrimental chromosome rearrangements, more so in fast-growing bacteria in which replication-related gene dosage gradients are stronger.



Direct repeats are present closer to each other in the same replichore (top left) than by chance. Inverted repeats are symmetrical around ori-ter axis across replichores (bottom left).

PUBLICATIONS

- Malhotra N, Seshasayee ASN. Replication-Dependent Organization Constrains Positioning of Long DNA Repeats in Bacterial Genomes. Genome Biol Evol. 2022 Jul 2;14(7):evac102. doi: 10.1093/gbe/evac102. PMID: 35776426; PMCID: PMC9297083.

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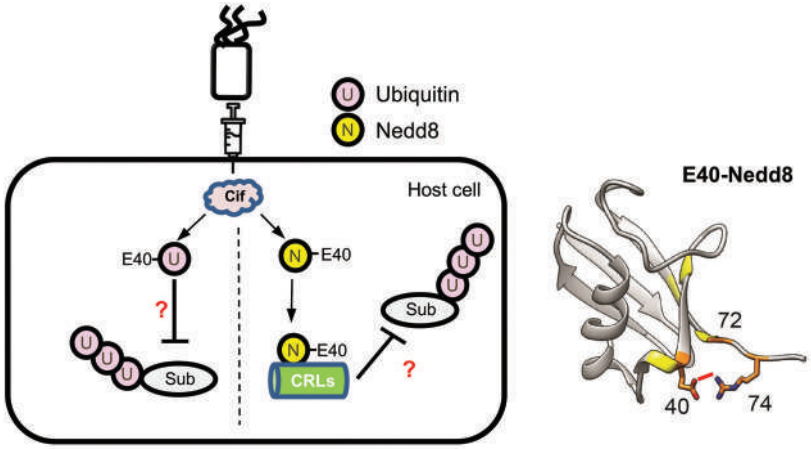
BIOPHYSICS, BIOCHEMISTRY, AND BIOINFORMATICS

Protein Modifications in Host-Pathogen Interactions

Protein post-translational modifications (PTM) regulate their function and lifetime. By careful analyses of the molecular interactions we study how PTM signaling is exploited to suppress the host immune response.

We study the role of PTMs in host-pathogen interactions. Our results provided the first structural insights into a collective action of Ubiquitination, SUMOylation, and phosphorylation that enhances the activity of the herpes simplex virus protein ICP0 to deplete the host immune responses *(Hembram et al. 2020).* We uncovered another crosstalk between PTMs exploited by the human cytomegalovirus (Tripathi et al. 2019, Tripathi et al. 2021). Few insect viruses encode a Ubiquitin variant—the central player in Ubiquitin signaling—to create unique Ubiquitin polymers that the host cannot regulate *(Negi et al. 2020).*

We also uncovered an intriguing mechanism, where deamidation of the host Ubiquitin Like protein NEDD8 modulates the dynamics of the Cullin RING Ligases to regulate cycle progression and deplete NFkB immune response *(Mohanty et al. 2021)*. We have begun to scratch the surface regarding the repertoire of PTM crosstalk in host-pathogen interactions. It is of great interest to explore how they modulate the pathogen's life-cycle and the host immune response.



Bacterial inactivation of the host Ubiquitin and Nedd8 signaling.

Schematic illustration showing the mechanism of Ubiquitin/Nedd8 signaling inactivation by the bacterial Cycle inhibitory factors (Cifs). The Cifs deamidate a particular Glutamate residue (Q40) and convert it to Glutamic Acid (E40) in both Ubiquitin and Nedd8. Subsequently, the process of substrate Ubiquitination is inhibited. Nedd8 conjugation activates Cullin-RING ligases (CRLs) to ubiquitinate and degrade cell-cycle repressors. However, deamidation of Nedd8 inactivates CRLs. Recently, we have shown that deamidation creates a new intramolecular salt-bridge in Nedd8, which interferes with its functional interactions and inhibits its activity (Mohanty et al., (2021), Frontiers in Immunology, 12, 3289.)

PUBLICATIONS

- Mohanty P, Chatterjee KS, Das R*, (2021), "NEDD8 Deamidation Inhibits Cullin RING Ligase Dynamics," Frontiers in Immunology, 12, 3289.
- Tripathi V, Chatterjee KS, Das R*, (2021), "Non-covalent Interaction with SUMO Enhances the Activity of Human Cytomegalovirus Protein IE1," Frontiers in Cell and Developmental Biology, 9:662522.

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BIOPHYSICS, BIOCHEMISTRY, AND BIOINFORMATICS

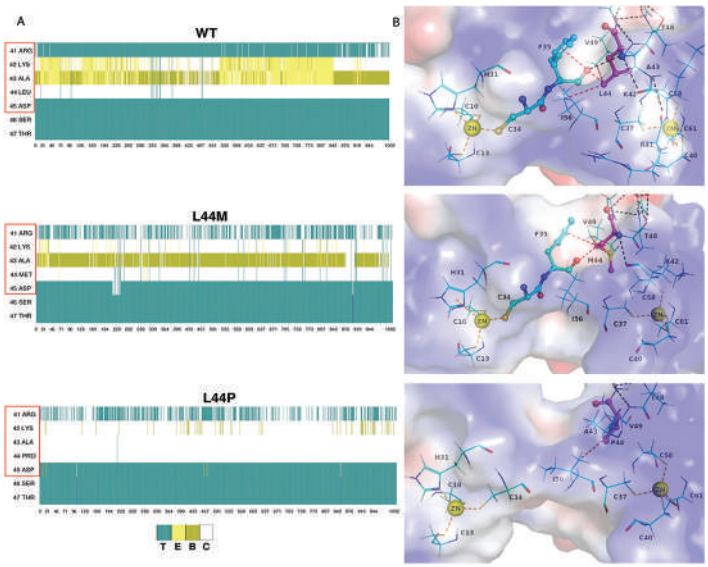
Computational Approaches to Protein Science

We employ computational algorithms to enable efficient annotation of functions to unknown gene products. Our future projects are geared towards modelling protein/ligand interactions and plant genomics, aided collaborative ventures.

AAAACGTTCTTCGTC
GATAATTGGAAACCCAC
GTGCACCC

Genome sequencing projects have enormous potential to benefit human endeavours. However, just as acquiring a language's vocabulary does not enable one to speak it, databases that list the amino acid compositions of proteins do not directly tell us much about the higher-level structures and functions of these proteins. Proteins with very similar amino acid sequences are 'no-brainers', but the real test is to detect the "essential" similarities in proteins whose non-critical sections have experienced random rearrangements during evolution.

Functionally similar proteins may have <25% sequence overlap. We seek to provide structural rationale for disease-causing mutations. Explicit computational pipelines have been devised to recognise parts of the genome that retain genic regions and applied in DNA or RNA assemblies of select medicinal plants like the drumstick and Shankhpushpi. Finally, we have identified families of enzymes such as terpene synthases and cytochrome P450s in herbal plant genomes to ascertain their roles in the biosynthesis of medicinally relevant secondary metabolites.



Molecular dynamics trajectories of CSRP3 protein to understand the effect of cardiomyopathic mutations (L44M (neutral) and L44P) in comparison to the wild type (WT). T: turn, E: extended, B: bridge and C: coil

PUBLICATIONS

- Chauhan, P. K., & Sowdhamini, R. (2022). LIM domain-wide comprehensive virtual mutagenesis provides structural rationale for cardiomyopathy mutations in CSRP3. Scientific reports, 12(1), 3562. https://doi.org/10.1038/s41598-022-07553-1.
- Naika, M., Sathyanarayanan, N., Sajeevan, R. S., Bhattacharyya, T., Ghosh, P., Iyer, M. S., Jarjapu, M., Joshi, A. G., Harini, K., Shafi, K. M., Kalmankar, N., Karpe, S. D., Mam, B., Pasha, S. N., & Sowdhamini, R. (2022). Exploring the medicinally important secondary metabolites landscape through the lens of transcriptome data in fenugreek (Trigonella foenum graecum L.). Scientific reports, 12(1), 13534. https://doi.org/10.1038/s41598-022-17779-8.

Deciphering Genetic and Molecular Alterations in Cancers

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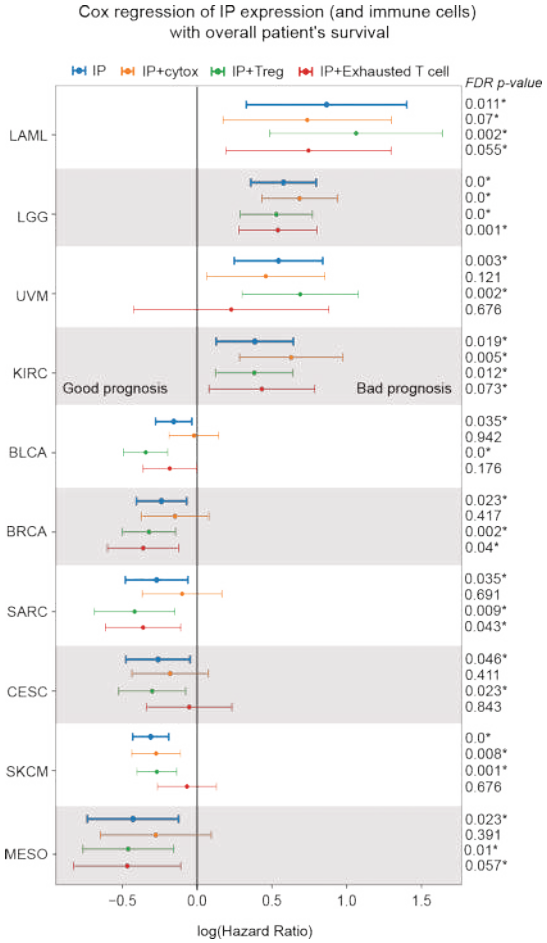
We are interested in understanding the genetic and molecular alterations responsible for cancer development and resistance to treatments, using computational and functional genomics approaches.

The specific research areas of interest are: **a)** Understanding the impact of chromatin architecture on somatic mutational processes and gene regulation in cancer, **b)** Identification of cancer driver mutations and their mechanism of action, and **c)** Understanding intra-tumoral heterogeneity and tumor-immune cells interactions.



Cox proportional hazard ratio for immunoproteasome (IP) expression alone and combined with three other confounders (regulatory T cell, cytotoxic cells and exhaustive T cell) in different tumor tissues from TCGA. The line represents the mean and 95% confidence interval, and the p-value (computed using Wald's test) is reported on the right. The asterisk (*) symbol indicates p-value less than 10% significance level.

Key findings from our recent studies:

a) the study of functional impact of gain-of-function mutant p53 in primary tumors revealed that the mutant p53 can affect the chromatin accessibility *(either directly or indirectly through interactions with other transcriptional factors)* and cause subsequent gene expression changes in tumor-type specific manner

b) the overexpression of immunoproteasome (a type of proteasome complex involved in degradation of proteins to aid in antigen-presentation) in tumor cells is associated with overall survival and response to immune checkpoint therapies. We also observed that the prognostic association is variable among solid tumor types and it can be explained by the tissue-specificity and the type of immune cells *(anti- or pro-tumorigenic)* infiltrating the tumors *(Figure on the left).*

PUBLICATIONS

- Dhaka B, Sabarinathan R. Differential chromatin accessibility landscape of gain-of-function mutant p53 tumours. BMC Cancer, 21:669, 2021.
- Kumar R, Dhaka B, Sahoo S, Jolly MK, Sabarinathan R. Prognostic association of immunoproteasome expression in solid tumours is governed by the immediate immune environment. bioRxiv (preprint), 2022.

HONORS AND AWARDS

- DBT/Wellcome-Trust IA Intermediate Fellowship (2021-25).

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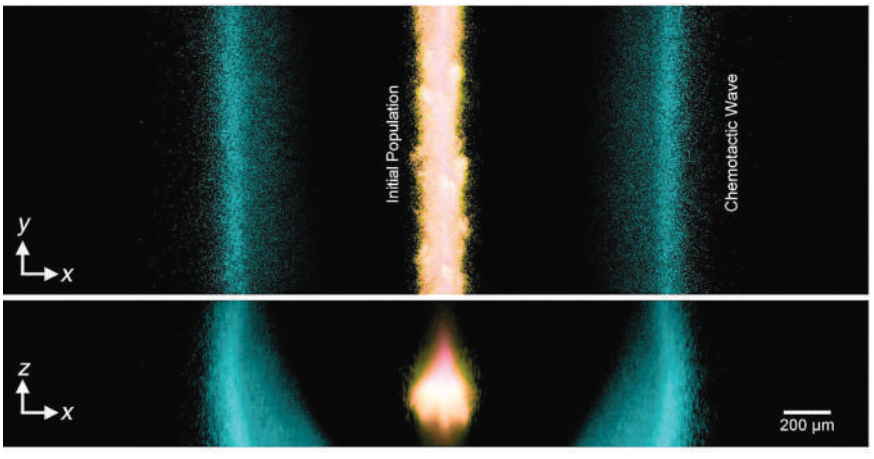
Active Living Material in Complex Environment

We aim to discover new physical and biological principles emerging from the interactions between living organisms and their complex, three-dimensional microenvironments.

Our lab works in the broad area of active living matter in complex environments and aims to discover new physical and biological principles emerging from the interactions between mammalian cells, bacteria, and their microenvironments. We design and fabricate biomimetic 3D media to mimic the natural habitat of mammalian cells, bacteria and even worms. We fine-tune the material properties of the media to explore how living organisms respond to the change in their microenvironment. The lab uses bioprinting and a variety of microscopy techniques to probe multicellular systems at three-dimensional biological interfaces. More specifically, the lab is exploring a spectrum of areas that include characterizing the properties of biomimetic gels, understanding worm behavior in 3D environment, exploring bacterial growth and response to antibiotics in 3D, designing long-term cultures of 3D-printed tissues, studying the interaction between microbes and mammalian tissues in 3D, and investigating mechanically assisted maturation of tissues.



A cylindrical bacterial population is 3D printed within a porous medium made of jammed microgels. Top and bottom panels show bottom-up (xy plane) and end-on (xz plane) projections of cellular fluorescence intensity measured using 3D confocal image stacks. Images show a section of an initial cylindrical population at three different times (shown in magenta, yellow, and cyan) as it chemotax radially outward in a porous medium.

PUBLICATIONS

- Theeyancheri, L., Chaki, S., Bhattacharjee, T.* & Chakrabarti, R*. Migration of active rings in porous media. Physical Review E (2022).
- Bhattacharjee, T., Amchin, D. B., Alert, R., Ott, J. A. & Datta, S. S*. Chemotactic smoothing of collective migration. Elife 11, e71226 (2022).

HONORS AND AWARDS

- Affiliated faculty member, The Center for the Physics of Biological Function, Princeton University, USA.

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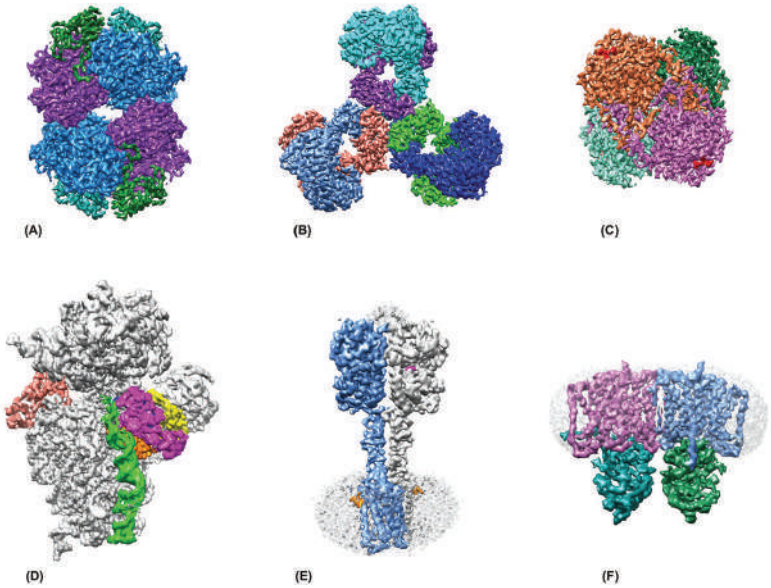
BIOPHYSICS, BIOCHEMISTRY, AND BIOINFORMATICS

Structures of Macromolecules and Dynamics

Our research is driven by the curiosity of how macromolecules function in the cell. We study macromolecules that function in the membrane, those that regulate translation and interesting microbial enzymes.

The lab's theme is 'Macromolecular Structure and Dynamics' and the research areas that we work on can be divided into membrane proteins, microbial enzymes and large macromolecules such as ribosomes. Within the broad area of membrane proteins, we are working towards understanding the mechanism of peptide and antibiotic resistance in bacteria, cleavage of transmembrane proteins by intramembrane proteases and membrane receptors *(Figure 1).* We also work on select microbial enzymes that have interesting catalytic mechanism and for their use as test samples for cryoEM *(to understand the behavior of specimen during freezing and also to optimize data collection)*. The molecules shown in panels A-C in the figure below fall in this category and these have been invaluable in setting up the whole workflow from cryoEM as well benchmarking data collection strategies. Large macromolecules such as ribosomes are well studied in particular how they function but less explored are the regulatory processes of translation and the maturation or ribosomes *(Panel D in the figure below).*



A gallery of macromolecules studied by cryoEM in our lab are shown. In panels A-C, the maps of DMFase, PaaZ and catalase are shown, which are robust and used as model proteins for EM sample preparation. In panels D, E and F, dynamic molecules such as the 30S subunit of ribosome bound with a methyltransferase, KsgA, the dimeric metabotropic glutamate receptor and a membrane enzyme with dual function is shown (Images not to scale).

PUBLICATIONS

- Singh, J., Raina, R., Vinothkumar, K.R., Anand, R. Decoding the Mechanism of specific RNA Targeting by Ribosomal Methyltransferase (2022) ACS Chemical Biology, https://doi.org/10.1021/acschembio.1c00732.
- Chen, S., Li, J., Vinothkumar, K.R., Henderson, R. Interaction of human erythrocyte catalase with air-water interface in cryoEM (2022) Microscopy, 71(S1), i51-i59.

2

Genetics and Development

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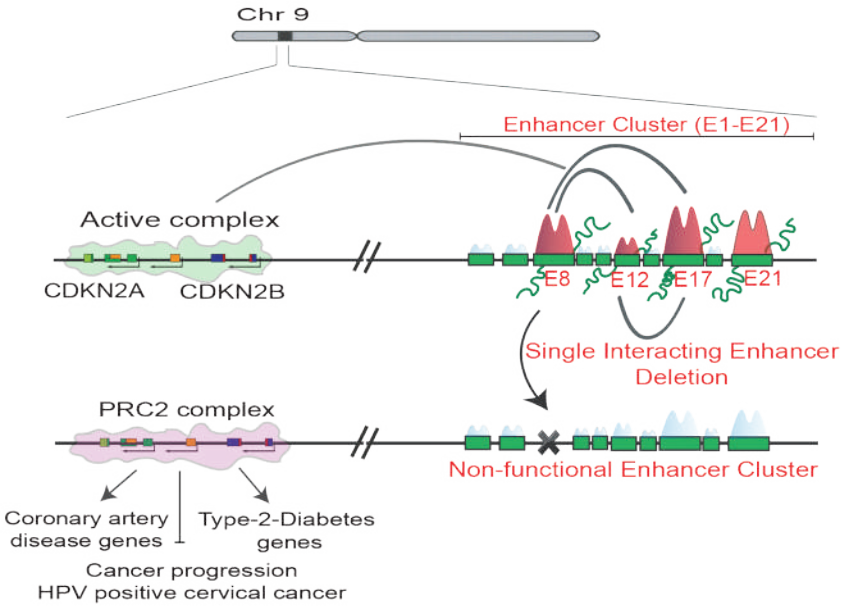
GENETICS AND DEVELOPMENT

Chromatin Dynamics in Gene Regulation

My group is interested in understanding the dynamic interplay between regulatory elements, non-coding RNAs, and chromatin-architecture in gene regulation.

Expression of genes is controlled by DNA sequences that are distal from the promoters known as enhancers. They regulate target genes by establishing looping with the promoter in a cell-type specific manner. Although discovered over forty years ago, how enhancers regulate their promoters remains poorly understood. Further, the enhancers that drive cyclic signaling response, are reversibly dynamic as opposed to developmental enhancers, adding another layer of complexity to this conundrum.

Using genomic techniques that quantify the alterations in TF binding, nascent transcription, three-dimensional architecture during the course of estrogen signaling, our work has revealed that chromatin state under basal signaling is the key to signaling response. Further, these and other enhancer clusters do not function as sum-of-all but they rely on complex hierarchies that cannot be predicted. Furthermore, promiscuous transcription and mutations in these enhancers lead to patho-physiologies including cancer.



Enhancer clusters revisited: Enhancer cluster regulates the INK4/ARF genes.

Out of 21 enhancers, only 5 enhnacers loop with promoters. Deletion of even a single looping enhancer causes polycomb loading on promoters of INK4/ARF resulting in their repression.

PUBLICATIONS

- Farooq U, Saravanan B, Islam Z, Walavalkar K, Singh AK, Jayani RS, Meel S, Sudha Swaminathan S, Notani D. An inter-dependent network of functional enhancers regulates transcription and EZH2 loading at INK4a/ARF locus. Cell Reports. 2021. 34(12):108898.
- Blobel GA, Higgs DR, Mitchell JA, Notani D, Young RA. Testing the super-enhancer concept. Nat Rev Genet. 2021;22(12):749-755. doi: 10.1038/s41576-021-00398-w.

HONORS AND AWARDS

- EMBO Global Investigator, 2020-2024.
- DBT/Wellcome Trust IA Intermediate Fellowship, 2016-2021.

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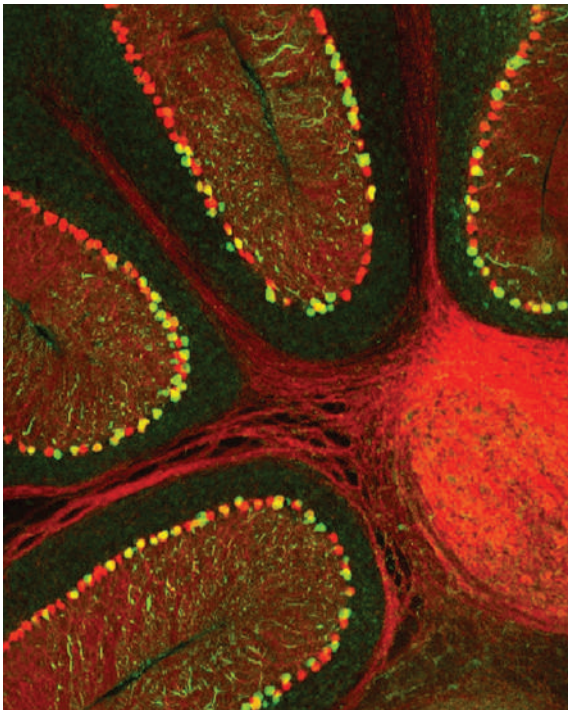
GENETICS AND DEVELOPMENT

Neuronal Calcium Signaling and Gene Expression

Neuronal cell-specific mutants for the IP_3R and STIM in flies and mice have helped identify age-dependent changes in gene expression of ion channels as an important downstream consequence of reduced neuronal SOCE.

Studies with mutants of the IP_3R, STIM and Orai, have identified store-operated Ca^{2+} entry as an important regulator of neuronal function in *Drosophila* and mouse. Cellular Ca^{2+} imaging and electrophysiological studies demonstrate changes in ion channel function in neurons with loss of IP_3/Ca^{2+} signaling and store-operated Ca^{2+} entry. Importantly, such changes are specific to neuronal subtypes. Transcriptomic studies from Purkinje neurons in the mouse brain identified specific changes in expression of genes downstream of store-operated Ca^{2+} entry that includes genes encoding ion channels, neurite growth, transcription factors and Ca^{2+} signaling. Transcriptional mechanisms that underlie changes in gene expression are under investigation in *Drosophila* neurons.The functional significance of store-operated Ca^{2+} entry across specific neuronal subtypes and in the context of neurodegenerative syndromes is under further investigation in *Drosophila*, a human neuronal cell line and human stem cell derived neurons.



Section of a mouse brain cerebellum. Purkinje neurons marked by a red fluorescent protein also express the ER Ca^{2+} sensor protein STIM1 (green).

PUBLICATIONS

- Mitra R, Richhariya S, Jayakumar S, Notani D, Hasan G. (2021). IP3-mediated Ca^{2+} signals regulate larval to pupal transition under nutrient stress through the H3K36 methyltransferase Set2. Development.148:dev199018; doi: 10.1242/dev.199018.
- Dhanya, Sreeja Kumari and Hasan, G., (2021). Purkinje neurons with loss of STIM1 exhibit age-dependent changes in gene expression and synaptic components. J. Neurosci 41, 3777-3798. https://doi.org/10.1523/JNEUROSCI.2401-20.2021.

HONORS AND AWARDS

- Sri M. Visvesvaraya Senior Scientist State Award for 2019, 2022.
- Honorary Fellowship of the Karnataka Science and Technology Academy, 2021.

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GENETICS AND DEVELOPMENT

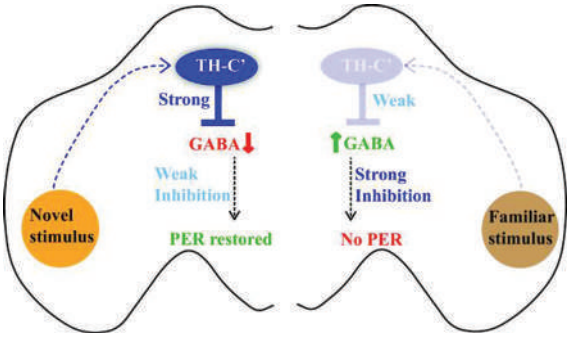
Development of Neural Circuits, Muscles, and the Emergence of Behaviour

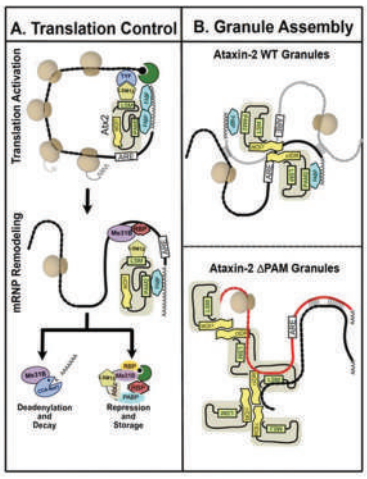
Our laboratory studies how the birth, morphogenesis, and connectivity of neurons and muscles translate into behaviour. We approach this complex problem by focussing on the olfactory, gustatory and motor system of drosophila melanogaster.

We endeavour to understand the principles of development culminating in behaviour, using Drosophila. Muscles, the nervous system and their interplay at cellular and molecular resolution, remain our focus. In our recent work on deciphering the neural correlates of habituation override when presented with a novel stimulus, we have identified a subset of dopaminergic neurons necessary for it. We also show that these dopaminergic neurons may form direct synapse with the sensory neurons (a).

Our work with Mani Ramaswami's group at Trinity, Ireland, has provided insights into regulation of mRNP granules of both human and Drosophila Ataxin-2. Ataxin2 is an intrinsically disordered ubiquitous RNA binding protein implicated in translational activation/repression, mRNA stability and mRNP granule assembly. In vivo experiments show that while both PAM2 and IDR-interactions promote Ataxin2-mediated cytotoxicity, LSm domain acts as an antagonist.

In collaboration with Maneesha Inamdar's group at JNCSR, we have uncovered challenge specific functions and heterogeneity in immune cell progenitor pools of Drosophila larvae (b).





a) Model for habituation override in the Drosophila gustatory system.

b) A model for Ataxin2 RNP dynamics and the role of PAM2 domain in determining its RNP composition and mRNA selection.

PUBLICATIONS

- Trisal S, Aranha M, Chodankar A, VijayRaghavan K, Ramaswami M. A Drosophila Circuit for Habituation Override. J Neurosci. 2022 Apr 6;42(14):2930-2941. doi: 10.1523/JNEUROSCI.1842-21.2022. Epub 2022 Mar 1. PMID: 35232763; PMCID: PMC8985855.
- Rodrigues D, Renaud Y, VijayRaghavan K, Waltzer L, Inamdar MS. Differential activation of JAK-STAT signaling reveals functional compartmentalization in Drosophila blood progenitors. Elife. 2021 Feb 17;10:e61409. doi: 10.7554/eLife.61409. PMID: 33594977; PMCID: PMC7920551.

HONORS AND AWARDS

- Elected to the American Philosophical Society in May 2021.

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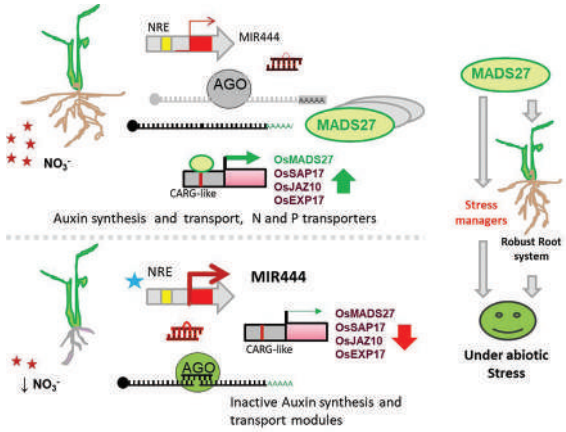
GENETICS AND DEVELOPMENT

Epigenetics and Small Silencing RNAs

A number of epigenetic regulatory layers are superimposed on the genome. We study mechanisms of small (s)RNA biogenesis, induction and maintenance of epigenetic changes, and functional significance of these regulatory layers.

sRNAs are a group of key molecules resulting from RNA silencing pathways. They regulate transcription and translation of their target RNAs by associating with Argonaute (AGO) protein effectors. sRNAs are also important factors in initiating and maintaining heritable changes in gene expression without changes in DNA sequence ('epigenetics'). sRNAs and epigenome modifications impact every aspect of eukaryotic development and disease. Our laboratory is interested in understanding the pathways and mechanisms that generate sRNAs and epigenome modifications in plants. We also strive to come up with novel strategies to enhance plant's resistance to abiotic and biotic stresses. We use various biochemical, genetic, bioinformatic and whole-genome approaches in a wide variety of model organisms. During the reporting period, we have discovered two important regulatory modules, both of which can help in generating climate-resilient plants.



miR444:MADS27 regulatory module is active in optimal N and mediates root growth and stress responses. miR444 gets induced upon N stress by an unknown step to target MADS27 RNA, thereby reducing MDAS27 levels resulting in poor root growth. MADS27 induces its own promoter and those of a few stress regulators having CARG or related motifs in their promoters (from Pachamuthu et al., 2022).

Generating plants with higher nitrogen use efficiency (NUE) is a holy grail. Inability of plants to absorb N fertilizers is a major reason for pollution and climate change. In rice seedlings, we identified a miRNA and its target transcription factor (miR444:MADS27) regulating root development and architecture, thereby mediating N-dependent growth. This regulatory module is responsible for controlling nitrate transporter proteins, root branching by regula-ting auxin, and very surprisingly in managing abiotic stresses. This multifaceted function of MADS27 was due to its ability to bind and regulate around 1200 regions in the rice genome. Expression of MADS27 in rice and heterologous systems such as tobacco proved beneficial in countering stresses and in improving NUE.

Organisms have to deal with both external and internal genotoxins. Plants being sessile are more prone to genotoxin-induced macromolecule damage. Among the inevitable damaging agents are reactive carbonyls that induce glycation of DNA, RNA and proteins to result in the build-up of advanced glycated end products. It was unknown how plants repair glycated macro-molecules. We show that Arabidopsis DJ-1D, a member of the DJ-1/PARK7 family *(implicated in Parkinson's and other diseases in animals)*, is a robust methylglaoxalase with deglycation property. These properties prove the existence of a previously unknown repair pathway in plants *(Melvin et al., 2022)*.

PUBLICATIONS

- Kannan Pachamuthu, Vivek Hari Sundar, Anushree N.,Rahul R Singh, Soumita Das, Harshith CY, Avik Pal, and Padubidri V Shivaprasad. (2022). Nitrate-dependent regulation of miR444-OsMADS27 signaling cascade controls root development in rice. J. Exp. Bot. 73:3511-3530
- Prasad Melvin*, Priyanka Kataria*, Sunayana Ningaraju, Kondalarao Bankapalli, Radhika Reddy, Chenna Swetha, Gautam Susarla, Radhika Venkatesan, Patrick D'Silva* and P. V. Shivaprasad* (2022) Methylglyoxalase DJ-1D from Arabidopsis is a robust macromolecule deglycase. New Phytol. In Print.

GENETICS AND DEVELOPMENT

Development and Morphogenesis of the Inner Ear

Raj Ladher
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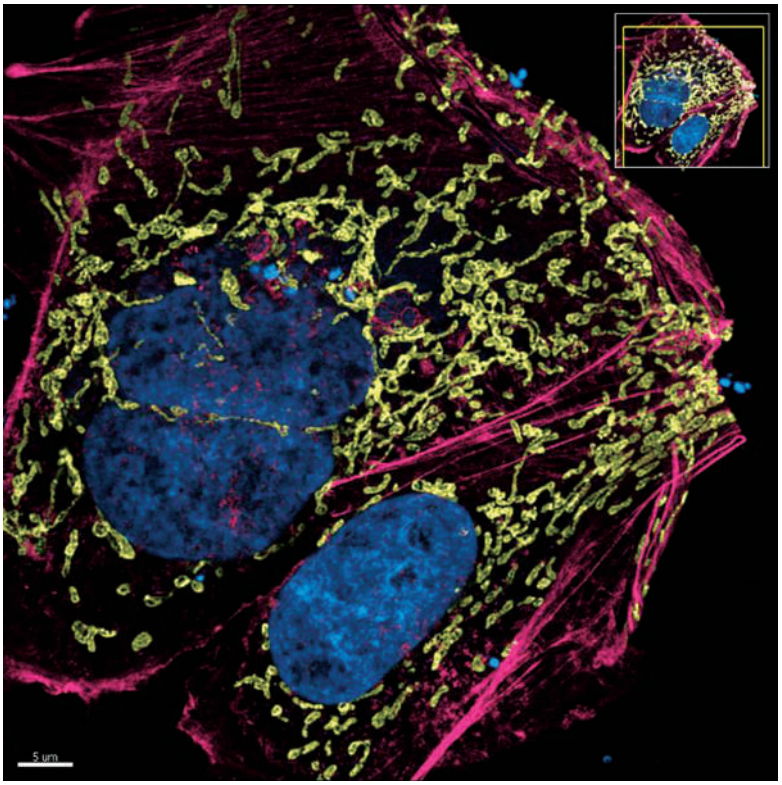
The mechanisms through which developmentally encoded genes coordinate changes in cell biology are responsible for pattern formation. We explore the connections between the two during the formation of the inner ear.

The inner ear is a complex structure that is generated from a relatively simple group of cells. These cells should have become skin, yet receive a series of instructions that change their potential and their shape. A subset of these cells form inner ear hair cells that convert the mechanical vibrations associated with sound into electrochemical impulses that are sent to the brain. How do development programmes instruct these changes to the cell ? Using a variety of molecular, cellular, imaging, and computational approaches, our aim is to understand the development of the inner ear.



MDCK cells stained for the mitochondria using an antibody to TOM20 (yellow). Magenta stains F-actin, and nuclei are blue.

PUBLICATIONS

- Singh N, Prakash A, Chakravarthy SR, Kaushik R, Ladher RK. In Ovo and Ex Ovo Methods to Study Avian Inner Ear Development. J Vis Exp. 2022 Jun 16;(184).
- Honda A, Kita T, Seshadri SV, Misaki K, Ahmed Z, Ladbury JE, Richardson GP, Yonemura S, Ladher RK. FGFR1-mediated protocadherin-15 loading mediates cargo specificity during intraflagellar transport in inner ear hair-cell kinocilia. Proc Natl Acad Sci U S A. 2018 Aug 14;115(33):8388-8393.

HONORS AND AWARDS

- Associate Editor, Developmental Biology.
- TIFR-Leading Edge grant.

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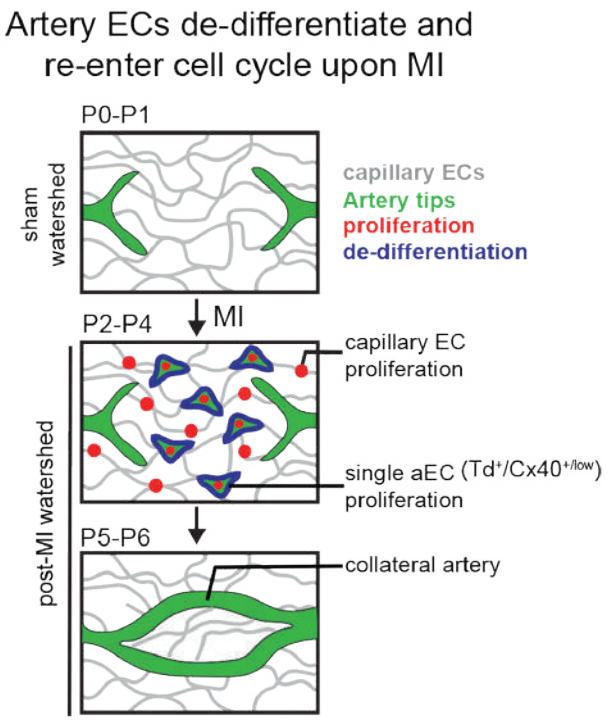
GENETICS AND DEVELOPMENT

Investigating the Role of Endothelial Cells in Cardiovascular Regeneration

We investigate the mechanisms utilized by endothelial cells (ECs) during vascular remodelling. We use genetic mouse models, whole organ-imaging, and functional assays to understand how ECs contribute to tissue regeneration.

Symptoms of occlusive diseases could be combated by growing new arteries called collateral arteries. These are special artery-subtype that connect occluded vessels with healthy vessels and create an alternate route for blood-flow. Collateral arteries have been associated with better survival in heart and stroke patients. Despite the high clinical significance, it is unclear how collaterals form. We showed that collaterals are built through Artery Reassembly migration, proliferation, de-differentiation and coalescence of pre-existing coronary artery endothelial cells (ECs) which drives cardiac regeneration in mice. We showed that VEGF and CXCL12 facilitate Artery Reassembly. Interestingly, this process is age-dependent and is not observed in adult mice.



A proposed model where upon Myocardial Infarction, pre-existing stably differentiated artery ECs (green) exit artery tips as single artery ECs, de-differentaite (blue), proliferate (red) and coalesce into coronary collateral arteries.

Why do adult ECs fail to build collateral arteries? How do collaterals attain maturity? Is Artery Reassembly observed in other ischemia-prone critical organs (brain)? These are some of the many questions we are currently pursuing. These studies will help us gain insights into the poorly understood biology of collaterals and elucidate ways for their induction in the heart.

PUBLICATIONS

- Arolkar, G.*, K, S.*, Wang, H., Gonzalez, K. M., Kumar, S., Rios Coronado, P. E., Joseph Woo, Y., Red-Horse, K., & Das, S. (2022). De-differentiation and Proliferation of Artery Endothelial Cells Drive Coronary Collateral Development. bioRxiv.
- Das, S.*, Feng, Q.*, Balasubramanian*, I., Lin, X., Liu, H., Pellón-Cardenas, O., Yu, S., Zhang, X., Liu, Y., Wei, Z., Bonder, E. M., Verzi, M. P., Hsu, W., Zhang, L., Wang, T. C., & Gao, N. (2022). Colonic healing requires Wnt produced by epithelium as well as Tagln+and Acta2+stromal cells. Development (Cambridge), 149(1). https://doi.org/10.1242/dev.199587. *(* equal contribution).*

Observing fly behaviour to understand the genetic basis of human disorder.
Photo credit: Sonal Katyal

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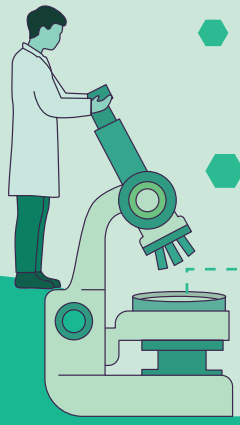

Cellular Organisation and Signalling

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CELLULAR ORGANISATION AND SIGNALLING

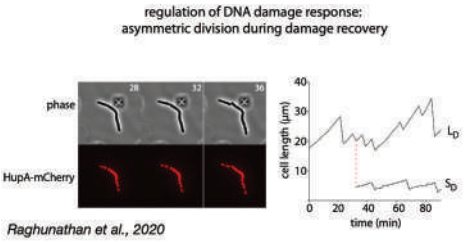
Cell Biology of Microbial DNA Damage Response and Repair

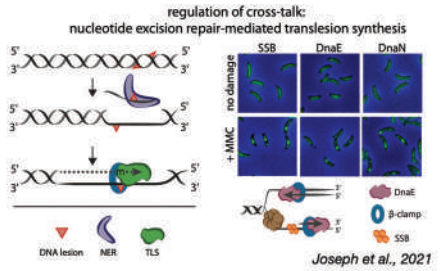
The overall objective of our work is to understand the fundamental regulatory mechanisms that govern the activity of genomic error-correction pathways, and how this can drive genome evolution under genotoxic stress. For this, we study how DNA damage response and repair is regulated in microbial systems.

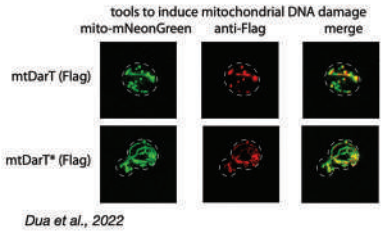
While repair pathways have been well-studied in isolated contexts in vitro, little is known about their dynamics, mechanisms of action, and regulation in a living cell. In our lab we study how DNA repair mechanisms are coordinated and regulated in vivo in microbes. For this, we employ quantitative live-cell imaging techniques to follow repair in real-time, in conjunction with genetic tools to introduce specific DNA damage perturbations. Our present efforts have focused on understanding how specific steps of repair are regulated in microbial systems in vivo, under the following themes:

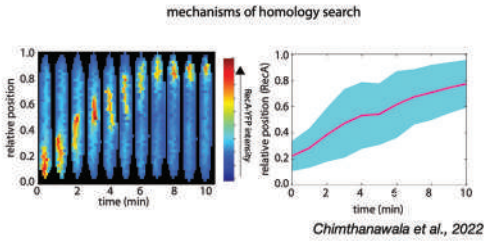
- Sensing and responding to DNA damage.
- Repairing damage and regulating repair pathway activity.

Our work has revealed **a)** the power of single-cell microscopy to study DNA damage response and repair in vivo and **b)** the need to consider coordinated action of repair pathways originally assumed to function independently. In future, we aim to understand how mutagenic and non-mutagenic repair is regulated in a cellular context and how genome maintenance is coordinated with other cellular stress responses as well as cell cycle progression. These studies provide insights into general principles of genome integrity maintenance, mechanisms of stress-induced mutagenesis and its impact on microbial adaptation/survival in stressful environments.









PUBLICATIONS

- Chimthanawala C, Parmar J, Kumar S, Rao M* and Badrinarayanan A*. SMC protein RecN drives RecA filament translocation and remodelling for in vivo homology search. Proceedings of the National Academy of Sciences, 2022, 119(46), e2209304119
- Dua N, Seshadri A and Badrinarayanan A*. DarT-mediated mtDNA damage induces dynamic reorganization and selective segregation of mitochondria. The Journal of Cell Biology, 2022, 10.1083/jcb.202205104

HONORS AND AWARDS

- DBT/Wellcome Trust India Alliance Intermediate Fellowship.
- HFSP Programme Grant.
- INSA Young Scientist medal.

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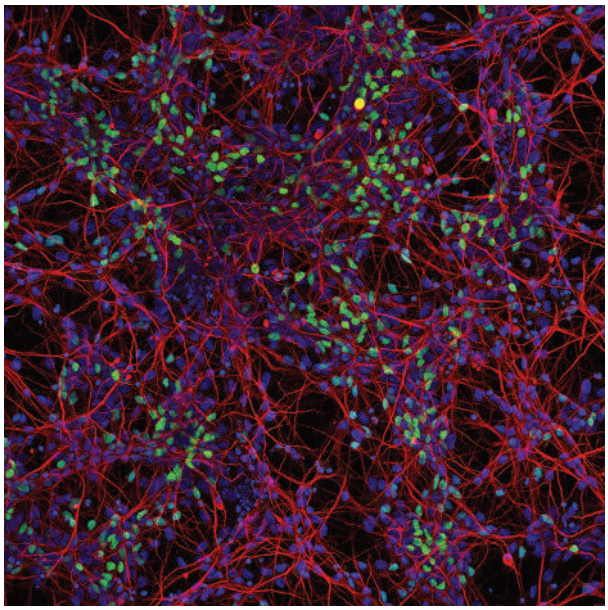
CELLULAR ORGANISATION AND SIGNALLING

Phosphoinositide Signalling in Cell Biology

Chemical messengers derived from the lipid phosphatidylinositol are part of an evolutionarily conserved mechanism of cell signalling. These molecules regulate key cellular and biological processes in eukaryotes. We study the logic underlying lipid signalling and its relevance to biomedical science.

Our long-term scientific interest is to understand cellular communication mediated by lipid molecules generated by the metabolism of phosphatidylinositol. Phosphoinositide signals provide molecular control for key subcellular processes such as membrane remodelling, cytoskeletal function, transcription, and translation. Through these processes, this signalling pathway orchestrates basic cellular behaviours such as cell division, shape changes, polarised movement, and cell death; and these behaviours play key roles in a number of physiological processes including early embryogenesis, lymphocyte development and function, as well as neuronal activity.

The overall goal of our work is to understand how the architecture in this signalling cascade is designed to optimally deliver physiological outputs. The work is multidisciplinary and done using a combination of Drosophila and human disease models. Over the last year, we have uncovered the function of key enzymes that regulate lipid signalling and provided a molecular mechanism by which they control cellular processes. These include the mechanism by which lipid molecules are exchanged between cellular compartments, the control of membrane turnover and receptor activity by lipids, and a quantitative model of the turnover of lipids during critical cell signalling reactions important for brain function.



We also study the function of phosphoinositides in neuronal cell biology and brain disorders using human iPSC-derived neural cells in cell culture. The goal of this work is to uncover the function of altered phosphoinositide signalling in brain disorders.

Cultures of human stem cell derived neural cells at 30 days in vitro. Neurons are marked by the mature neuronal marker MAP2 (red) and deep layer specific marker CTIP2 (green).

PUBLICATIONS

- Akhtar BM, Bhatia P, Acharya S, Sharma S, Sharma Y, Aswathy BS, Ganapathy K, Vasudevan A & Raghu P. A human stem cell resource to decipher the biochemical and cellular basis of neurodevelopmental defects in Lowe Syndrome. Biology Open 15;11(1):bio059066. doi:10.1242/bio.059066 Epub 2022 Feb 4.
- Kumari A, Ghosh A, Kolay S and Raghu P*. Septins tune lipid kinase activity and PI(4,5)P 2 turnover during G-protein-coupled PLC signalling in vivo. Life Sci Alliance. 2022 Mar 11;5(6):e202101293. doi: 10.26508/lsa.202101293. Print 2022 Jun.

HONORS AND AWARDS

- Dr. C. Sitadevi Oration - Association of Clinical Biochemists of India, 2022.

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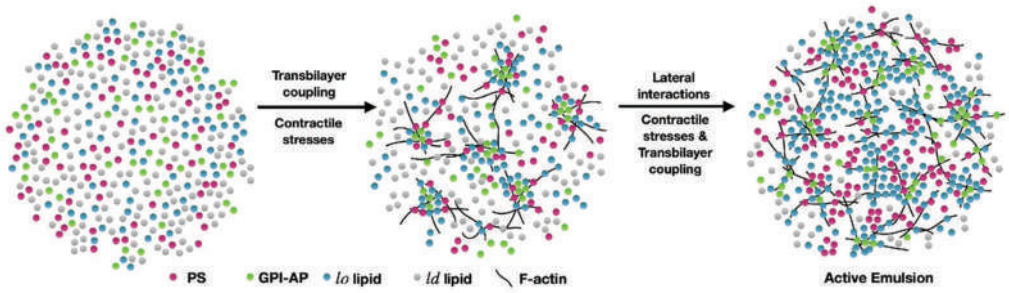
CELLULAR ORGANISATION AND SIGNALLING

Mechanisms of Membrane Organization and Endocytosis

Our laboratory studies physico-chemical rules that govern local organisation of cell membrane components in a living cell and connect this to cellular and organismal physiology. In this context we explore how functional signalling complexes and responsive endocytic platform are built.

The plasma membrane that demarcates the boundary of a cell is far from a well-mixed 2-D fluid membrane bilayer. It is a macromolecular assembly teeming with activity and local heterogeneities. It is the site where information transfer and endocytic activities take place potentially modulated by the local organization and structure of the membrane. Our laboratory studies how local membrane heterogeneities arise providing a new understanding of the membrane as an active composite of a lipid bilayer in conjunction with a dynamic cytoplasmic cortical actin scaffold. Dynamic contractile actin filaments help in controlling the local composition of the membrane, and endocytic processes help to regulate global composition and tension in the membrane. In this last year we have discovered that the contractile activity of the cytoskeleton engages with very specific membrane lipids such as phosphatidylserine at the inner-leaflet. Trans-bilayer interactions of phosphatidylserine with long acyl-chain containing lipids at the outer leaflet lipid in the presence of cholesterol, generate nanoscopic domains which organize as mesoscopic domains of liquid-ordered lipid species, resulting in active emulsions in the cell membranes [1]. These are sites where sorting of specific membrane components take place based on mechanisms available to actively stirred components. In parallel we have explored how membrane receptors are recruited to the sites of clathrin and dynamin-independent endocytic pathways [2].



Active emulsions: emergent mesoscale domains at the cell surface.

PUBLICATIONS

- Saha et al, Active emulsions in living cell membranes driven by contractile stresses and transbilayer coupling. Proc. Nat. Acad. Sci., (2022), e2123056119, 119(30).
- Moreno-Layseca P, et al. Cargo-specific recruitment in clathrin- and dynamin-independent endocytosis. Nat Cell Biol. 2021 Oct;23(10):1073-1084. doi: 10.1038/s41556-021-00767-x. Epub 2021 Oct 6. Erratum in: Nat Cell Biol. 2022 Sep;24(9):1445. PMID: 34616024.

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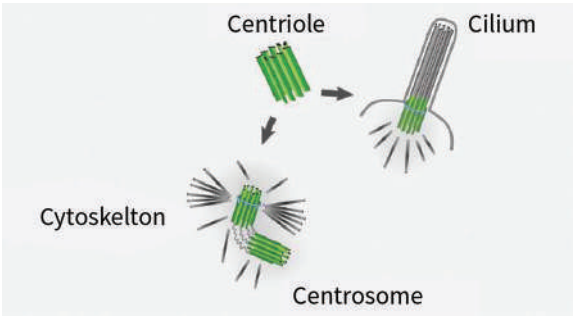
CELLULAR ORGANISATION AND SIGNALLING

Organelle Biology: Implications in Physiology and Diseases

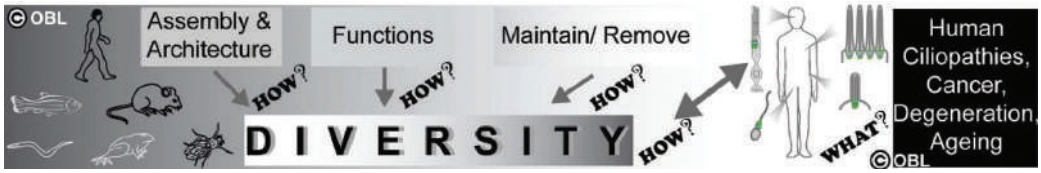
The Organelle Biology Laboratory (OBL) investigates mechanisms for building, diversity, evolution and maintaining organelles, primarily Cytoskeleton, Centrosome, and Cilium (i.e., 3Cs), in various organisms using a multifaceted approach.

Essential eukaryotic structures, the cytoskeleton, centrosome, cilium, mitochondria and lysosome, are implicated in numerous human diseases, including degenerative diseases, cancer and ciliopathies *(combined affect 1 in every 3 individuals)*. Despite these organelles' importance to human health, **our knowledge of their roles in pathologies is limited.**

The OBL primarily focuses on the Cytoskeleton, Centrosome and Cilium (3Cs) and their involvement in numerous signalling processes, which are vital for organism development and homeostasis. We, for example, ask : **1)** What controls the organisation of several critical building blocks of 3Cs? **2)** How are different portions of these structures assembled? **3)** How are these vital structures maintained and go wary with pathological conditions? And we apply a combination of approaches/techniques/tools *(including bio-physics, -chemistry and -informatics, genetics, transcriptomics, proteomics, advanced imaging, electrophysiology and animal behaviour).* We also apply our acquired knowledge in chemical biology, biomedicine and biotechnology.



Scheme shows the dual life of centriole in centrosome and cilium.
Centrosomes are evolutionarily conserved centrioles surrounded by pericentriolar material (PCM) and act as major cytoskeleton organising centres. During 'centrosome-tocilium' conversion (C2Cc), some centrioles acquire critical structures to become the base of the cilia.



The scheme displays a few questions the OBL address.

PUBLICATIONS

- Jana SC† Centrosome structure and biogenesis: Variations on a theme? Semin Cell Dev Biol. 110. 123-138. 2021.
- Jana SC*†, Jain A*, Datt P* et al.. Kinesin-2 transports Orco into the olfactory cilium of Drosophila melanogaster at specific developmental stages. PloS Genetics. 17 (8). e1009752. 2021.

  †- corresponding author

HONORS AND AWARDS

- Principal Investigator, FCT Research Grant, FCG-IGC, Portugal (2018-2022).
- Grant-in-Aid, SERB, DST, India.
- Scientific Meeting Grant, Company of Biologists, UK.

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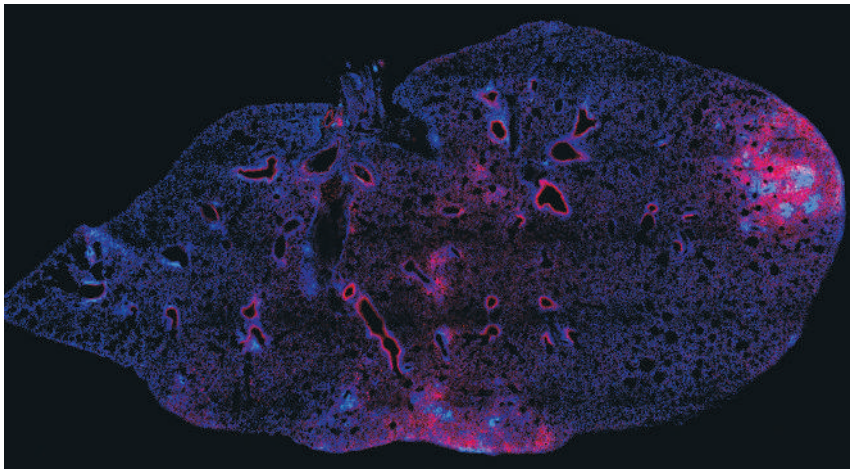
CELLULAR ORGANISATION AND SIGNALLING

Biology of Host-Pathogen Interactions During Intracellular Infections

The broad goal of our lab is to understand the interactions between intracellular pathogens and host cells, with particular interest in the modulation of host cellular pathways, and exploit this knowledge for host-directed therapeutics against infectious diseases.

My lab works on host-pathogen interactions, specifically on how fundamental host cellular processes such as trafficking *(endocytosis, autophagy, and lysosomes)* are modulated by intracellular infections. We combine cell biological methods, high content imaging and computational approaches with conventional cell and molecular biology tools. We address distinct aspects of these interactions at molecular, cellular and tissue scales across a broad range of intracellular pathogens including virus (SARS-CoV-2), bacteria *(M. tuberculosis)* and parasite *(Plasmodium spp, liver stage)*. Simultaneously, we aim to exploit this knowledge for drug discovery to identify small molecules that can be used as adjuncts in host directed therapeutics.

Our recent results shows a requirement of functional endo-lysosomal pathway for the uptake and survival of many intracellular pathogens, while concomitantly these pathways are actively modulated and altered by the pathogens. These alterations include sub-cellular redistribution of specific endosomal pools and an increase in the numbers and contents of distinct endosomal populations specifically in the infected cells. In case of M. tuberculosis infections, the endosomal system influences the infectivity of the pathogen, and lysosomes distinctly modulate their intracellular survival. Abrogation of these alterations by chemical modulation results in killing of the pathogen, or, in further enhancing their survival. In ongoing projects, we are understanding the mechanisms and significance of these modulation.



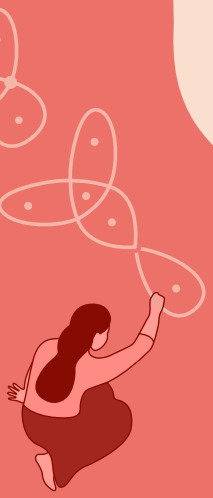
Lung tissue from mice infected with M. tuberculosis expressing mCherry (red) and stained with DAPI (blue). Scale bar 1 mm.

PUBLICATIONS

- Lahree A, Baptista SJS, Marques S, Perschin V, Zuzarte-Luís V, Goel M, Choudhary HH, Mishra S, Stigloher C, Zerial M, Sundaramurthy V, Mota MM. Active APPL1 sequestration by Plasmodium favors liver-stage development. Cell Rep. 2022 May 31;39(9):110886.
- Anand K, Sundaramurthy V. Mycobacterial lipids in the host-pathogen interface: roles in pathogenesis and host immune response. Biology of Mycobacterial Lipids, Page 52-82. Academic Press, Elsevier Inc. ISBN: 978-0-323-91948-7.

4

Theory, Simulation, and Modelling of Biological Systems



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THEORY, SIMULATION, AND MODELLING OF BIOLOGICAL SYSTEMS

Emergence and Control in Development and Evolution

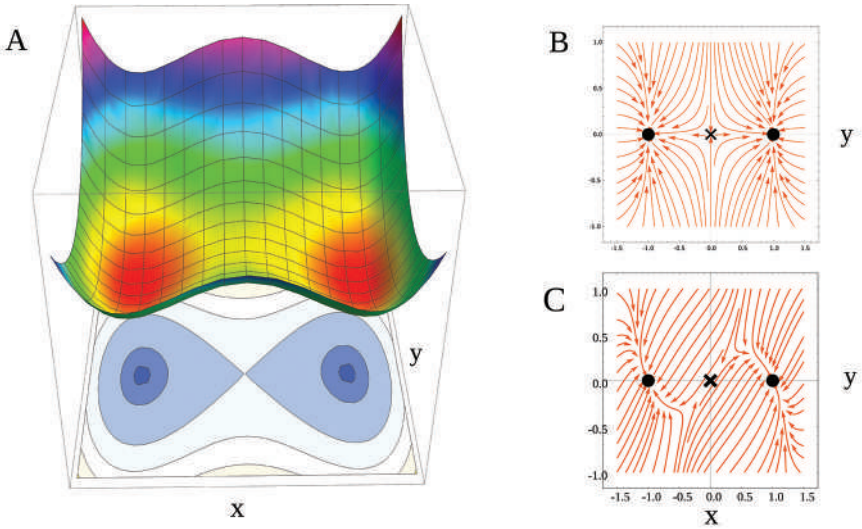
I am interested in the theoretical modeling of cell fate specification during development, both to make more parsimonious representations of data as well as to clarify broader concepts.

Previously, I was working on a proposal to mathematically formalize the concept of a Waddington Landscape to organize different models in developmental biology under a common framework. Since then, I have been working on a concrete example in the early mouse blastocyst to illustrate the application of such models. I have also been trying to relate the idea of motifs in gene regulatory networks to landscapes.

I have further developed a model which examines the consequences for evolution of Waddington's work. We have been trying to quantitatively understand old experiments on genetic assimilation which have been recently repeated.

Further, we are looking at the specification of digits in mice, which has recently been proposed to operate through a Turing mechanism. Turing mechanisms are notorious for being noisy and we are trying to quantify their robustness by formulating them as a landscape.

Finally, we are also looking at the effect of lineage correlations on cell-fate and developing models of phenotypic memory.



(A) The Waddington landscape corresponds to potential which is shown here both as a 3D plot and as a contour-plot. Both are equivalent ways to look at the potential which defines the flow.

(B) The gradient of the potential defines a flow. This flow can be visualized using streamlines.

(C) The potential does not fully determine the dynamics and It is possible for there to be a metric which can significantly alter the flow as shown here.

PUBLICATIONS

- Rand, David A., et al. "Geometry of gene regulatory dynamics." Proceedings of the National Academy of Sciences 118.38 (2021): e2109729118.

Theoretical Approaches in Cell Biology: Physics of Active, Evolving Systems

Madan Rao
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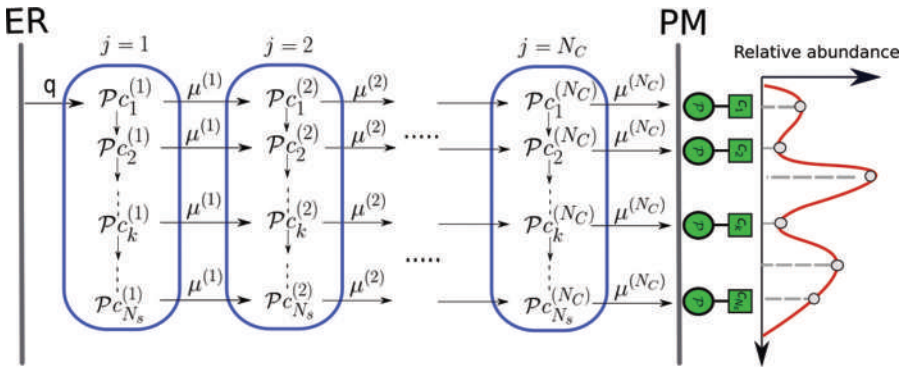
Our group studies the interplay between active mechanics, molecular organisation, geometry, and information processing in a variety of cellular contexts such as cell surface signalling and endocytosis, packing of chromatin within the nucleus, organelle biogenesis, and tissue morphogenesis.

We are interested in how living systems, composed of physical entities such as molecules and molecular aggregates, driven far from equilibrium, have self-organised *(evolved)* to perform, "engineering tasks", such as efficient processing of information, computation, and control. This potentially brings together many fields of research, including non-equilibrium statistical physics, soft active mechanics, information theory, and control theory, to the study of biology.

We explore new physical and chemical principles underlying biological organisation across scales, from functional biomolecules, to subcellular organelles, to the cellular and tissue scale. We are interested in the folding and packaging principles that govern the three-dimensional functional organisation of large biomolecular assemblies, such as proteins and chromatin, and their interactions with other cellular components. At a larger scale—at the subcellular, cellular, and tissue level—organisation is often driven by active mechanisms fueled by energy.



Enzymatic reaction and transport network in the secretory pathway.

Typically these active forces arise from: **(a)** the coupled dynamics of the cytoskeleton, motors, and cytoskeletal regulatory proteins, and **(b)** the active dynamics of fission and fusion of organelles, and regulate the flux of mass, stress, energy, and information. Using the framework of active hydrodynamics, we study the mechanical response, pattern formation, symmetry breaking, hydrodynamic instabilities, and information flows in both in vivo and in vitro reconstituted active systems.

PUBLICATIONS

- Banerjee, J. P., Mandal, R., Banerjee, D. S., Thutupalli, S. and Rao, M. 2021. Active ploughing through a compressible viscoelastic fluid: Unjamming and emergent nonreciprocity. arXiv preprint arXiv:2109.10438.
- Ramakrishnan, N., Gowrishankar, K., Kuttippurathu, L., Sunil Kumar, P. B. and Rao, M. 2021 Active remodeling of chromatin and implications for in-vivo folding. Accepted in Journal of Physical Chemistry.

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THEORY, SIMULATION, AND MODELLING OF BIOLOGICAL SYSTEMS

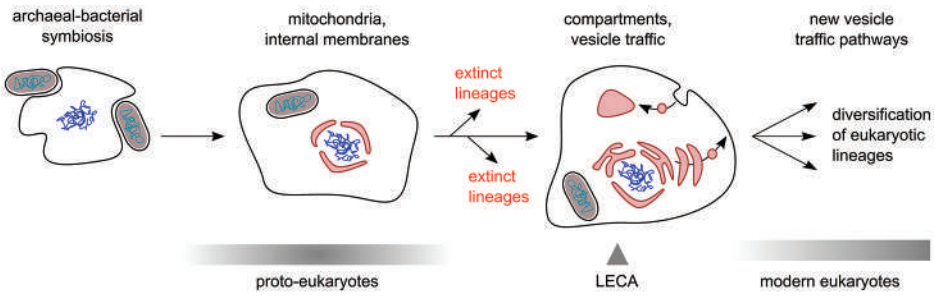
The Whats, Hows and Whys of the Eukaryotic Cell Plan

We use the membrane traffic system as a window to study the mechanistic and evolutionary origins of the eukaryotic cell plan, using tools from mathematics, physics, and computer science.

As a physicist practising biology, I am interested in how cellular complexity emerges from molecular rules. My group is based within the Simons Centre for the Study of Living Machines at NCBS. We use biophysical, mathematical and computational principles to understand how cells work. We have been deeply involved in developing evolutionary cell biology as a rigorous field of study.

We ask:

- What? We study the evolution of proteins involved in membrane traffic, to shed light on the natural history and diversity of this system across species and time.
- How? We use mathematical and computational methods to understand how the global structure of the membrane traffic system emerges from local molecular interactions.
- Why? We explore the selective advantage of having intracellular organelles and intra-organellar transport, with particular focus on the structure and function of the Golgi apparatus.



The architecture of eukaryotic cells was established over billions of years of evolution. We are interested in the period since the last eukaryotic common ancestor (LECA) during which the membrane traffic apparatus expanded and diversified. Figure adapted from: Thattai, Current Opinion in Cell Biology, 2023.

PUBLICATIONS

- Purkanti, R., & Thattai, M. (2022). Genome doubling enabled the expansion of yeast vesicle traffic pathways. Sci Rep: Collection on Eukaryogenesis. Sci Rep 12: 11213.
- Mani, S., Krishnan, K. & Thattai, M. (2022). Graph-theoretic constraints on vesicle traffic networks. J Biosciences 47: 1-19.

Sandeep Krishna
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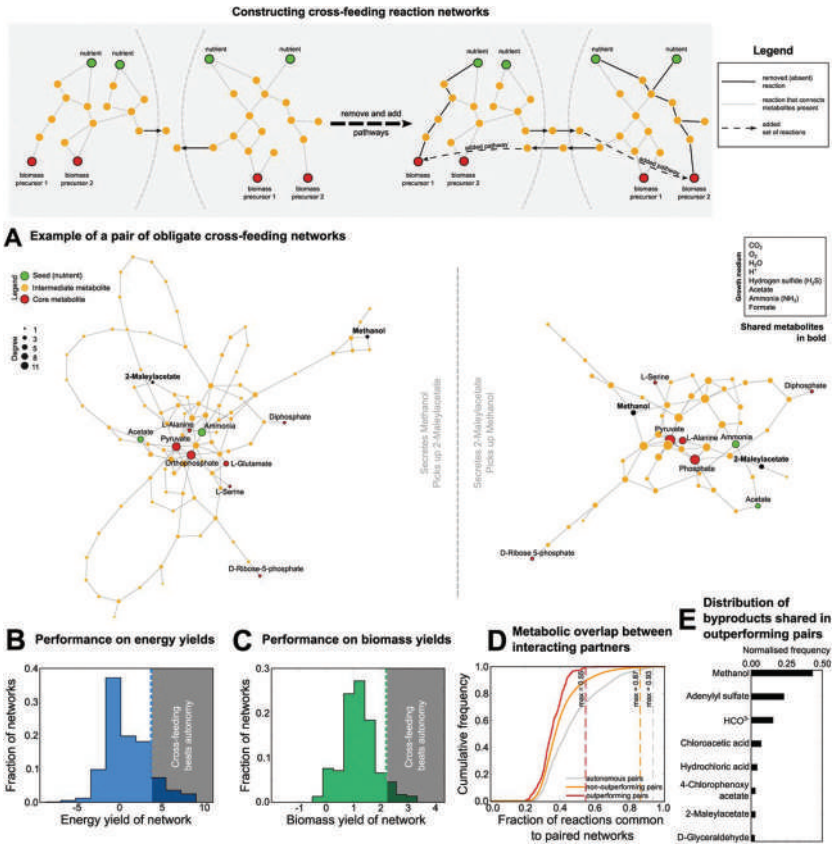
THEORY, SIMULATION, AND MODELLING OF BIOLOGICAL SYSTEMS

Non-equilibrium Dynamics of Living Systems across Scales

I study the complex, far-from-equilibrium dynamics of biological systems, ranging from molecules to cells to populations.

At the molecular level, I am interested in using a combination of experimental data and mathematical models to study the dynamics of different mechanisms of protein regulation and their roles in feedback loops. At the cellular level, I have been interested in oscillatory behaviour, synchronisation, and entrainment in signalling pathways. Finally, at an ecosystem level, I have been studying infectious diseases and microbial communities to understand issues related to the spontaneous emergence of heterogeneity in isogenic populations.



We randomly assembled an ensemble of metabolic networks using reactions known to occur in prokaryotes which are capable of synthesizing biomass precursors in a given nutrient environment (top panel). Comparing autonomous networks (which can do this task on their own) with obligate pairs of cross-feeding networks (each of which need their partner to do this task, panel A), we find that there exist cross-feeding metabolic networks that can produce a higher yield than even the best autonomous networks (panels B and C). This demonstrates a chemical benefit for the existence of metabolic cooperation in microbes via cross-feeding and makes specific predictions about the nature of such metabolic networks (panels D and E). Figure adapted from publication 1 shared below.

PUBLICATIONS

- A Goyal, S Krishna (2022) The chemical basis of metabolic interdependence in microbial communities, bioRxiv 2022.03.14.484247; doi: https://doi.org/10.1101/2022.03.14.484247.
- P Cherian, S Krishna, GI Menon (2021) Optimizing testing for COVID-19 in India, PLoS Comput. Biol. 17 (7), e1009126.

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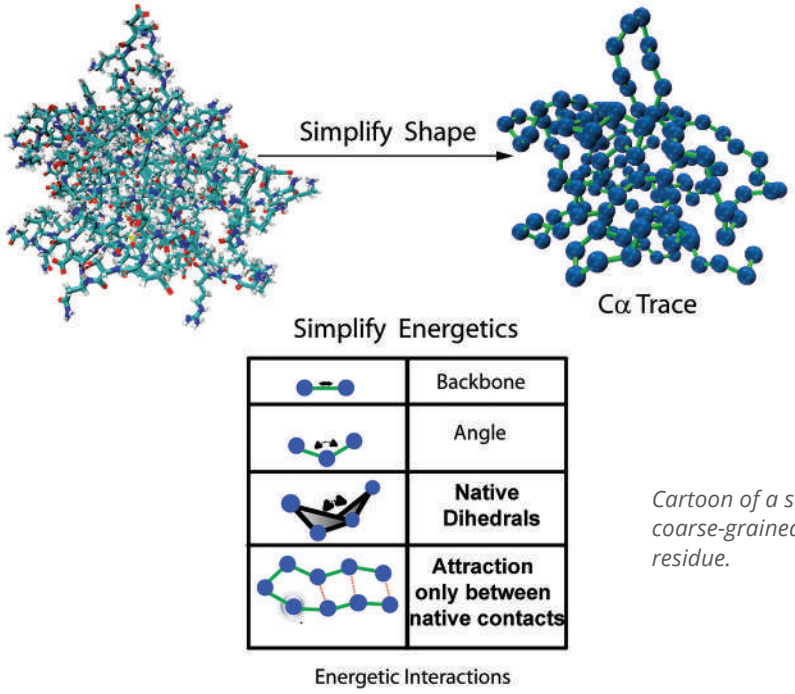
THEORY, SIMULATION, AND MODELLING OF BIOLOGICAL SYSTEMS

Computational Dynamics of Biomolecular Self-Assembly

My group uses computational methods, specifically molecular dynamics simulations of coarse-grained and structure-based models, to understand the dynamics of protein folding and self-assembly.

Natural proteins fold robustly because of a funnel-shaped energy landscape. This funnel shape arises because native interactions dominate the folding landscape, while interactions not present in the native state (i.e. non-native interactions) contribute only in an average way. Structure based models (SBMs) of proteins ignore non-native interactions by encoding only the folded structure of the protein into the energy function. This energy function can then be used to perform molecular dynamics (MD) simulations. The advantage of using SBMs is that they simplify the energy function such that long time-scale biomolecular motions such as protein folding, large conformational transitions and protein self-assembly can be easily sampled. We have been using and developing SBMs to understand mechanisms of biomolecular self-assembly, including those of multimerization and domain-swapping in viral proteins and how pieces of a protein (self-peptides) interact with the whole protein.



Cartoon of a structure-based model coarse-grained to a single Cα bead per residue.

PUBLICATIONS

- D Lalwani Prakash, S Gosavi, "Understanding the Folding Mediated Assembly of the Bacteriophage MS2 Coat Protein Dimers," The Journal of Physical Chemistry B 125, 8722-8732, 2021.
- S Yadahalli, LP Jayanthi, S Gosavi, "A Method for Assessing the Robustness of Protein Structures by Randomizing Packing Interactions," Frontiers in Molecular Biosciences 9, 2022.

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THEORY, SIMULATION, AND MODELLING OF BIOLOGICAL SYSTEMS

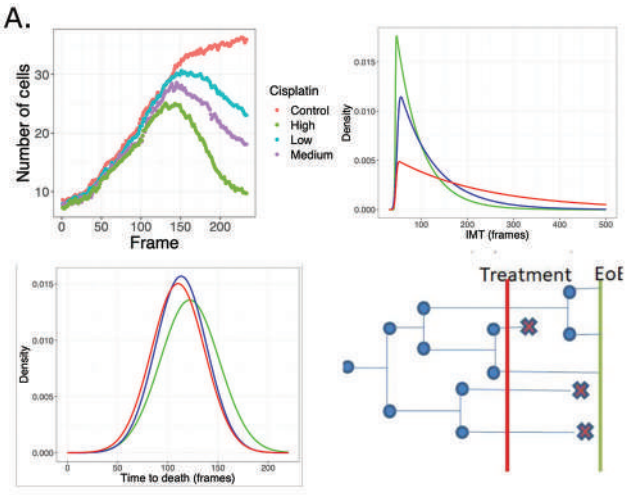
Quantitative Cell Biology: Cellular Proliferation in Development and Disease

My research combines theory and experiments to study cellular proliferation at the single cell level: its underlying physical principles, control mechanisms, and consequences in development and disease.

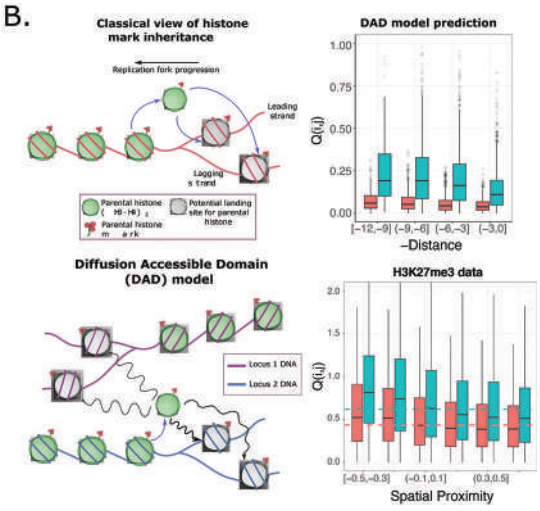
My lab continues to explore a variety of research directions with cell proliferation forming the unifying element within somewhat disparate cell-biology questions.

We are establishing a simple theoretical framework for understanding how population growth laws emerge in cancer cells during treatment with anti-cancer therapies, from fluctuations (non-genetic heterogeneity) at the single cell level.

These fluctuations induce a variety of lineage correlation patterns which we are using as probes to understand how the circadian clock drives cell proliferation, and also to infer the phase of the circadian clock in single cells. Along with development of these theoretical frameworks, we have also successfully established single molecule FISH protocols to quantify and utilize information hidden in the lineage correlations. Finally, we have been studying how epigenetic inheritance across cellular generations and the architecture of the epigenome can be shaped by simple physical laws such as diffusion.



(A) Using single cell division time distributions and correlations in end fate to predict population cell proliferation.



(B) A new model for epigenetic inheritance.

PUBLICATIONS

- "Diffusion controls local versus dispersed inheritance of histones during replication and shapes epigenomic architecture", Archit Singh and Shaon Chakrabarti, bioRxiv (https://doi.org/10.1101/2022.08.31.505992).

HONORS AND AWARDS

- Awarded the SERB SUPRA grant to develop a microscopy based technology to infer circadian time in tissues.

Living Metamaterials: Towards a Synthetic Biology from a Physical Perspective

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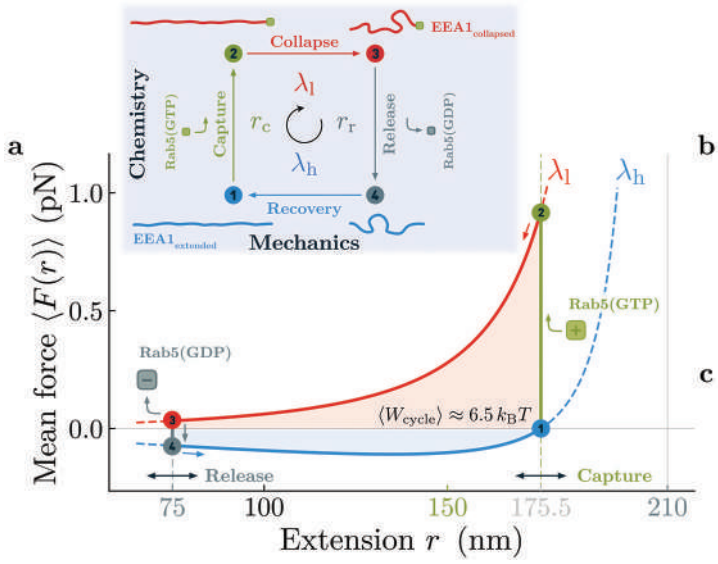
We are interested in the underlying principles of emergence and organization in living systems -- towards this goal, we develop quantitative experiments combined with conceptual frameworks.

The field of active matter physics has met with some initial success in its application to biology. In extending it by including aspects of growth and replication, we aim for a synthetic biology, analogous to the laboratory science that is a source of new phenomenology in condensed matter physics. Such an extension means that the emergent mechanics and spatial organization as highlighted by the program of active matter, intersects with the underlying topological structures of the processes of information processing, self-assembly, self-replication, and ultimately the ability to evolve. We use two complementary viewpoints - **(i)** to endow artificial active matter systems with the abilities of heritable self-replication and thereby create scenarios for evolutionary dynamics and increasing complexity and **(ii)** to use experimental evolution of biological systems to bridge eco-evolutionary processes with emergent mechanics. This juxtaposition -- placing evolution, mechanics and topology at the crux of the two complementary approaches -- is the central aspect of the synthetic biology that we envision.



The long coiled-coil tether EEA1 and its small GTPase partner, Rab5, form a two component molecular motor, constituting a first example of a GPTase driven mechanical molecular machine. Mechanics and chemistry couple via the interactions between these two molecules – binding, GTP hydrolysis – to perform a work cycle (a,b), which we have confirmed using optical tweezers experiments (c).

PUBLICATIONS

- A Singh, JA Soler, J Lauer, SW Grill, M Jahnel, M Zerial, S Thutupalli, GTPase-dependent cyclic flexibility transitions drive the two-component EEA1-Rab5 molecular motor, bioRxiv, 2022.07.18.500463 (2022).
- JP Banerjee, R Mandal, DS Banerjee, S Thutupalli, M Rao, Unjamming and emergent nonreciprocity in active ploughing through a compressible viscoelastic fluid, Nature Communications 13 (1), 1-10 (2022).

HONORS AND AWARDS

- 2022 Emerging Investigator, Soft Matter.
- 2022 Associate Editor and Member Editorial Board, European Journal of Physics-E.
- 2021 Review Editor, Frontiers in Soft Matter.

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THEORY, SIMULATION, AND MODELLING OF BIOLOGICAL SYSTEMS

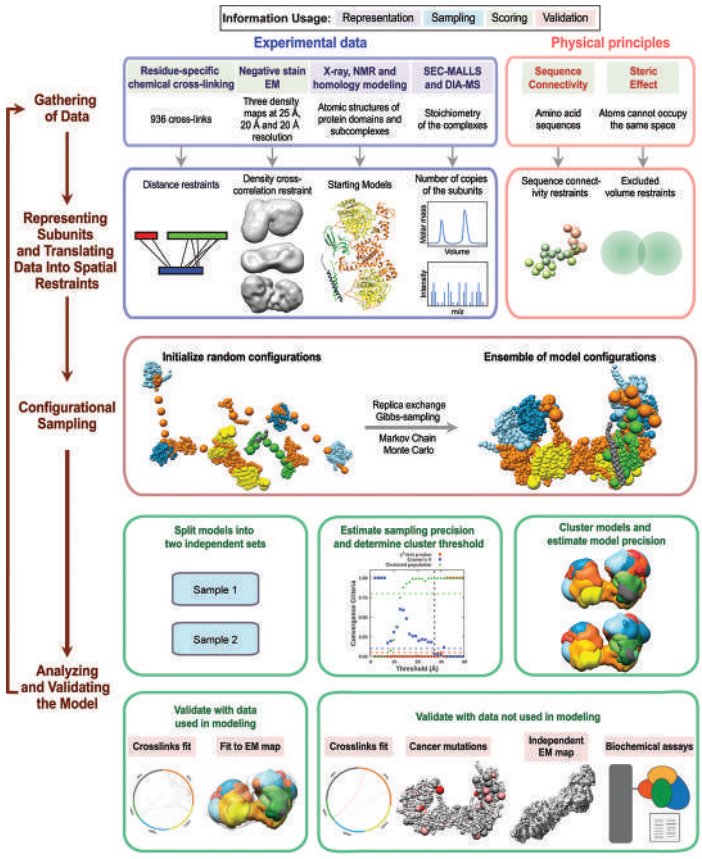
Integrative Structural Biology of Large Macro-Molecular Assemblies

Using an integrative approach, we develop and apply methods to determine protein organization in cells by characterizing their structures in binary complexes, macromolecular assemblies, and nanoscale architectures.

Large protein assemblies, such as the ribosome or proteasome, contain tens to hundreds of proteins, and are molecular machines. The structures of these assemblies are key to understanding mechanistic details of biological function. We seek to understand: How did these machines evolve? How are they assembled and regulated in the cell?

Determining the structures of these assemblies using a single experimental method is challenging. Therefore, we use an integrative approach, combining data from biophysical, biochemical, genetics, and cell biology experiments, along with statistical inference, physical principles, and prior models. We are currently characterizing assemblies in three broad areas: assemblies involved in chromatin remodeling, assemblies at cell-cell junctions, and assemblies involved in cytoskeletal structuring, such as centriolar and centrosomal protein complexes.

Our other focus is developing rigorous methods and software for computational modeling of protein organization. Our methods are used by the wwPDB. We are currently developing deep learning-based methods to characterize binding interfaces formed by intrinsically disordered proteins.



Integrative structure determination of the NuRD complex. Using information from several biochemical and biophysical experiments, we investigated the molecular architecture of the NuRD complex.

PUBLICATIONS

- S. Arvindekar, M. J. Jackman, J.K.K. Low, M.J. Landsberg, J.P. Mackay, S.Viswanath, Molecular architecture of nucleosome remodeling and deacetylase sub-complexes by integrative structure determination, Protein Science (2022).
- V. Ullanat, N. Kasukurthi and S. Viswanath, PrISM: precision for integrative structural models, Bioinformatics (2022).

HONORS AND AWARDS

- Protein Society Travel Award 2022 to Shreyas Arvindekar for his work on Integrative structure determination of the NuRD complex.
- Cover image on Protein Science Oct 2022 virtual issue for Molecular architecture of nucleosome remodeling and deacetylase sub-complexes by integrative structure determination.

Hard work on display: Students during their poster presentations.
Photo credit: Sonal Katyal

5

Neurobiology

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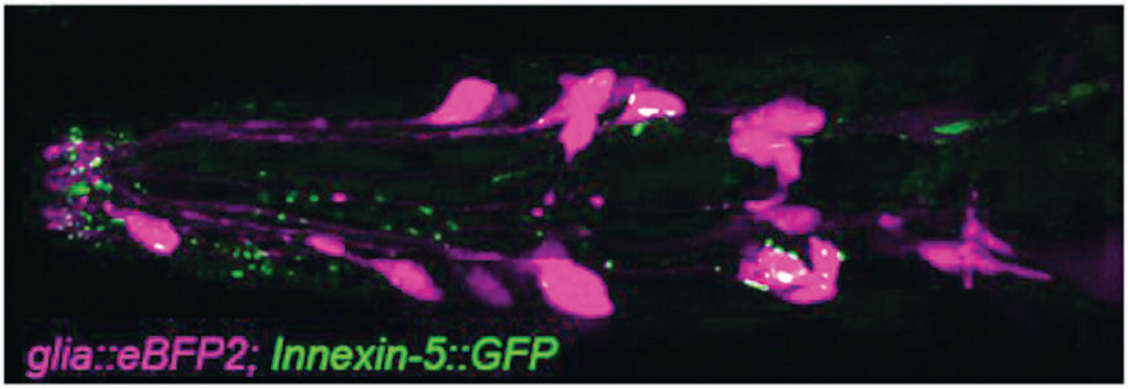
NEUROBIOLOGY

Mechanisms of Electrical Synapse Formation, Regulation and Function

We are investigating the fundamental principles regulating formation and functioning of electrical synapses, a conserved, critical, yet much understudied feature of the nervous system.

Understanding how an individual neuron finds a specific synaptic partner *(synaptic specificity)* and connects with different partners using synapses that bear distinct properties *(functional diversity),* have remained pivotal questions in neuroscience. While the complex biology of chemical synapses has been widely studied, electrical synapses remained much understudied, despite playing conserved and critical roles in the establishment and functioning of the neural circuit. The overall research goal of our lab is to understand the fundamental molecular principles regulating the assembly and functioning of the electrical synapse connectome, areas that are still very poorly understood. More specifically, we are working to understand **a)** how individual neurons form molecularly and functionally distinct synapses with different synaptic partners, **b)** how plastic changes in the electrical synapse network is achieved in response to intrinsic and extrinsic cues and **c)** how gap junctions on glial cells regulate nervous system development and function.



Extensive network of gap junctions on glial cells in C. elegans head (pseudocolored in magenta) is visualized using a CRISPR/Cas9-mediaded GFP-tagged conditional allele of Innexin-5 (green). Innexin-5 is a pan-glially expressed gap junction channel component.

PUBLICATIONS

- Reilly, M.B., Tekieli, T., Cros, C., Aguilar, R.G., Lao, J., Toker, I.A., Vidal, B., Leyva-Diaz, E., Bhattacharya, A., Smith, J.J., Kovacevic, I., Gulez, B., Fernandez, R., Bradford, E.F., Ramadan, Y.H., Kratsios, P., Bao, Z., Hobert, O*. Widespread employment of conserved C. elegans homeobox genes in neuronal identity specification. PLOS Genetics (Accepted).
- Berghoff, E.G., Glenwinkel, L., Bhattacharya, A., Sun, H., Mohammadi, N., Antone, A., Feng, Y., Nguyen, K., Cook, S. J., Wood, J. F., Masoudi, N., Cross, C., Ferkey, D. M., Hall, D. H., and Hobert, O*. The Prop1-like homeobox gene unc-42 specifies the identity of synaptically connected neurons. eLlife. 2021 Jun 24; 10: e64903. PMID: 34165428.butterflies in the biogeographically complex Indo-Australian Region. bioRxiv, DOI: https://doi.org/10.1101/2022.03.23.485569.

Hiyaa Ghosh
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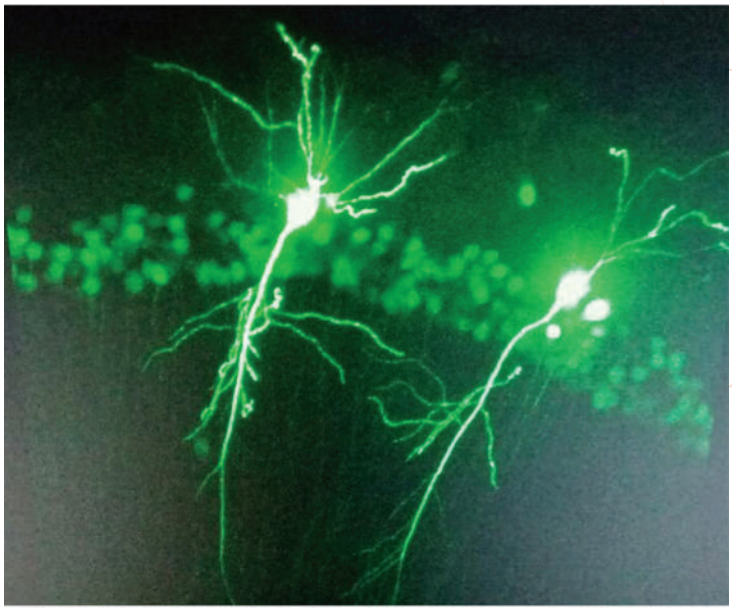
NEUROBIOLOGY

Brain Homeostasis and Neuroinflammation

Research in my laboratory seeks to understand genetic regulations that underlie homeostatic functioning of the brain, and deregulations that cause neuroinflammation.

Our goal is to uncover innate genetic programs within adult neuron and glial cells that could enable adaptive changes under conditions of physiological perturbations, in order to maintain homeostasis. To this end, we study neurons, microglia and adult neural stem cells (NSC) using the mouse as a model-system. We also employ various disease-models including neurodegeneration, infection, injury and stress, to understand how and if tissue-homeostasis in the adult brain is regained after physiological and pathological insults. Our approaches involve investigations at the level of molecules and cells to circuit, behavior and cognition. Our recent studies have revealed that adult brain cells such as neurons and adult NSC retain the flexibility to adapt their form and function, potentially conferring adaptive advantage under conditions that are deviant from normal. We are currently investigating functional diversity and cellular heterogeneity within neuronal and glial cells, to decipher the fundamental principles of cellular homeostasis in the brain, and improve our understanding of impaired or aberrant brain functions.



Projection neuron in mouse brain hippocampus: Shown is the dendritic arborization of a dye-filled pyramidal neuron from the CA1 region of the hippocampus.

PUBLICATIONS

- Cx3Cr1-Cre induction leads to microglial activation and IFN-1 signaling caused by DNA damage in early postnatal brain. Sahasrabuddhe V, Ghosh HS. Cell Rep. 2022 Jan 18;38(3):110252. doi: 10.1016/j.celrep.2021.110252.
- Adult neural stem cells have latent inflammatory potential that is kept suppressed by Tcf4 to facilitate adult neurogenesis. Shariq M, Sahasrabuddhe V, Krishna S, Radha S, Nruthyathi, Bellampalli R, Dwivedi A, Cheramangalam R, Reizis B, Hébert J, Ghosh HS. Sci Adv. 2021 May 21;7(21):eabf5606. doi: 10.1126/sciadv.abf5606. Print 2021 May.

HONORS AND AWARDS

- EMBO Global Investigator.
- DBT/Wellcome Trust India Alliance, Senior Fellow.

Sanjay P Sane
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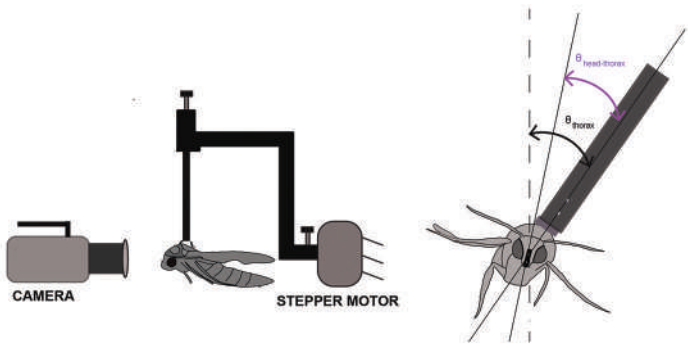
NEUROBIOLOGY

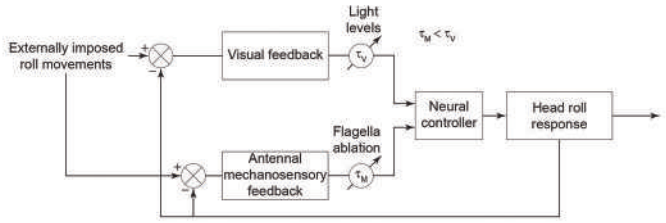
Physics, Neurobiology, and Ecophysiology of Insect Flight and Insect Architecture

We study the physics, neurobiology, and ecophysiology of insect flight and insect architecture, including flight-related behaviours such as aerial manoeuvers, territorial chases, short/long-distance navigation, and individual or collective nest-building.

Insect flight is an extraordinary feat of evolution. Insects were the first animals to evolve flight and have maintained their mastery over the aerial habitat. Across various scales of size and neural complexity, insects fly with exquisite speed, control, and maneuverability. Their wings can flap at several hundred beats per second—each wingstroke finely controlled by a sensorimotor system that acquires and processes information at similarly rapid rates. Sensory acquired by visual, olfactory, mechanosensory, hygro-, and thermo-sensory organs is communicated to the central nervous system, which generates motor responses in the form of head, leg, and wing movements. To understand the mechanistic details of even mundane observations about flying insects *(e.g. flies chasing other flies, moths hovering on flowers, dragonflies or hoverflies guarding territories, etc.)*, we must conduct a multi-disciplinary study of the entire chain of events from sensory input to motor output and flight force generation.



My laboratory integrates physics, engineering, biomechanics, neurobiology, muscle mechanics, and behavioural biology to address diverse flight-related phenomena and how the flight system of insects adapts to the miniaturisation of their body size. We also study complex nest-building behaviour in insects, which involves intricate coordination of their movements at individual and collective levels.



A block diagram (bottom panel) illustrating the role of visual and antennal mechanosensory feedback in the head stabilization response (Top panel). The visual and antennal mechanosensory feedback sections of the loop have time delays (τ_v ,τ_m) which vary based on illumination levels and agella ablation state respectively. These responses combine to elicit the head roll response.

PUBLICATIONS

- Chatterjee, P., Prusty, A.D., Mohan, U, and Sane, S.P. (2022) Integration of visual and antennal mechanosensory feedback during head stabilization in hawkmoths. eLife, 11, e78410.
- Deora, T., Sane, S. S., & Sane, S. P. (2021) Wings and halteres act as coupled dual-oscillators in flies. eLife, 10, e53824.

HONORS AND AWARDS

- 2022: Editorial advisory member of "Current Biology".
- 2020: Selected for the Japan Society for Promotion of Science Invitational Fellowship.
- 2020: Selected as an Editor of the Journal of Experimental Biology.

Sumantra Chattarji
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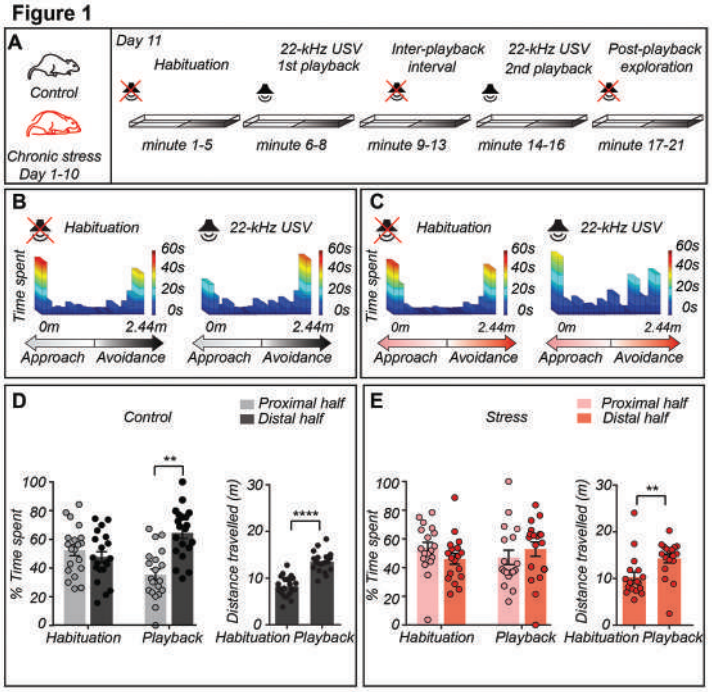
NEUROBIOLOGY

Effects of Stress Distributed across Neural Networks: the Amygdala and Beyond

Debilitating emotional symptoms are a hallmark of stress-related psychiatric disorders. We use animal models to explore the neural basis of these phenomena in the brain's emotional hub, the amygdala, across biological scales, from molecular and synaptic mechanisms, to behavioural consequences.

All memories are not created equal – some are more equal than others. For instance, emotionally salient experiences tend to be well-remembered, and the amygdala plays a central role in this. But the rapid and robust encoding of emotional experiences, such as aversive memories, can become maladaptive. Prolonged stress often turns them into a source of debilitating anxiety. What are the neural mechanisms underlying these powerful emotional symptoms? To answer this, we combine a range of behavioural, morphometric, molecular, and electrophysiological techniques to analyse stress-induced modulation of neuronal structure and function in the amygdala. We identified unique features of stress-induced plasticity in the amygdala, which are strikingly different from those in the hippocampus, and could have long-term consequences for behavioural symptoms seen in affective disorders.

Figure 1



Effects of stress on avoidance behavior elicited by playback of aversive 22-kHz USV calls. Shukla & Chattarji, 2022.

In earlier studies, stress-induced plasticity in brain regions was viewed as a stand-alone effect, manifested as properties intrinsic to individual structures. Further, function was inferred from analysis at the cellular and behavioural levels without any online readout of dynamic changes in neuronal activity in the intact animal. However, neuroanatomical data also points to extensive interconnections between the hippocampus and amygdala. This raises the intriguing possibility that some of the structural and physiological changes triggered by stress in one brain area may, partly, influence other areas. Therefore, we use *in vivo* recordings in freely moving animals to investigate the potential interdependence and interactions between brain areas differentially affected by stress.

PUBLICATIONS

- *Correction of amygdalar dysfunction in a rat model of fragile X syndrome.* Fernandes G, Mishra PK, Nawaz MS, Donlin-Asp PG, Rahman MM, Hazra A, Kedia S, Kayenaat A, Songara D, Wyllie DJA, Schuman EM, Kind PC, Chattarji S. Cell Rep. 2021 Oct 12;37(2):109805. doi: 10.1016/j.celrep.2021.109805.
- *Stressed rats fail to exhibit avoidance reactions to innately aversive social calls.* Shukla A, Chattarji S. Neuropsychopharmacology. 2022 May;47(6):1145-1155. doi: 10.1038/s41386-021-01230-z. Epub 2021 Nov 30.

Upinder Bhalla
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NEUROBIOLOGY

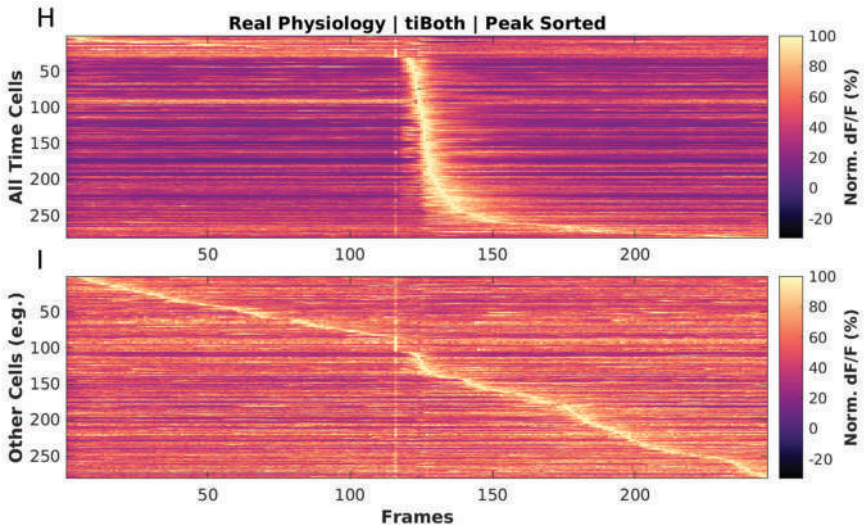
Brain Computation and Memory: from Molecules to Behaviour

We study how pattern recognition and memory formation emerge from molecular, electrical and mechanical signalling in neurons. We use computer models and experiments including optical recordings, optogenetics, and electrophysiology.

In vivo, we use 2-photon imaging to monitor hippocampal activity from hundreds of neurons in mice as they learn new associations, new stimuli, and then forget.

In vitro, we use optogenetics to deliver precise patterned stimuli to the hippocampal network to study the interface between excitatory-inhibitory balance, and network plasticity, using patch recording in brain slices.

In silico, we have developed an array of tools for building data-driven models of brain function in health and disease *(https://findsimweb.ncbs.res.in)*. We have developed a system (HillTau) to abstract complex signalling pathways using compact and efficient formats that retain direct connections to the data. All our tools and data are open sourced and use standard formats such as SBML and NeuroML. We have used these tools to develop multiscale models of synaptic plasticity, subcellular sequence recognition, and activity-triggered protein synthesis in synapses with particular relevance to autism. We also model the mechano-chemical basis for dendritic spine formation.



Time-cell classification algorithm performance on a physiological dataset recorded using 2-photon imaging from mouse hippocampal CA1 pyramidal neurons. The upper panel are classified as time cells, and the lower panel as non-time cells. X axis is frame number (at 14 fps) and each row on the Y axis is a different cells, sorted by time of peak response. Data from Ananthamurthy and Bhalla, in press.

PUBLICATIONS

- HillTau: A fast, compact abstraction for model reduction in biochemical signaling networks.
  Bhalla US.
  PLoS Comput Biol. 2021 Nov 29;17(11):e1009621. doi: 10.1371/journal.pcbi.1009621.
- Computation, wiring, and plasticity in synaptic clusters.
  Pulikkottil VV, Somashekar BP, Bhalla US.
  Curr Opin Neurobiol. 2021 Oct;70:101-112. doi: 10.1016/j.conb.2021.08.001.

Vatsala Thirumalai
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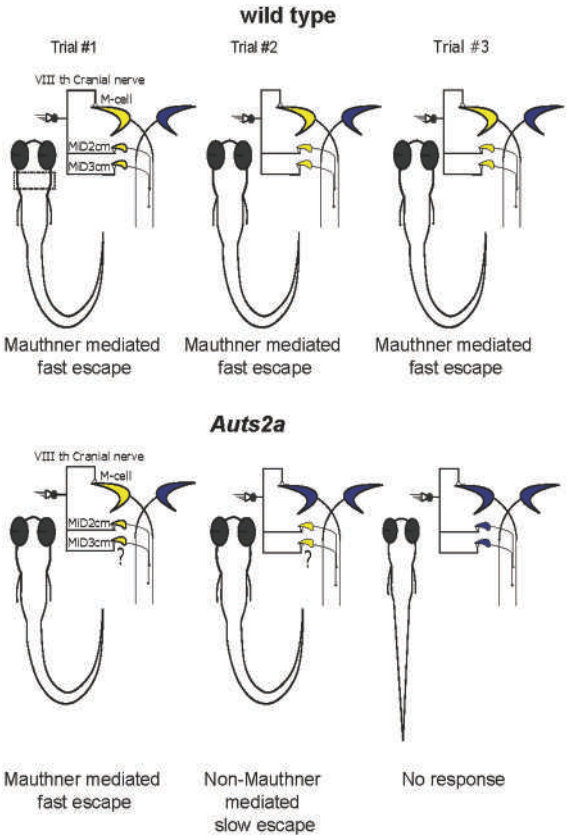
NEUROBIOLOGY

Development, Modulation, and Function of Motor Systems

In vertebrates, locomotion is generated by multiple circuits in the brain and spinal cord acting in a coordinated fashion. We study how these circuits assemble and how they function at all stages of life.

My lab focuses on the function and development of brain circuits that control locomotion using the small freshwater fish zebrafish as our model system. Our work aims to understand how disparate circuits in the optic tectum, cerebellum, hindbrain, and spinal cord work together to generate appropriate locomotor behaviour. We also examine how locomotory circuits are assembled de novo, quite early in development when much of the nervous system is immature.



We use a range of techniques to probe how single neurons compute, how such computations are integrated circuit-wide and how behavior is generated. Some of the tools we use include genome editing, whole cell patch clamping, calcium imaging and high speed videography of larval swim kinematics. Lately, we have also forayed into building models of neurons to ask how their activity patterns are generated.

Summary of behavioral abnormalities in escape response in auts2a mutants showing increased trial-to-trial variability compared to wild type larvae.

PUBLICATIONS

- High Behavioral Variability Mediated by Altered Neuronal Excitability in auts2 Mutant Zebrafish. Jha U, Kondrychyn I, Korzh V, Thirumalai V. eNeuro. 2021 Oct 8;8(5):ENEURO.0493-20.2021.
- Gjd2b-mediated gap junctions promote glutamatergic synapse formation and dendritic elaboration in Purkinje neurons. Sitaraman S, Yadav G, Agarwal V, Jabeen S, Verma S, Jadhav M, Thirumalai V. Elife. 2021 Aug 4;10:e68124.

HONORS AND AWARDS

- Senior Fellow, DBT/Wellcome Trust India Alliance, 2018-23.
- Program Committee, Society for Neuroscience, 2020-23.
- Editorial Board, eLife and Journal of Physiology.
- Elected to the Board of Directors, International Zebrafish Society, June 2022

Relocation of Apis dorsata (honey bee) colony.
Photo credit: Rajath Siddaganga

6

Ecology and Evolution

Axel Brockmann
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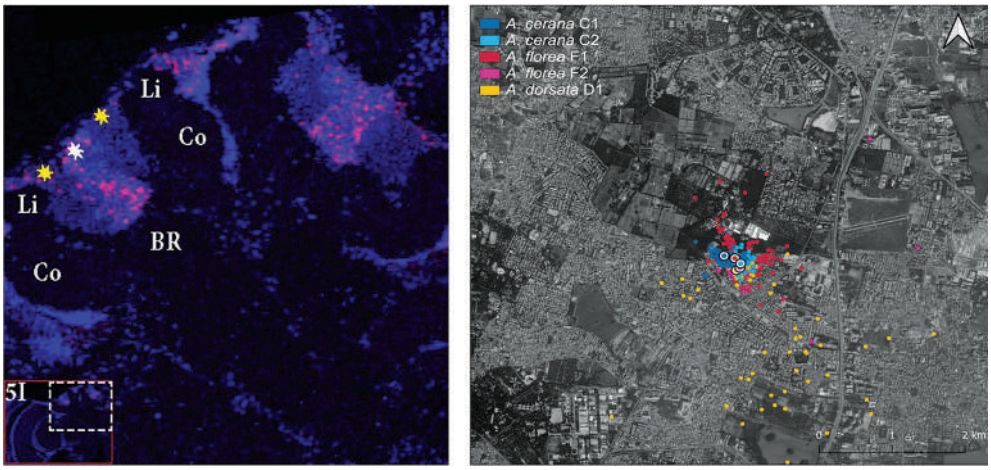
ECOLOGY AND EVOLUTION

The Honey Bee Lab: from Brain Processes to Movement Ecology

Our research comprises two major themes: (a) molecular processes underlying time-memory in *Apis mellifera*, and (b) the biology and ecology of Asian honey bees with a focus on *Apis dorsata*.

We established behavioural paradigms and technical procedures to identify molecular processes involved in social and cognitive capabilities. Using mass spectrometry of individual brains, we showed that the same neuromodulatory systems are used in individual search behaviour and social scouting. Combining feeder time-training and in-situ hybridization, we demonstrated that expression of the transcription factor *Egr-1* in the mushroom bodies likely plays an important role in time-memory formation.

In addition, we started ecological studies on the Asian honey bees, which are the most important pollinators in India. For example, we published the first comparative study on temporal and spatial foraging activities of the three major honey bee species *A. florea, A. dorsata, and A. cerana.* Regarding social outreach, Axel and colleagues from other universities founded the Indian Pollinator Initiative *(inpollin.com)* to promote research and conservation of pollinators in India. Axel also co-produced the award-winning documentary movie 'Colonies in Conflict' on the life of *Apis dorsata* colonies in Bengaluru *(coloniesinconflict.com).*



Left: Time-trained honey bee foragers show Egr-1 expression in mushroom body neurons in anticipation of leaving the colony for foraging. Right: Foraging map of A. florea, A. cerana, and A. dorsata colonies in the urban landscape of Bengaluru.

PUBLICATIONS

- Young A.M., Kodabalagi S., Brockmann A., and Dyer F.C. (2021) A hard day's night: Patterns in the diurnal and nocturnal foraging behavior of Apis dorsata across lunar cycles and seasons. PLoS ONE. 16(10): e0258604. https://doi.org/10.1371/journal.pone.0258604.
- Chatterjee A., Bais D., Brockmann A., and Ramesh D. (2021) Search behavior of individual foragers involves neurotransmitter systems characteristic for social scouting. Frontiers in Insect Science 1:664978. doi: 10.3389/finsc.2021.664978.

HONORS AND AWARDS

- Associate Editor, Frontiers in Insect Sciences - Section Insect Neurobiology.

Deepa Agashe
dagashe@ncbs.res.in

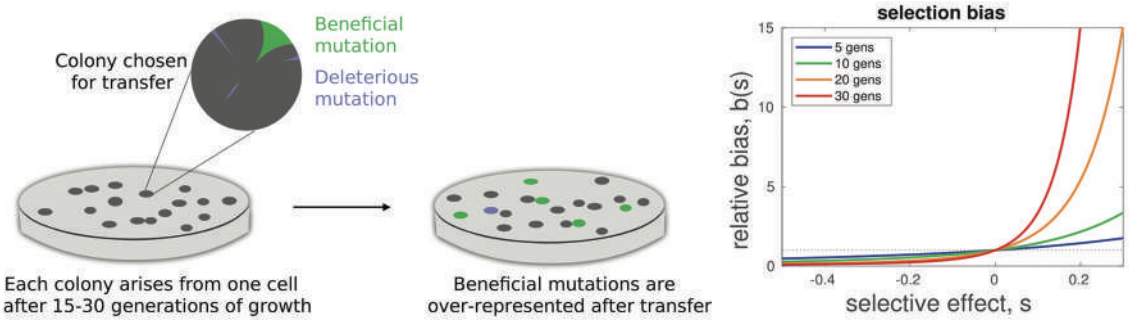
ECOLOGY AND EVOLUTION

Genetic and Ecological Factors Underlying Adaptive Evolution

We aim to understand evolutionary processes, focusing on the genetic and ecological drivers and consequences of adaptation to new niches.

Mutation accumulation (MA) is an important experimental paradigm to understand the mutational process and its evolutionary consequences. In MA experiments, bacterial lineages are passaged through serial bottlenecks. The resulting near-absence of selection is expected to allow the retention of all sampled mutations (except lethals), and the evolutionary or phenotypic impacts of these mutations can then be assayed.

In such MA experiments with E. coli, we found an unexpectedly high number of beneficial mutations *(Sane et al 2018 Evolution)* indicating that the MA protocol was not working as expected. Collaborating with a mathematician, we found that our results are partly explained by non-negligible selection acting during the colony growth phase of typical bacterial MA experiments, such that newly occurring beneficial mutations are more likely to spread and hence be transmitted *(Fig 1; Wahl and Agashe 2022 Evolution)*. Importantly, we provide a simple, useful correction method to account for such selection bias, enhancing the accuracy of evolutionary inferences drawn from MA experiments.



Contrary to expectation, selection can favour the spread of beneficial mutations during mutation accumulation experiments due to colony growth between bottlenecks (schematic in left panel). A mathematical model and simulations show that this selection bias increases with the fitness benefit of mutations, and with the number of generations during colony growth (right panel). The figure is adapted from Wahl and Agashe 2022.

PUBLICATIONS

- Wahl LM and Agashe D (2022). Selection bias in mutation accumulation. Evolution 76: 528-540.
- Mahajan S and Agashe D (2022). Evolutionary jumps in bacterial GC content. G3: Genes|Genomes|Genetics 12:jkac108.

HONORS AND AWARDS

- Vice President, American Society of Naturalists (2022).
- Editorial board of PLoS Biology (2022 – present).
- Council member, European Society for Evolutionary Biology (2021 – present).

Krushnamegh Kunte
krushnamegh@ncbs.res.in

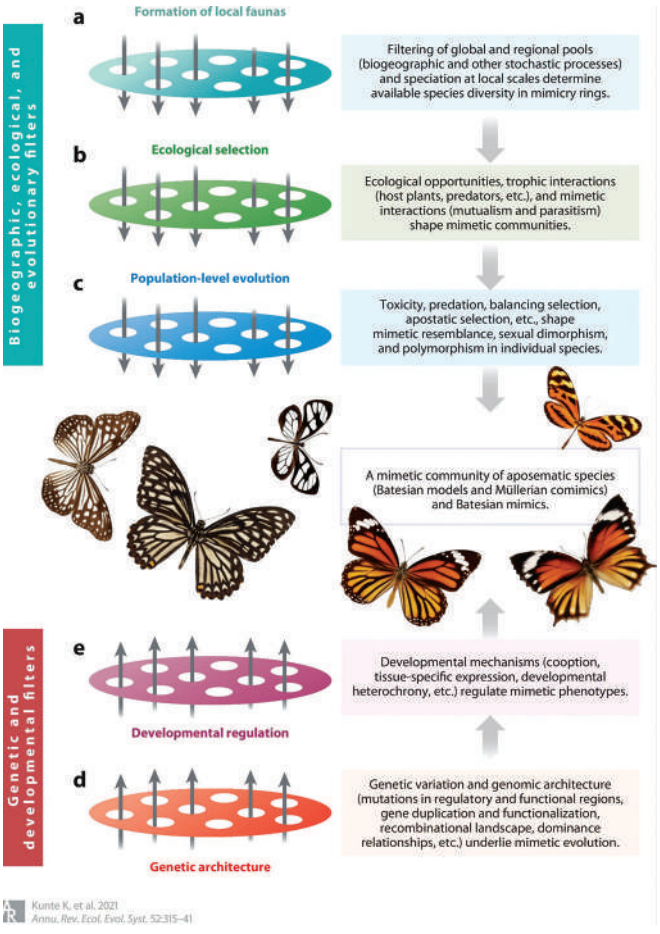
ECOLOGY AND EVOLUTION

Speciation, Adaptation, and Morphological Diversification in the Tropics

Diversity is the cornerstone of life on earth. We are evolutionary biologists who study the origins and mechanisms that underlie the proliferation of biodiversity in tropical regions such as India.

I have a broad interest in evolutionary biology, ecology and genetics, encompassing the fields of natural selection theory, evolutionary genetics, population and community ecology, and conservation biology. Specifically, we study ecological, sexual and population genetic underpinnings of why populations and traits diverge, and why they often result in new species or sexually dimorphic and polymorphic adaptations. This provides a larger perspective on the evolution of biodiversity.

Our main study system is Batesian mimicry, which is a phenomenon in which unprotected prey species *(called 'mimics')* gain protection from predators by mimicking toxic or otherwise protected species *(called 'models').* Predators learn to avoid models based on prior experience, and subsequently avoid eating mimics due to misidentification. Hundreds of mimetic insects *(especially butterflies)* are known from tropical forests. There is tremendous variation in Batesian mimicry: mimicry can be sexually monomorphic, polymorphic, or sex-limited within and across species. Our research aims to understand selective pressures that favour such variations in mimetic colour patterns, and uncover its genetic basis.



The sieving of mimetic adaptations as a window into biodiversification from genes to communities: Biogeographic processes, ecological selection, and genetic and developmental mechanisms work in concert in the evolution and diversification of mimicry rings. [Figure from Kunte et al. 2021. Ann. Rev. Ecol. Evol. Syst.]

PUBLICATIONS

- Kunte, K., A. G. Kizhakke, and V. Nawge. 2021. Evolution of mimicry rings as a window into community dynamics. Annual Review of Ecology, Evolution, and Systematics, 52:315–341.
- Joshi, J., and K. Kunte. 2022. Polytypy and systematics: diversification of Papilio swallowtail butterflies in the biogeographically complex Indo-Australian Region. bioRxiv, DOI: https://doi.org/10.1101/2022.03.23.485569.

HONORS AND AWARDS

- 2020-2021: Prof. T. N. Ananthakrishnan Award for research excellence in evolution, entomology and taxonomy.

Mahesh Sankaran
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ECOLOGY AND EVOLUTION

Terrestrial Ecosystems and Community Ecology

Can our ecosystems cope with the challenges of ever-expanding human activities? We work on understanding the dynamics of mixed tree-grass ecosystems, their responses to changes in climate—particularly drought—and what this means for their future distribution and functioning.

Current research in the lab is grouped around the following broad themes that examine:

(a) how interactions and feedbacks between climate, biogeochemistry, fires, and herbivory influence the structure, composition, and stability of ecosystems and the cycling and sequestration of nutrients; and

(b) how projected changes in climate, such as increasing variability of rainfall, frequency of droughts, aridity in the tropics, nitrogen and phosphorus deposition, and rising CO2 levels will impact ecosystem function, stability, and services.

Most of our research is carried out across a range of systems, from savannas and grasslands to tropical forests, in India and Africa. Our current and planned future work will employ both long and short-term experiments, as well as targeted field surveys to address the above questions across the gamut of natural ecosystem types of the Indian subcontinent, with the goal of bringing a comprehensive understanding of biome-scale vegetation and nutrient dynamics in the Indian subcontinent.

Long-term grassland monitoring plot at the Kalakad-Mundanthurai Tiger Reserve

(Photo: Aaroha Malagi)

Establishing a long-term plot in a semi-arid savanna

(Photo: Aaroha Malagi)

PUBLICATIONS

- Anujan, K., Ratnam, J., & Sankaran, M. (2022). Chronic browsing by an introduced mammalian herbivore in a tropical island alters species composition and functional traits of forest understory plant communities. Biotropica, 54(5), 1248-1258.
- Raghurama, M., & Sankaran, M. (2022). Invasive nitrogen-fixing plants increase nitrogen availability and cycling rates in a montane tropical grassland. Plant Ecology, 223(1), 13-26.

HONORS AND AWARDS

- Elected Fellow of the Indian National Science Academy 2021.
- Infosys Prize for the Life Sciences 2021.

ECOLOGY AND EVOLUTION

Tracking the Objects of Insect Affections across Species and Continents

Shannon Olsson
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The Naturalist-Inspired Chemical Ecology (NICE) group takes field trips, records neurons, and builds virtual worlds to understand how insects have evolved to detect relevant cues and make decisions in nature.

The NICE group listens to nature's chemical conversations across India's diverse ecosystems. This past year saw the culmination of two major projects.

First, as part of a project in collaboration with the University of Kashmir, we found that a common medicinal plant *(Artemesia brevifolia)* adjusts secondary metabolite production to cope with harsh environments. This study reveals the climate adaptability of such species in highly threatened regions of our planet such as the Himalayas.

Second, in collaboration with colleagues at U. Florida, we found changes in neuromodulation during specific stages of adult brain development in two populations of insects could link life history timing with host preference, promoting ongoing speciation and providing a new hypothesis for the genesis of our planet's most specious multicellular taxon.

In addition, we continue our work on high-altitude pollination in the face of environmental change, innate object recognition in generalist pollinators, the impact of air pollution on wild systems, and microplastic pollution in our oceans.

One of our field sites for our high altitude study in Kargil, Ladakh.

PUBLICATIONS

- Olsson, SB; Kaushik PK (2021) Insect decision making, American Scientist, 109(6) 368 doi: 10.1511/2021.109.6.368
- Nataraj, N, Hussain, M, Ibrahim, M, Hausmann, AE, Rao, S, Kaur, S, Khazir, J, Mir, BA and Olsson SB (2022) Effect of Altitude on Volatile Organic and Phenolic Compounds of Artemisia brevifolia Wall ex Dc. From the Western Himalayas. Front. Ecol. Evol. 10:864728.

HONORS AND AWARDS

- Special Scientific Envoy to India, Danish Academy of Technical Sciences.
- Counsellor, International Society of Chemical Ecology.
- 75 Women in STEAM in India, awarded by Office of the Principal Scientific Advisor to the Government of India in partnership with Red Dot Foundation, British High Commission, and FICCI FLO, highlighted in the 2nd edition of the 'She Is' book series, 2022.

Uma Ramakrishnan
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ECOLOGY AND EVOLUTION

Understanding Human Impacts on Biodiversity and Facilitating Future Survival through a Genetic Lens

India has over a billion people, yet harbours incredible biodiversity. How are we impacting this diversity, and can we facilitate its survival? My research attempts to address this question.

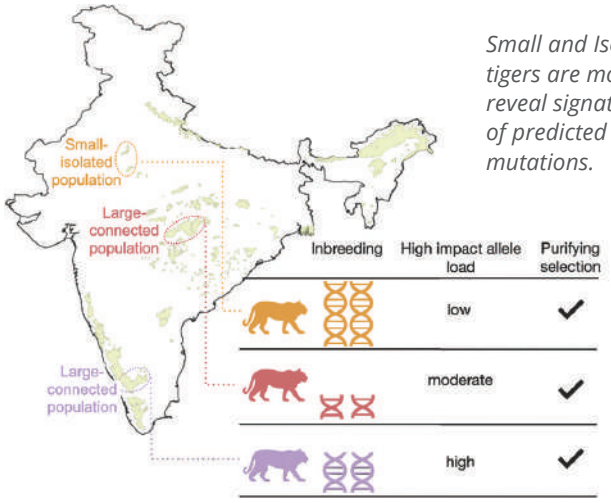
Indian biodiversity: tracking its history, conserving its future.

In my group, we use genetic information to better understand wild populations. We aim to use these insights to suggest strategies for the conservation of threatened species, or to minimize zoonotic spillover in the Indian subcontinent.

How isolated are populations of endangered species today? What determines connectivity? Are individuals in isolated populations inbred? How has human-induced fragmentation impacted the probability of zoonoses? We use field-collected samples *(invasive at times, but mostly non-invasive)*, generate genomic *(or genome-wide)* data, and use computational tools to analyze this data to answer these questions.

A mother and her cub in Ranthambore.

We are already working with on-the-ground teams around the country to support action-oriented programmes for tigers. We hope to continue and enhance such engagement in conservation and the emerging infectious disease space.



Small and Isolated populations of tigers are more inbred, but also reveal signatures of purging, or loss of predicted high impact damaging mutations.

PUBLICATIONS

- Khan, A ..... and Ramakrishnan, U (2021). Genomic evidence for inbreeding depression and purging of deleterious genetic variation in Indian tigers. Proc. Nat. Acad. Sci. Dec 7; 118(49).
- Tyagi, A, Khan, A, Thatte, P, Ramakrishnan, U (2022). Genome-wide SNP markers from fecal samples reveal anthropogenic impacts on connectivity: case of a small carnivore in the central Indian landscape. Animal Conservation. https://doi.org/10.1111/acv.12770.

HONORS AND AWARDS

- 2020: Homi Bhabha Award for Science Education, TIFR.
- 2021: Conservation Beacon Award, Society for Conservation Biology.

NCBS Library - Inquisitive minds.
Photo credit: Sonal Katyal

Administration, Academics and Facilities

Administration, Procurement & Finance
G. Ravi Shankar

The Master's Programme in Wildlife Biology and Conservation
Vivek Ramachandran

Archives at NCBS

Research Facilities

Administration, Procurement & Finance

G. Ravi Shankar
Head, Administration and Finance

NCBS-TIFR was established as a Centre of TIFR in 1991, as approved by the Union Cabinet. In the three decades since its establishment, NCBS-TIFR has grown into an exceptional Centre of Excellence in the disciplines of biological sciences.

The role of administration in a research institution such as NCBS is helping the faculty to carry out research and representation of the institute's interests in the ever-growing complexity, changing economic conditions and needs of society. The administration at NCBS is involved in coordinating the dissemination and implementation of policies, processes, guidelines and facilitating inter and intra-department coordination within NCBS.

The Administration at NCBS is comprised of three divisions *(Establishment, Procurement, and Finance)*, which include distinct operations with 45 employees *(both permanent and temporary)* involved in various assessment activities that each unit has undertaken. The strength of the NCBS-TIFR administration division continues to be hard work, punctual performance and delivering a wide range of services throughout the campus. For the past year, the Administration division has demonstrated a solid team effort in their everyday actions, an outstanding service attitude, creativity and resourcefulness in improving services, and a positive attitude in working with students, faculty, and staff.

The details of personnel at NCBS as on March 2022 are as follows:

Particulars	Sanctioned positions	Filled in positions	No. of Vacancies	Deputation	Pachmarhi Field station
Academics	40	37	3	1	0
Scientific & Technical	49	35	14	0	0
Administrative	33	22	11	0	01
Auxiliary	5	3	2	0	05
TOTAL	**127**	**97**	**30**	**1**	**06**

Contract & outsourced staff of NCBS:

S. No.	Particulars	No.
1	Contract	53
2	Outsourced	358

Procurement

A remarkable model of cooperative effort in the procurement support system. NCBS procurement responsibilities include procurement of lab consumables, equipment, furniture, high-end sophisticated laboratory equipment, managing service and labour contracts *(Canteen, Security, Lab Kitchen, Animal House, maintenance of buildings etc.)*, AMC, import/export, live shipments, disposal and finalizing agreements. The responsibility of mentoring the procurement and contract procedural system for the Institute for Stem Cell Biology & Regenerative Medicine (inStem) and Centre for Cellular and Molecular Platform as part of Bangalore Life Science Cluster (BLiSC). NCBS procurement division handles 40% to 50% of NCBS's total annual expenditure, with a small team. The growth in infrastructure and facilities on our campus has posed the Purchase division new challenges with the increased complexity of handling multiple tasks, by individuals and the Unit Head. The strategic way forward taken by the division was to sustain the growth path with the appropriate alignment of all resources, most importantly, the human resources. The procurement division played a major role in mobilizing materials for COVID-19 for testing and sequencing in a timely and efficient manner to support RT-PCR (swab), sequencing and saliva testing. The procurement division deals not only with routine procurements but also specialized procurements of expensive capital equipment for biological and other scientific research, and the finalization of contracts and agreements. In the discharge of these multifarious and complex functions, displays excellent knowledge of the rules & procedures, a great initiative in dealing with the unexpected and an abiding commitment towards providing effective services, to our researchers to achieve scientific excellence.

Finance

During this year, 32 new grants were added to the ever-growing list of extramural support. The Department of Biotechnology, Science and Engineering Research Board, Department of Science and Technology, Department of Health Research (GoI), Wellcome Trust-DBT India Alliance, Wipro Foundation, Simons Foundation, The Human Frontier Science Program, University of Edinburgh, Action on Hearing Loss, UK, and The Open University, London were the major contributors in the extramural category. Smt. Sudha Murthy has been financially and morally supporting the Dengue Vaccine Development Programme through her generous contributions. Shri. Gopalakrishnan and Smt. Sudha Gopalakrishnan, Trustees of Pratiksha Trust, continued their generous support this year in helping the cause of world-class research in neurobiology. CCMB-Hyd supported the SARS-CoV-2 Genomic Surveillance. Also, our special thanks to M/s TNQ Technologies Pvt. Ltd., Hindustan Unilever Limited., Azim Premji Philanthropic Initiatives Pvt. Ltd., Standard Chartered Global Business Services Pvt. Ltd., and IQVIA RDS (India) Pvt. Ltd., for their extraordinary support and generous contributions to COVID-19 research.

We take this opportunity to express our deepest gratitude and appreciation to all our supporters *(financial, moral, and intellectual)* for their continued generosity, and for the faith and confidence they place in NCBS. Further, we would like to highlight the vital and timely support of Indian corporations, including the Nuclear Power Corporation of India Ltd.

Expenditure (Rupees in Millions):

S. No.	Particulars	2019-20	2020-21	2021-22
1	Research & Development	302.66	183.40	328.10
2	Extra Mural Grants	400.84	374.62	445.93
3	Salaries & Fellowships	296.94	268.43	292.92
4	Operational Expenditure	321.19	261.86	253.84
5	Construction	70.57	0.19	0.01
	Total	**1392.20**	**1088.50**	**1320.80**

Last but not the least, we would like to take this opportunity to thank our faculty, students, partners, and the entire NCBS community for their continued support during the year 2021-22.

The Master's Programme in Wildlife Biology and Conservation

Vivek Ramachandran

The Master's Programme in Wildlife Biology and Conservation is a distinctive Academia-NGO partnership for capacity building in higher education.

Since it began in 2004, the programme has stood for excellence in training through intensive coursework and field research projects. We have trained 133 graduates as of 2020, who through their research and conservation action contribute to the conservation of our natural heritage.

The global pandemic resulted in a tumultuous year for the cohort of 2020-22. The students were all set for their field research projects in December 2021 when the Omicron wave delayed their work and set them back by a month. The students persevered, successfully completing their projects and research reports.

From the snowy mountains of Kargil, to the rain-drenched forests of Arunachal Pradesh and Western Ghats, to the mangroves of the Sundarbans and the grasslands of Kutch, the research projects were conducted in diverse ecosystems and on varied taxa and questions of research and conservation concern.

Studying the effect of fishing on Reef fish communities in the Lakshadweep archipelago

We welcomed the new cohort of 2022-24 in August after a rigorous selection process, including a written exam and in-person interviews. The students of the new class are neck-deep in course work as well as field trips. With the loosening of pandemic restrictions, we have also been able, once again, to host guest speakers from other institutions in Bangalore and beyond, for invigorating lectures and interactions with the students.

As always our dedicated faculty and resource people from across the multiple academic and conservation organizations have supported the programme and students through these trying times. We gratefully acknowledge this support system that enables us to deliver the program, and greatly enhances student experience and development.

In a recent development, we welcomed the Wildlife Conservation Society-India (WCS-India), which joins the Nature Conservation Foundation (NCF) and NCBS as a full-time partner in our Wildlife program. With this, we have the beginnings of a multi-partner consortium for conservation, anchored at NCBS, which, in addition to the program itself, will work collaboratively towards other initiatives in wildlife research, outreach and capacity building. With this longer term vision in mind, we are building a core team of fellows associated with the consortium, to helm the program and its expanded initiatives in conservation science in the coming decade.

Archives at NCBS

The Archives at NCBS *(https://archives.ncbs.res.in/)* is a public centre for the history of science in contemporary India. Over 150,000 processed objects across 24 collections are housed at the 2000-square-feet state-of-the-art physical centre. Our objectives are four-fold: to strengthen research collections and public access in our domain, push the frontiers of research in archival sciences in India, build capacity through education, and reimagine the archives as part of the commons through vibrant public engagement. Much of our work is generously supported by TNQ Technologies.

Grants and Collaborations

The Archives at NCBS received a grant from Arcadia *(a charitable fund of Lisbet Rausing and Peter Baldwin)* toward a three-year project, "Documenting the Contemporary History of Science in India", from December 2022 - November 2025. The intent of the grant is to collect, preserve and make available online endangered cultural artefacts related to the contemporary (~200 years) history of science in India. We are also part of a three-way partnership with oral historians at Newcastle University Oral History Unit and Collective and Centre for Public History at Srishti Manipal Institute toward designing a research pilot to gain a better understanding of intergenerational impact on climate consciousness and activism.

We were host to over a dozen archivists and various online participants as part of the third Milli Sessions held on campus between Jun 8-10, 2022. Milli is a network of individuals and communities interested in the nurturing of archives *(https://www.milli.link).* The founding members, including Archives at NCBS, agreed to formalize Milli as a not-for-profit entity that will develop public tools and offer individual services toward developing archives, inclusive archival standards, conservation, physical and digital access, and pedagogy. Also in collaboration with Milli, and with funding from NCBS and the International Council on Archives, the Archives worked with Divij Joshi and Farah Yameen to publish "Archives, Ethics and the Law in India: A Guidebook and Training Programme for Archivists in India".

Obaid Siddiqi Chair in the History and Culture of Science

The Obaid Siddiqi Chair was founded to bridge gaps in the practice, history, and philosophy of science and the humanities. The position is awarded to eminent scholars whose work has spanned these disciplines and enriched our knowledge of the history and culture of science. Prof. Ganesh N Devy was chosen as the recipient of the second Obaid Siddiqi Chair, 2022-23. Prof Devy is a literary scholar, historian, and social and cultural activist, and is perhaps best known for establishing the People's Linguistic Survey of India (PLSI). In 2014, he received a Padma Shri for his work on nomadic tribes and dying languages.

The first Obaid Siddiqi Chair (2021-22), MD Madhusudan, worked on two interdisciplinary projects. In the Making of Indian Conservation Project (with Hari Sridhar and Preeti Venkatram), he recorded 100s of hours of interviews with 23 persons and gathered other material chronicling the engagements of diverse constituents with wildlife conservation. In the India Open Land Cover Project (with Pradeep Koulgi), he produced a map of seven land-cover types from the neglected open natural ecosystems that dominate India's semi-arid zone using public earth-observation data and open code. In addition,

he presented a critical assessment of 16 India State of Forest Reports that have provided biennial estimates of India's forest cover trends since 1987, and helped anchor collective efforts of knowledge-based outreach to journalists and parliamentarians. Madhusudan delivered the annual Obaid Siddiqi Lectures, two in English and one in Kannada, and co-taught a module on Environmental History to Master's students at the NCBS Programme in Wildlife Biology and Conservation, focusing on the interface between society, science and conservation.

Collections and Conferences

New accessions include the papers of MS Swaminathan (with a public launch event in October 2022), BV Sreekantan, TSG Sastry and Leslie Coleman. The Archives also started expansion into a new additional space at NCBS, which will include office space, processing space, quarantine area, and a conservation lab. The team started development of new catalog and digital preservation systems, and also received a three-year oral history interview approval from the external Ethics Committee.

The Archives was invited to present at the annual conference of the International Council on Archives Section on University and Research Institutions (ICA SUV). It was also invited to discuss its work and future projects at IIT Madras, the National Museum of American History, Smithsonian Science Education Center, the American Museum of Natural History, and Caltech Archives.

Outreach

In March 2022, the Archives launched its 2022-23 exhibition, "Bodies at Sea" (https://studioslip.com/bodiesatsea-ncbs-exhibition-design), by Kamini Rao (Studio Slip) and Devika Sundar. The exhibition traverses the boundaries between the visible and unknown, examining the hidden complexity of our interior bodies alongside oceanic bodies of the deep sea. Anuja Ghosalkar, an artist, developed a public discussion, Unbelong, using the archival papers of Veronica Rodrigues, and later developed an artist's manual with Roshan Shakeel on the idea of an archive. Line Krom, a BangaloREsidency / Goethe Institut artist-in-residence, presented her work on 'Dust and Debris in the Archives' in December 2022.

The Archives Public Lecture Series is a monthly public fixture to initiate dialogue and debate on diverse topics and histories of ideas. Talks in 2022 covered feminism, the body as an archive, Kabir, data and democracy, history of the idea of a virus, and dissent and sedition. The series completed 50 editions in September 2022, with a lecture delivered by Ramachandra Guha.

The Archives maintains an active social media presence on various channels:

https://twitter.com/archives_ncbs

https://www.instagram.com/archives_ncbs/

https://www.facebook.com/archives.at.NCBS/

2022 team

Abhijith AV, Anjali JR, Anima Goyal, Deepika S, Hari Sridhar, Malavika Anilkumar, Meera K, Niranjana K, Ojas Kadu, Preeti Venkatram, Ravi K Boyapati, Samira Agnihotri, Sanjna G Yechareddy, Sindhu Nagaraj, Soumya Swain, Swathi S, Venkat Srinivasan.

The 2022-23 exhibition, "Bodies at Sea", by Kamini Rao (Studio Slip) and Devika Sundar. at the Archives at NCBS gallery

(Photo credit: Ravi K Boyapati)

Archives at NCBS reception wall featuring the posters for the Archives Public Lecture Series

(Photo credit: Ravi K Boyapati)

Photographs from the M S Swaminathan Papers, MS-007-6-2-OS4-7, Archives at NCBS

Research Facilities

Centralized research facilities at NCBS provide cutting edge technology platforms along with the state-of-the-art expertise. Currently there are 25 facilities helping researchers in their various needs, including sophisticated biological manipulations at tissue and organismal levels and in-depth knowledge in operating and using new technology at atomic and molecular levels. These facilities have been particularly instrumental in providing to non-expert users and bringing new laboratories up to speed with comparatively less individual time and resource expenditure. In addition, facilities train internal and external researchers, aiding in generating a pool of well-trained scientists in India and worldwide. The contribution of the research facilities has been acknowledged in over 150 publications during 2021–22.

Facilities Coordination Committee: Raghu Padinjat, Krishnamurthy H, Dimple Notani, Shivaprasad P V, Taslimarif Saiyad, Vinothkumar Kutti Ragunath

Animal Care and Resource Centre

Animal Care and Resource Centre (ACRC) is a unique state-of-the-art high barrier Specific Pathogen Free (SPF) health status laboratory animal facility which provides services and resources to accomplish animal research objectives while ensuring optimal animal welfare conditions and animal ethics regulations.

Achievements in 2021-22

- Maintained **360** strains of mice, **22** lines of rats and **40** lines of zebrafish.
- Used by **32 labs** and handled over **70 projects.**
- Trained **45 internal animal users** and **27 external scientists** in various aspects of lab animal management.
- Was acknowledged in **13 publications**.

Crew: Mohan G H, Aurelie Jory-Lily, Latha Chukki, Yogesh C, Sreenivasulu T, Manjunath A M, Lalitha, Sharath D P and Abhirup Dutta

Faculty Advisory Committee: Colin Jamora, Raj Ladher, Sumantra Chattarji, Vatsala Thirumalai and Raghu Padinjat

Biosafety Facility

Biosafety Facility at NCBS comprises dedicated BSL-2 and BSL- 3 laboratories. The BSL-3 facility is certified for the regulatory biosafety guidelines by the Review Committee on Genetic Manipulation (RCGM), DBT-GOI in 2022. It has two independent workspaces for viral and bacterial work. The BSL-2 facilities are equipped with class-2 biosafety cabinets and essential equipment to perform studies involving risk group-2 agents.

Achievements in 2021-22

- **4 users** were trained for BSL-3 facility.
- **18 users** were trained for BSL-2 facilities.

Crew: Akshay Tharali, Chaitra Jagannathrao

Faculty Advisory Committee: Varadharajan Sundaramurthy, Colin Jamora, Praveen Kumar Vemula

C Elegans Facility

C elegans facility trains new users in regular C. elegans work, maintains C. elegans strains in frozen and growing condition and supply C. elegans culture plates, media, worm specific buffers etc. The facility provides services in making new transgenic C. elegans strains through germline microinjection, CRISPR/Cas-9 based knock-out and knock-in alleles.

Achievements in 2021-22

- **5 students** trained in microinjection.

Crew: Selvanayaki E

Faculty Advisory Committee: Abhishek Bhattacharya, Raghu Padinjat

Central Imaging and Flow Cytometry

Central Imaging and Flow Cytometry Facility (CIFF) is equipped with 20 state-of-the-art high-end microscopes and 11 flow cytometers.

Achievements in 2021-22

- Was used for **12302 hours**.
- Trained **121 internal** and **60 external** students/researchers on microscopy/flow cytometry.
- Acknowledged in **35** papers in peer-reviewed journals.

Crew: Krishnamurthy H, Raksha K, Bhuvana S, Shraddha Sharma, Chandana S, Anil Kumar H V

Faculty Advisory Committee: Anjana Badrinarayanan, Arjun Guha and Satyajit Mayor

Electron Microscopy

Electron Microscopy Facility is equipped with high-end electron microscopes and an X-ray Source Micro-Computed Tomography (micro-CT) scanner machine. For high resolution imaging the facility has Transmission Electron Microscope (Talos F 200 C G2 and Techni T12 G2 Spirit) and Field Emission Scanning Electron Microscope (Merlin Compact VP).

Achievements in 2021-22

- **29 users** trained.
- Acknowledged in **9 publications**.

Crew: Priti Bhardwaj, Sunil Prabhakar, and Anjana M U

Faculty Advisory Committee: Vinothkumar Kutti Ragunath, Swadhin Chandra Jana and Sanjay P Sane

Fly Facility

Fly Facility provides services in Drosophila stock maintenance, and genomic manipulations in Drosophila melanogaster including molecular cloning of DNA constructs, generation of transgenic and CRISPR based mutants. It is the only facility worldwide that provides a complete CRISPR service in Drosophila melanogaster.

Achievements in 2021-22

- Generated **100 transgenic flies** and **15 CRISPR flies**.
- Maintained **~7000** fly stocks.
- Catered to projects from **14** internal and **50** external users.
- Acknowledged for contribution in **17** publications

Crew: Deepti Trivedi, Yashwantha K, Hemavathy C, Anitha V A, Nataraj N, Kishore V, Jithin R, Bilal Akhtar, Srigouri Patil, Usha K, Bintul Syed

Faculty Advisory Committee: Tina Mukherjee and Swadhin Jana

Genomics Facility

Genomics Facility includes Sanger sequencing and Next Generation Genomics Facility (NGGF). The Sanger Sequencing facility is equipped with a state-of-the-art 48 capillary Sanger sequencing machine. The NGGF is equipped with two state-of-the-art high-throughput next generation sequencing platforms (NovaSeq 6000 and Hiseq2500), one bench-top next generation sequencing platforms (Miseq) and one Single Cell Genomics platform (10x Genomics).

Achievements in 2021-22

- **25 users** trained.
- Acknowledged in **22** published papers.
- **25316** samples sequenced for Sanger sequencing.
- **29887** samples sequenced for NGS.

Crew: Awadhesh Pandit, Lakshminarayanan C P, Suresraj Y

Faculty Advisory Committee: Aswin Seshasayee, Dimple Notani, and Dasaradhi Palakodetti

Greenhouse Facility

Greenhouse Facility has 7 greenhouses that allow researchers to maintain pure/transgenic strains of plants and insects and study plant-animal interactions. The greenhouses are equipped with adjustable and fully automated climatic control systems to control light, temperature, and humidity levels using special lights, shading screens, evaporative pads, fan cooling systems, heaters, humidifiers, and dehumidifiers. A number of model plants *(Arabidopsis, tobacco, rice, Nerium)* are grown in the greenhouses.

Crew: Ranjith P P, K Thirumalaraju, Narasimha Raju, and Parvatamma

Faculty Advisory Committee: Shivaprasad P V, Mahesh Sankaran

High-Performance Computing Facility

High-Performance Computing Facility caters to the ever-increasing demands from our scientific community. The facility at NCBS is a symbiosis of computing, network, graphics, and visualization. The facility is a functionally distributed super-computing environment and shared memory systems with state-of-the-art computing systems and open source software packages all of which are inter-connected via an Infiniband network.

Facility Infrastructure

- **3 HPC setup** providing around **200 TFlops** of compute power, inclusive of GPU.
- **750 TB 20 GB/s** parallel file system.
- Centralized storage system with **1 Lakh IOPS**.

Crew: P K Baruah, Rajshekar K S, Rajesh R, Chakrapani, Alok B, Divya K, Vishnu K, Raghavendra B, Rakesh S, Bhanupriya G and Dinakar M

Faculty Advisory Committee: Sabarinathan Radhakrishnan, Sruthi Vishwanath, Dasaradhi Palakodeti and Upinder Singh Bhalla

High Throughput Screening

High throughput screening facility is equipped with state-of-art automated liquid handlers, multimode plate readers, automated imaging platforms, multiplexing systems to quantify multiple analytes from single sample while housing collection of RNAi libraries, small molecules and cell lines. The facility assists users in adaptation of both biochemical and cell-based assays in HTS/HCI formats through miniaturization and automation.

Crew: Latha Chukki

Faculty Advisory Committee: Varadharajan Sundarmurthy, Arjun Guha and Raghu Padinjat

Insectary

supports contemporary research on insecticides, repellents, attractants, vector development and physiology, disease transmission, host-parasite/pathogen interactions, life histories studies, population dynamics, behavioural genetics, ecological interactions, and related subjects. There are three major components **(a)** mosquito rearing facility **(b)** parasite culture facility and **(c)** transformation facility.

Achievements in 2021-22

- Published **5** research publications
- Acknowledged in **2** publications.
- Successfully trained **35** users
- Active engagement in **outreach programs**.

Crew: Sunita Swain, Chaitali Ghosh, Naveen Kumar, Soumya M, Soumya Gopal Joshi, Chethan Kumar R, Joydeep Roy

Faculty Advisory Committee: Sanjay Sane, Varadharajan Sundaramurthy, Sonia Sen

Mass Spectrometry Facility

Mass Spectrometry Facility is equipped with advanced Mass spec (MS) technologies and established workflows to characterize biological and chemical molecules such as Metabolites, Glycans, Lipids, Proteins, Biosimilars, Antibodies and synthetic lab molecules. It also provides post-translation identification and quantitation of biomolecules using labeled and label free workflow.

Achievements in 2021-22

- Trained **~60** researchers in different LC-MS/MS technologies, such as, lipidomics, proteomics, metabolomics, and glycomics.
- Contribution of the facility is acknowledged in several publications.

Crew: Nirpendra Singh, Alifia Jaffer, Sohail Khan, Jyothi Prabha, Theja PP

Faculty Advisory Committee: Arvind Ramanathan, Ranbir Das, and Raghu Padinjat

Mouse Genome Engineering Facility

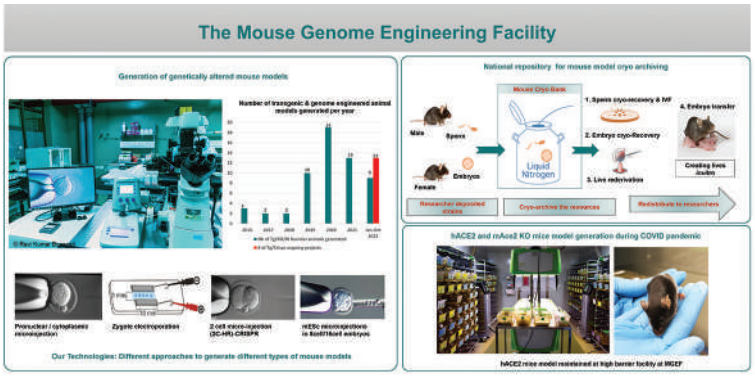
Mouse Genome Engineering Facility is a well-equipped state-of-the-art functional facility for the generation of transgenic and gene-edited mouse models. The main operational domains of the MGEF Facility are: **1)** using the latest gene-editing tools and technologies to generate customized new mouse models; **2)** mouse sperm and embryo cryo-banking services; **3)** access to the latest mouse-assisted reproductive technologies to maintain and recover complicated mouse lines; **4)** training & workshops.

Achievements in 2021-22

- Catered to **206 projects** related to genome editing and assisted reproductive technologies.
- **70** mice strains cryo-archived.
- **11** mice strains distributed all over India.

Crew: Mahesh Sahare, Aurelie Jory, Latha Chukki, Shilpa B A, Vaishak Nair P, Suba Soundarya S A, Salil Hangnekar, Priya, Aswani R B, P Charulekha

Faculty Advisory Committee: Raj Ladher, Colin Jamora, Soumyashree Das, Dhandapany Perandurai



Microfluidics and Microfabrication Facility

Microfluidics and Microfabrication Facility has a Class 10000 (ISO 7) cleanroom that is equipped with state-of-the-art fabrication and characterization tools to design, manufacture, and test PDMS and other polymer-based microfluidic devices and microstructures. The facility supports research activities in the campus by offering services in designing, fabricating and optimization of experiments that require micron-scale precision.

Achievements in 2021-22

- **52** researchers, students, and innovators were trained in various aspects of microfluidics.

Crew: Karthik Mahesh

Faculty Advisory Committee: Shashi Thutupalli, Tapamoy Bhattacharya, Arvind Ramanathan

Field Station Facility

Field Station Facility provides support for field research in frontier areas of ecology, evolution and conservation genetics. It hosts long-term monitoring programs of diverse natural habitats, flora and fauna and supports science education and public outreach.

Achievements in 2021-22

- Documented moths and butterflies on campus during the **moth-week** and **butterfly month**.
- Trained government school students to use citizen science Apps **@seasonwatch** and **@inaturalist**.
- Organised various field events for school students on the **National science day**.
- Organised **Workshop** on DNA isolation and biodiversity for B. Sc students.
- Organised **उत्कर्ष:** - a design thinking workshop for finding solutions to local problems.
- Organised a talk on **"Awareness on snakes"** by King Cobra expert Mr. Gowri Shankar from Kalinga Centre for Rainforest Ecology.

Crew: Yeshwanth H M, Savith Chib, Nagaraj N R

Faculty Advisory Committee: Uma Ramakrishnan, Sanjay Sane, Mahesh Sankaran and Shivaprasad P V

Collection Facility

Collection Facility is a state of the art facility for biodiversity-related work and serve as a national repository of type specimens and other specimens of research importance to NCBS and to the broader global community of biologists. It facilitate networking with museums worldwide, and museum-based collaborations with taxonomists and biodiversity experts. Provides science education and public outreach through the museum and collections facility.

Achievements in 2021-22

- Organised outreach activities on **Earth day**.
- Organised **exhibition** on the world of insects.
- Organised vertebrate and insect taxonomy **workshop**.
- **Feather library** with bird feathers has been initiated.
- Acknowledged in **10** reseach publications.

Crew: Yeshwanth H M, Tarun Karmakar, and Aswathanarayana G

Faculty Advisory Committee: Uma Ramakrishnan, Sanjay Sane, Mahesh Sankaran, and Shivaprasad P V

NMR Facility

Nuclear Magnetic Resonance (NMR) Facility is equipped with two machines (800 MHz and 600 MHz) with cryo-probes. The facility aids in studies focusing on de novo structure determination of macro molecules such as proteins and nucleic acids, and their dynamics in the picosecond to millisecond time scales.

Achievements in 2021-22

- Trained **5** researchers
- Acknowledged in **4** publications.

Crew: Purushotham Reddy P

Faculty Advisory Committee: Ranabir Das, Minhaj Sirajuddin, and Praveen V

Radioactivity Facility

Radioactivity Facility has been classified as a Type-2 radioactive laboratory. The facility is equipped to handle ^{32}P, ^{55}Fe, ^{125}I, ^{3}H, and ^{14}C isotopes, and operates strictly within the guidelines set by the Atomic Energy Regulatory Board (AERB). The facility also has a cobalt-based Gamma Irradiation Chamber (GIC) to irradiate animal cells.

Achievements in 2021-22

- **26** users used the facility
- **8** new users trained in using the facility under the supervision of the campus Radiological Safety Officer (RSO).
- **3** publications acknowledged the contribution of the facility.

Crew: Akshay Tharali

Faculty Advisory Committee: Shivaprasad P V (RSO) and Sunil Laxman

Stem Cell Facility

Stem Cell Facility (SCF) provides services and training for research using human pluripotent stem cells (hiPSC/ hESC) in addition to a high-end BSL-2 shared space needed to culture, edit and image stem cells. Services include generation of iPSCs, detailed characterization and expansion of iPSC, lineage specific differentiation of iPSCs, fibroblast isolation, feeder preparation and Mycoplasma testing.

Achievements in 2021-22

- Initiated **bio-banking efforts** for sharing stem cells.
- Trained **32** users for approved methods of stem cells culturing practices that meets international standards.
- Acknowledged in **5** peer reviewed publications.
- Work carried out in SCF lead to **one patent**.
- Organised 2 hands-on **training workshops** for Good cell culture practices and Essentials techniques in stem cell research.

Crew: Deepti Abbey, Niharika Patlolla, Utkarsh Nikhade and Pretty Ponnachan

Faculty Advisory Committee: Colin Jamora, Raghu Padinjat and Bhavana M

Retirement Notes

Vishalakshi

Written by Mukund Thattai

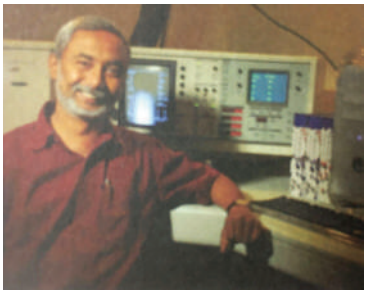
Institutions change over time, as they must. Yet, even as we look to the future, we must maintain a link to the past: a thread of continuity to remind us where we came from. Now, over 30 years since NCBS was founded, there are fewer and fewer people who remember how things were at the very beginning. Vishalakshi is one of those people. In the early days of NCBS, everybody had many jobs; it was a true collective effort to keep the place running. After moving through various administrative roles, Vishalakshi ended up at what became the Academic Office. She remained the anchor of that office until her retirement, following 32 years of service. Over her time there, the graduate programme became formalised: the processes we are familiar with today were slowly put in place. Vishalakshi knew every single one of those rules and processes. But more importantly, she also knew every student who passed the NCBS graduate programme. Whenever a student walked into the Academic Office, she would greet them by name. If they had difficulty navigating the sometimes Byzantine processes, she was there to help. After a successful thesis defence, Vishalakshi was the first person there to congratulate the newly minted Doctor of Philosophy, and she shared their joy. Vishalakshi, on behalf of all of us here now and also on behalf of all our alumni, we thank you for your service. You have helped make NCBS what it is today, and we will miss having you here.

H. Krishnamurthy

Written by Satyajit Mayor

A job well done never ends: H. Krishnamurthy.

When I first met Krishna in 2002, he indicated that he had come back to India from Columbia University, New York, to contribute to Science with the aim of making an impact! And today, if I look back all those years till this last month when he had to retire at the young age of 60, there is no doubt that he has made a monumental impact on Indian Life Sciences. He was interested in creating core facilities that would be second to none and provide a training platform for all those who needed it. I was very excited at that time that if Krishna joined us, we could do more than what was possible in a single laboratory and provide facilities for a range of users, thereby helping to do more impactful science. I naturally supported him and said that if we started small and did the job well, we would be quickly able to multiply this in quick time. With one BioRad confocal, quickly followed by a flow cytometer (BD FACScan), Krishna made sure that these precious equipment were not only made accessible to all those who needed it, he took on the task on ensuring that those who wished to use it were trained by him.



Krishna in front of his beloved Flow cytometer circa 2007/8.

His commitment set off a chain reaction, where one machine followed another and then one facility followed up another, eventually establishing the excellent BLiSC Core Facility that we have today, an envy of all those who visit it. Now that Krishna has stepped down from the founding Head of Facilities at our campus, it is hard to find one individual to fill all the roles he fulfilled. The facility managers and the heads of facilities who he has trained are now in many high places and see him as their prime mentor. So not only the use of equipment but trained people have been spread far and wide by Krishna- a true multiplier! He is already a legend in his own right today.

Showing a stained mouse skeleton and chicken embryo as model systems to study developmental biology. Parikrma School, Bengaluru.
Photo credit: Surender Ponnalagar

Flagship Programmes

Discovery Biology of Severe Mental Illness
Raghu Padinjat

Bangalore Sustainability Forum

IndiaBioscience
Shantala Hari Dass

The Simons Centre for the Study of Living Machines at NCBS Bangalore
Siddharth Kankaria

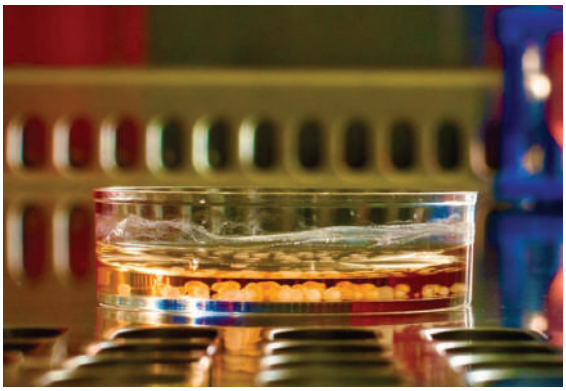
Discovery Biology of Severe Mental Illness

Raghu Padinjat

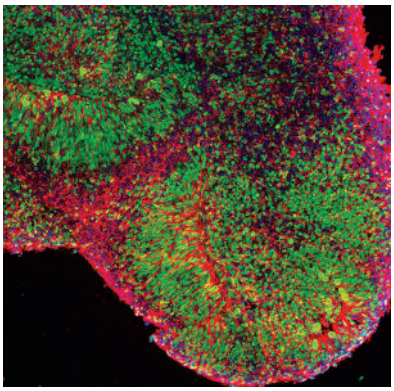
The Accelerator program for Discovery in Brain disorders using Stem cells (ADBS) seeks to understand the genetic and cellular basis of severe mental illness by harnessing the power of modern human genetics and stem cell technology. ADBS is a collaborative initiative of three institutions from Bengaluru, India: The National Centre for Biological Sciences (NCBS), the Institute for Stem Cell Science and Regenerative Medicine (inStem), and the National Institute for Mental Health and Neurosciences (NIMHANS). ADBS is supported by the Department of Biotechnology, the Government of India and the Pratiksha Trust.

We have five major forms of severe mental illness (SMI): ***schizophrenia, bipolar disorder, obsessive compulsive disorder, substance dependence,*** and ***dementia*** which are known to have an inherited basis. In order to study these disorders, the ADBS program has assembled a prospective cohort of families with a strong family history of SMI from the endogamous populations of India. The ADBS program pursues three distinct but interactive lines of analysis on these families: **(i)** Detailed clinical analysis to understand changes in brain structure and function; **(ii)** We have established about 100 induced pluripotent stem cell lines from affected individuals in these families and unaffected controls. **(iii)** Next Generation Sequencing and family-based bioinformatics are being used to discover the genetic basis of SMI. **(iv)** Genome editing technologies for the analysis of genetic variants using stem cell derived models of brain cells have been developed.

The datasets generated by the ADBS program are being assembled into an integrated database to facilitate the application of sophisticated data analysis for discovery biology. The stem cell lines and other biomaterials have been assembled into a bio-repository as a resource for discovery biology in the area of SMI.



Control iPSC derived dorsal forebrain organoids maintained for 35 days in-vitro



Spheriods were cryosectioned and stained using Immunohistochemistry for Pax6 (green) that exhibits presence of neural rosettes zones and beta 3 tubulin (red) staining neurons arising around the neural rosette zones.

SELECTED PUBLICATIONS

- Akhtar BM, Bhatia P, Acharya S, Sharma S, Sharma Y, Aswathy BS, Ganapathy K, Vasudevan A & Raghu P. A human stem cell resource to decipher the biochemical and cellular basis of neurodevelopmental defects in Lowe Syndrome. Biology Open 15;11(1):bio059066. doi:10.1242/bio.059066 Epub 2022 Feb 4.
- Sankhanil Saha, Harini Krishnan & Raghu Padinjat, IMPA1 dependent regulation of plasma membrane phosphatidylinositol 4,5-bisphosphate turnover and calcium signalling by lithium. bioRxiv 2022.10.14.512101; doi: *https://doi.org/10.1101/2022.10.14.512101*

Bangalore Sustainability Forum

The Bengaluru Sustainability Forum is an inter-institutional initiative to foster conversations, build bridges and encourage interdisciplinary collaborations working towards Bengaluru's sustainable future. It was founded in January 2018 with the intention of tackling sustainability questions in the local context, at in-person retreats and through programs involving the city's diverse stakeholders.

The participating institutions at BSF are the National Centre for Biological Sciences, Azim Premji University, Biome Environmental Trust, Science Gallery Bengaluru and Wipro Ltd.

From 2019, BSF has awarded 29 projects over 4 cohorts in the areas of urban biodiversity, urban climate change, urban water and urban waste management through its Small Grants Programme. We are currently in its 5th edition, with inspiring and exciting projects coming from the heart of the city's community.

Over the last year, we have facilitated discussions and exchange of knowledge through:

Jacaranda Tales Film Festival

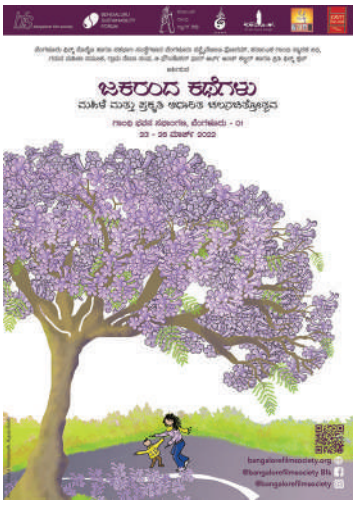
The Jacaranda Tales film festival was a celebration of women's symbiotic relationship with nature and recognising their often overlooked contributions to the nurturing of the environment.

It was organized in collaboration with Bangalore Film Society (BFS), Karnataka Gandhi Smaraka Nidhi, Gamana Women's Collective, Gram Seva Sangh, G Foundation for Art and Culture, and Kriti Film Club between 23rd and 26th March 2022. The festival reached out to about 650 people at Gandhi Bhavan auditorium and the online version between 9th and 18th April 2022 saw more than 10000 viewers.

Listen to the panel discussions on the BSF youtube channel: *https://www.youtube.com/@bengalurusustainabilityfor6490*

Celebrating the multiple facets of women's relationships with nature

Image credit: BSF Team



Poster in Kannada for the Jacaranda Tales Film Festival

Ooru Podcast

Bengaluru's Sustainability Podcast

The Ooru podcast is a collaboration between Bengaluru Sustainability Forum and Vaaka Media. The podcast was released in September 2022. In the episodes, we explore questions on the city's planning, infrastructure, food and lifestyle through conversations with diverse communities working on the ground. To find out what we're doing to plan for our city's sustainability, listen to all the episodes of the series here *(https://www.bengalurusustainabilityforum.org/ooru-podcast/)* and subscribe to us on all your podcast apps!

Small Grants Programme (SGP) Events with Grantees

Carbon Summer School with Science Gallery Bengaluru

Lake Health Index

This seminar and field visit was conducted by V Ramprasad, the convenor of this project at Puttenahalli lake in Yelahanka.

Sarjapura Curries

Suresh Kumar, the founder of Sarjapura Curries, facilitated a session on urban greens;

Image credit: Science Gallery Bengaluru

As the Drain Goes

As the Drain Goes photo exhibition - Voices from the communities

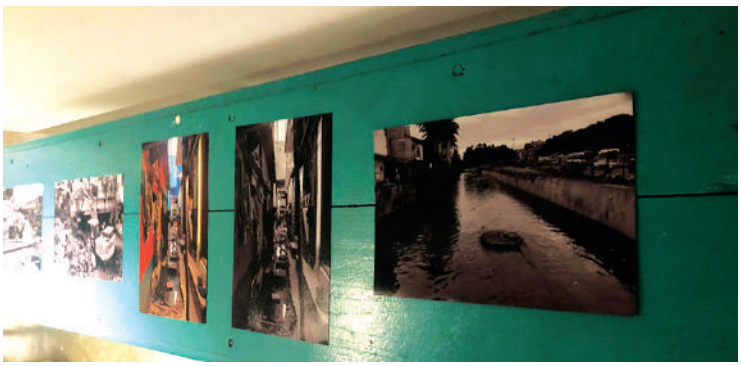
Image credit: Science Gallery Bengaluru

Teacher's Workshop and Tree Walk by Kartikeyan S. and Srinivasa T.S. with Azim Premji Foundation (APF) on 27th Aug 2022

Srinivasa explaining the structure of a leaf and how a tree can be identified by it

Image credit: BSF Team

As the Drain Goes: Drain Tour, Book Launch and Photo Exhibition with Pinky Chandran, Nalini Shekar and Citizen Matters on 25th Nov 2022



As the Drain Goes photo exhibition at 1Shanthiroad Studio/Gallery, part of Bengaluru Design Week

Image credit: Girish Balachandran via Twitter

Launch of The Living Museum Book by Cafe Oikos with Anisha Jayadevan, Ishika Ramakrishna and Manini Bansal

Image credit: Cafe Oikos

BSF remains committed to its vision of enabling multidisciplinary interactions and building synergies for working towards urban sustainability.

Behind the scenes of BSF. Team: Manasi Pingle (R) and Namrata Narendra (L)

bsf@ncbs.res.in

https://twitter.com/sustainBLR

https://www.instagram.com/sustainBLR/

https://www.facebook.com/sustainBLR/

FLAGSHIP PROGRAMMES

IndiaBioscience

Engaging Communities, Enabling Change

Shantala Hari Dass

IndiaBioscience (IBS) strives to be a catalyst to promote changes that affect the culture and practice of the field, through engagement with academia, government, and industry at various levels. Below is a snapshot of (some of) our 2022.

Growing a community

Our annual flagship Young Investigators' Meetings (YIM) pre-dates us. The *(virtual)* YIM2022 brought together YIs, PDFs, science administrators, grant advisors and established scientists to interact, network and foster collaborations while showcasing Indian science to the global community at large. The recordings of the talks can be found at *bit.ly/YIM2022Videos.*

Our interactive database of researchers (>700 members) is an initiative to compile life science researchers from across India. We invite you to join *(bit.ly/LS_Database_IBS).*

Facilitating the community

We conducted multiple online and offline workshops on topics such as *Crafting your Career (CYC) in science, science communication, research communication, etc.* We were thrilled to conduct an in-person CYC for the BLiSC campus.

Taking Science out of the lab

The IndiaBioscience Outreach Grants (IOG) promotes the practice of outreach amongst young scientists. We funded 7 projects in IOG 2022. The application call for IOG 2023 will open in Sept 2023.

Money matters

To help researchers navigate the national and international funding scenario, in partnership with the RDO, we published *On the Road to Excellence - Funding opportunities for Life Science Researchers in India.* Our International Grants Awareness Program (iGAP) conducted sessions on the MSCA and ERC grants.

Shining a light on the community and its needs

As a first-of-a-kind activity for us, IndiaBioscience conducted a nationwide survey with ~500 respondents assessing the current status of independent life science researchers in India to create actionable insights. Do keep an eye out for a report of our findings!

In 2022 we launched a podcast series- Radio PDF- to highlight the research and issues faced by postdocs in India. In the first season we spoke to 4 researchers from across India. We are on the lookout for more postdocs to feature!

Connecting educators and researchers

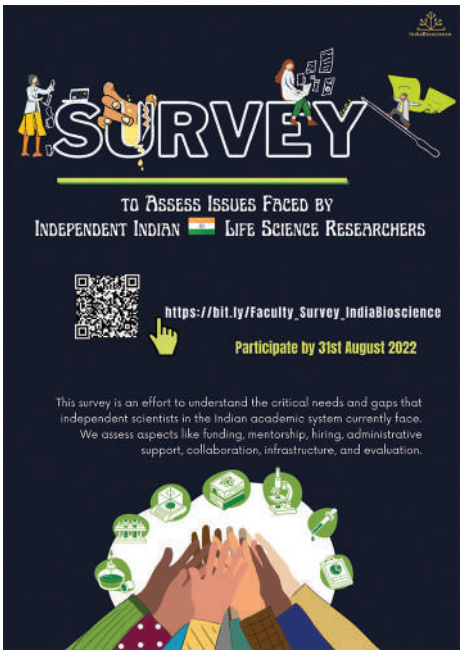
IBS facilitates undergraduate biology educators of India to network, share their ideas and challenges, and build their pedagogical skills. We conducted a one-day seminar series on exciting research happening in the city titled *'Emerging trends in life sciences'* featuring, among others, talks by P. Balaram and Deepa Agashe. We also hosted 3 webinars for educators. We hope that more from the BLiSc community will join us in engaging with educators and students.

In 2022, IndiaBioscience received a third phase of funding from the Department of Biotechnology (DBT). We also received financial support/had partnerships with APU, TNQ Technologies, Cactus Communications, Ignite Life Science Foundation, International Union of Biological Sciences, ASAPBio, and Euraxess India.

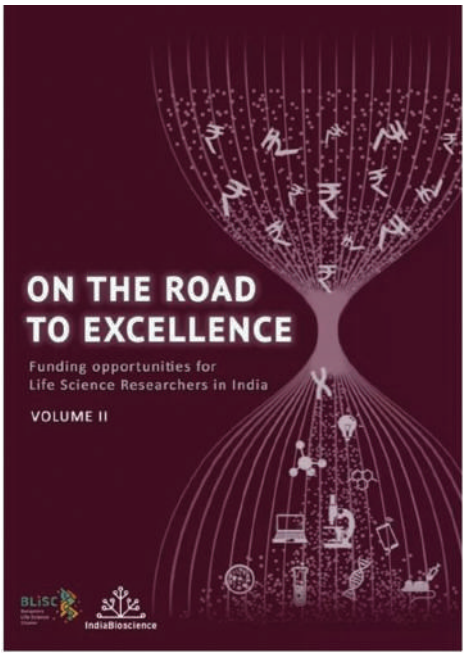
IBS team

Aditya Parekh, Ankita Rathore, Manjula Harikrishna, Shantala Hari Dass, Shwetha C, Suchibrata Borah, and Vijeta Raghuram.

IBS Team and guest speakers from C-CAMP at the CYC event conducted for the BLiSc Campus in July 2022.



IndiaBioscience conducted a nationwide survey to assess the issues faced by independent researchers in life sciences



In-house publication on funding opportunities for independent researchers

The Simons Centre for the Study of Living Machines at NCBS Bangalore

Siddharth Kankaria

The Simons Centre for the Study of Living Machines is a dedicated space for the study of molecules, cells, and organisms as living machines: products of natural selection which consume energy to achieve specific goals.

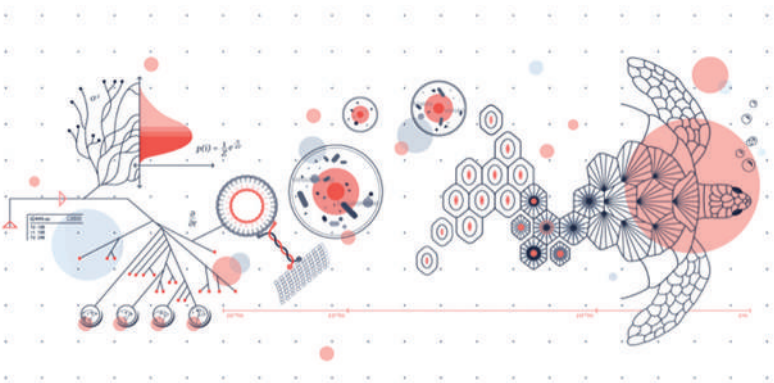
Our research relies on interdisciplinary approaches that blend theory and experiment for solving fundamental biological problems spanning across a range of length and timescales: from protein function, computational cell biology and evolution, to the physics of active systems.

The Simons Centre was established at NCBS in 2013 through a five-year $1 million grant from the Simons Foundation, which was renewed for another 5 years in 2018. It brought together five NCBS faculty and their research groups, with an aim to foster an environment of active collaborations between theory and experiment in biology.

At present, the Centre has grown further and comprises the following 7 faculty members and their groups: Archishman Raju, Madan Rao, Mukund Thattai, Sandeep Krishna, Shachi Gosavi, Shaon Chakrabarti and Shashi Thutupalli. The current Advisory Committee of the Simons Centre at NCBS includes Frank Julicher (MPI for the Physics of Complex Systems, Dresden) & Rob Phillips (California Institute of Technology, USA).

Keeping true to the vision of 'Biology without Boundaries', the Centre has grown into a fully-functional 'centre for theory, embedded within an experimental biology research environment', and serves as an international hub for researchers from physics, mathematics, computer sciences, and engineering backgrounds to engage with biological problems.

The work culture and ethos of the Centre also specifically prioritises frequent and deep interactions, random collisions of ideas, and sustained collaborative efforts involving the use of theoretical approaches. Currently, the Centre's is nucleated around three collaborative research themes: Cellular Compartments; Organismal Communities; Programmable Landscapes.



With the backing of the Simons Foundation, the Centre has also organised several cross-disciplinary meetings and workshops such as the "Emergence and Evolution of Biological Complexity", "Interface of Biology and Theoretical Computer Science", and "Conflict and Cooperation in Cellular Populations". The Centre has also for several years organised the "Simons-NCBS Annual Monsoon School - Physics of Life" for attracting some of the most talented undergraduate students in the physical sciences and engineering to come engage with fundamental biological problems.

Bangalore Life Science Cluster

Research Development Office
Vineetha Raghavan

Centre for Chemical Biology and Therapeutics
Anandi Karumbati

Antiviral Translational Platform
Anandi Karumbati

Biosafety Level 3 Animal Facility for Enabling Animal Model Use for Infectious Disease Research
Hiyaa Ghosh

Wastewater Surveillance to Understand Community Health
Farah Ishtiaq, Uma Ramakrishnan

Research Development Office

Vineetha Raghavan

The Research Development Office (RDO) facilitates research and training on campus via research funding and collaborations. The RDO offers several key services at the boundaries of science, management, resource development and outreach.

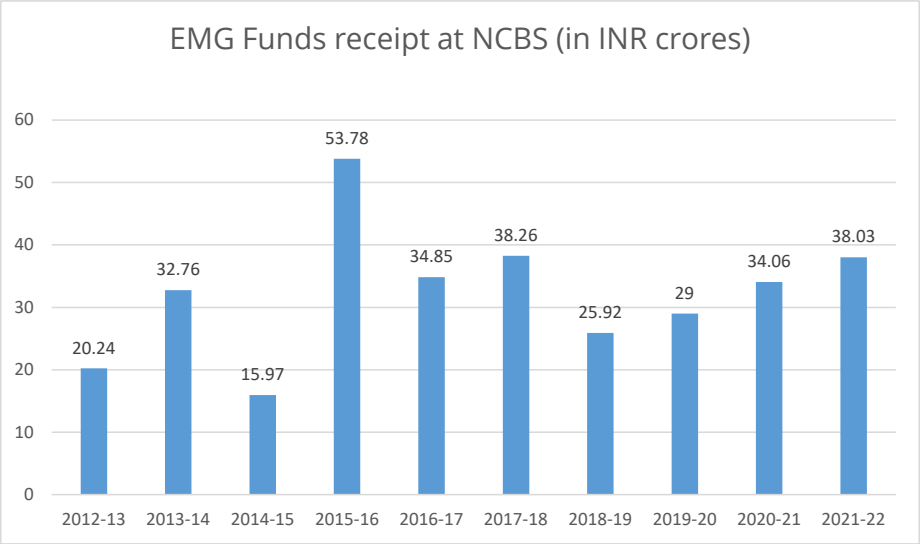
Several programmes initiated in the last two years to aid the management of the COVID-19 pandemic such as the COVID biorepository, Translational platforms for COVID-19 therapeutics and BIRAC Mission COVID Suraksha programme to support preclinical studies for Covid-19 continued during this period. The Indian SARS-CoV-2 Genomics Consortium (INSACOG) in which NCBS is a partnering institution, has recently been approved for renewed support.

Under its corporate social responsibility initiative, Unilever extended its support for the VISION *(Vaccine Immunology Studies- Indian Outbreak Response Network)* project at NCBS, a platform activity to generate immunogenicity data addressing the needs of the COVID vaccination program in the country. NCBS is also a partner in a consortium of collaborating clinical and research institutions to track SARS-CoV-2 variants through genomics, bioinformatics and global data sharing with financial support from the Rockefeller Foundation to CSIR-CCMB.

Another recent highlight at NCBS is funding for disease ecology and pathogen discovery. Prof. Uma Ramakrishnan is the theme lead for the One Health initiative of the Bengaluru Science and Technology Cluster (BeST cluster), supported by the office of the PSA, Govt. of India, which proposes a multi-sectoral effort centered on disease ecology, pathogen discovery and environmental surveillance. The Department of Biotechnology, Govt. of India has recently approved a consortium grant for the genomics-based discovery of (potential) pathogens for India's North-Eastern Region. NCBS also continues to participate in GenomeIndia, a Department of Biotechnology, Govt. of India funded human genome sequencing initiative to map the human genetic diversity across the country and create a platform for biomedical genetics.

Private and philanthropic funding supports specific initiatives at NCBS. The Arcadia Foundation, UK awarded a grant to the Archives at NCBS, to collect, preserve and make available endangered cultural artefacts related to the contemporary history of science in India. Wildlife Conservation Society, New York has provided financial support for activities in conservation capacity building for the Master's Program in Wildlife Biology and Conservation.

The RDO continues to support the establishment of national and international collaborations. Recent highlights include Global Investigator Network Award from European Molecular Biology Organisation (EMBO) to Dr. Hiyaa Ghosh and a research grant from the Human Frontier Science Program (HFSP) to Dr. Anjana Badrinaryanan. Recent international collaborations facilitated by grants at NCBS include collaborations with the Institute of Plant Biology, Szeged, Hungary; Newcastle University, UK; CNRS, University of Montpellier, Biochimie et Physiologie Moléculaire des Plantes (BPMP), France and Imperial College, London U.K. NCBS has also become a scientific member of the Indian Cancer Genome Atlas (ICGA) Foundation, which aims to create an indigenously developed, open source, comprehensive database of molecular profiles of cancers prevalent in Indian populations.


EMG Funds receipt at NCBS (in INR crores)
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50
40
30
20
10
0
20.24
32.76
15.97
53.78
34.85
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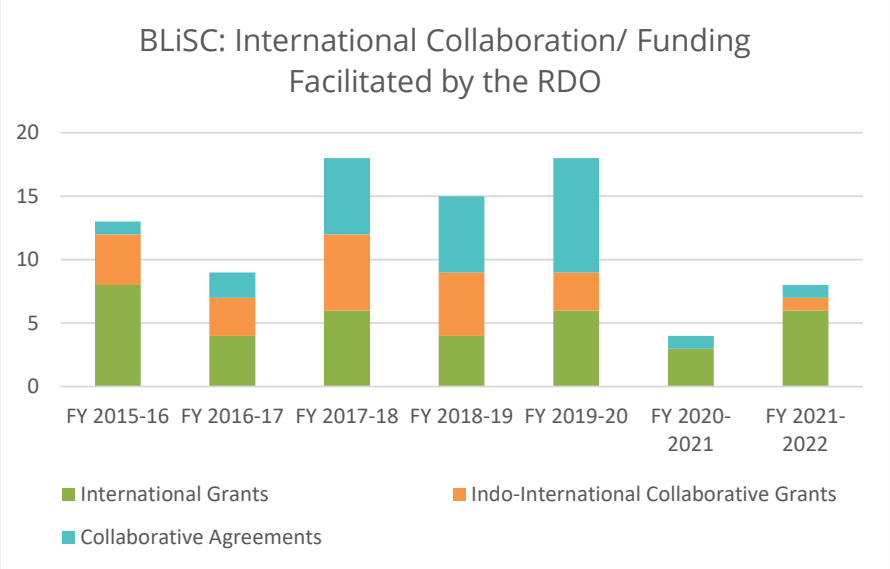
2021-22


BLiSC: International Collaboration/ Funding Facilitated by the RDO
20
15
10
5
0
FY 2015-16
FY 2016-17
FY 2017-18
FY 2018-19
FY 2019-20
FY 2020-2021
FY 2021-2022
International Grants
Indo-International Collaborative Grants
Collaborative Agreements

RDO team

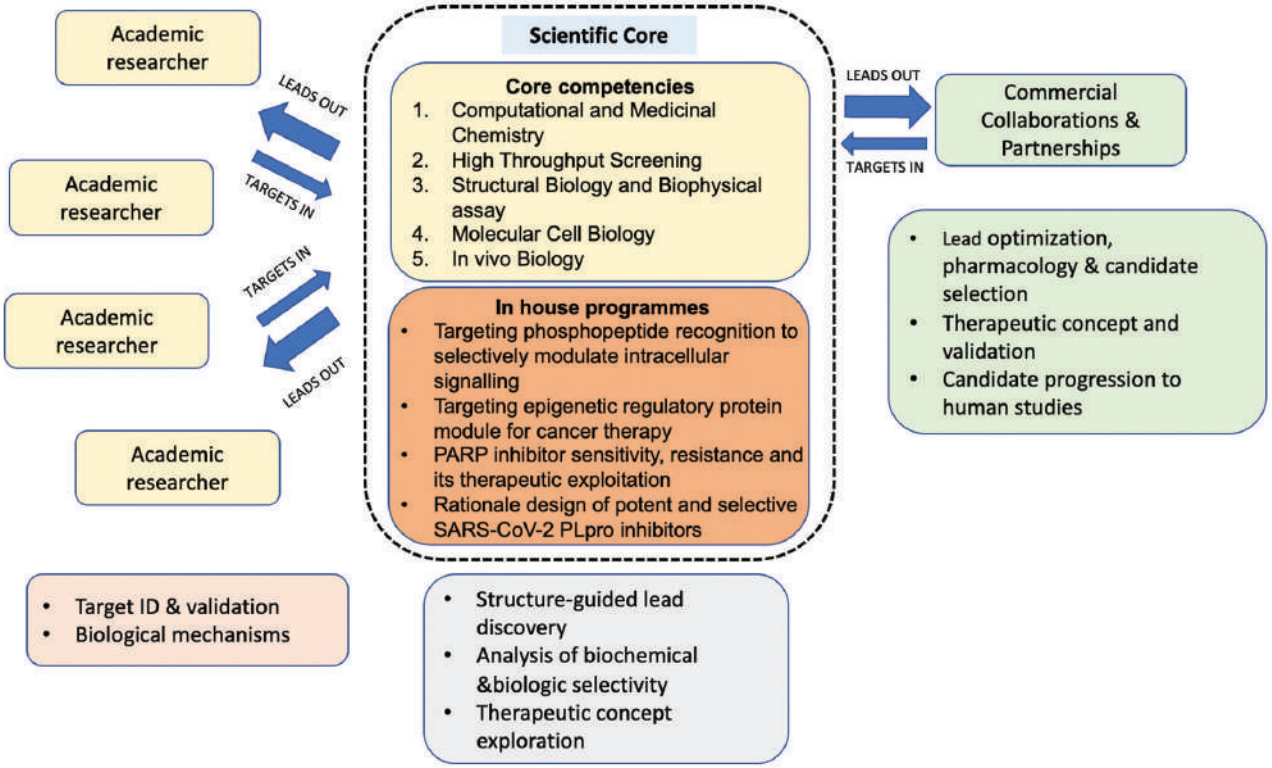
Centre for Chemical Biology and Therapeutics

Anandi Karumbati

Knowledge about the genetic and biochemical basis of human diseases should allow us to develop new drugs. This requires understanding all human proteins (the 'proteome') and which can be targeted for clinical conditions, and how drugs get into cells and induce therapeutic effects.

Since its inception, the Centre for Chemical Biology and Therapeutics (CCBT) has established a unique and powerful integrated platform to address these challenges, through the installation of cutting-edge technologies, and the phased recruitment and training of multidisciplinary teams spanning the areas of screening, computational chemistry, structural biology, synthetic chemistry and molecular cell biology.

We have established powerful capabilities **(a)** to discover and develop small-molecule chemical tools against novel targets, which integrate unique resources for protein chemistry, high-throughput screening, computational chemistry and in silico design, and structural biology of target-ligand complexes; and **(b)** to validate intracellular target engagement by chemical probes using new approaches in fluorescence microscopy and cellular biophysical assays, to elucidate and validate their mechanisms of action using molecular cell biology and biochemistry, and to discover new therapeutic concepts for the clinical development of new drugs using a range of in vitro and in vivo approaches, thereby addressing the challenges drug discovery and targeting pose.



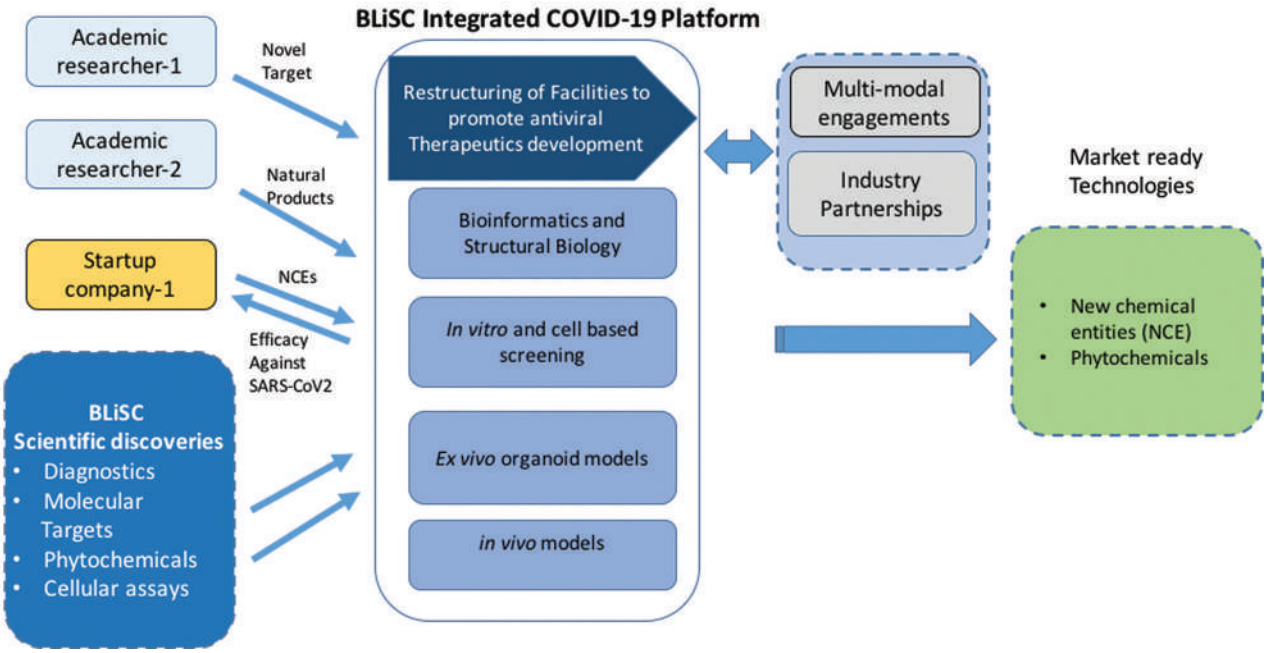
We have made good progress in developing first-in-class drug-like compounds that selectively block phosphopeptide substrate recognition by the tandem (t) BRCT family of protein domains, opening a new therapeutic concept for cancer via the interruption of intracellular signalling. Furthermore, we adopted a structure-guided rationale design to selectively target the potentiating PARPi sensitivity for therapeutic exploitation, epigenetic regulatory protein module for cancer therapy and SARS-CoV-2 PLpro inhibitors.

BANGALORE LIFE SCIENCE CLUSTER

Antiviral Translational Platform

Anandi Karumbati

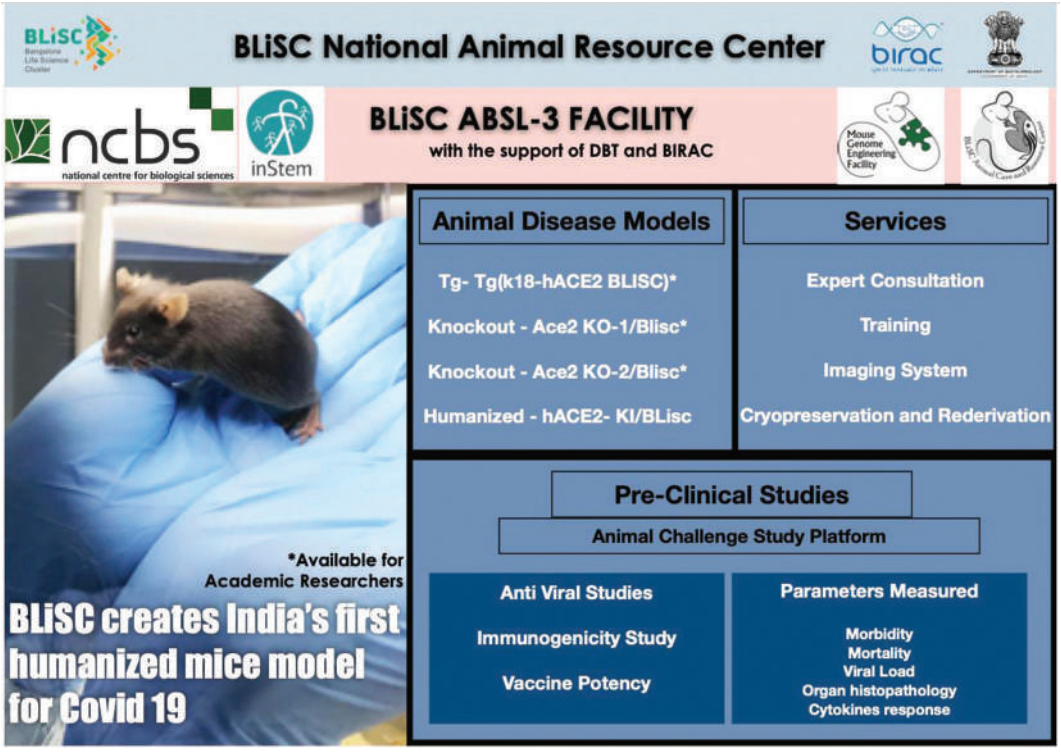
The COVID-19 pandemic had created a need to develop new agents against the SARS-CoV-2 virus in various forms- disinfectants, devices, vaccines, drugs, herbal extracts and formulations. To facilitate antiviral testing requests from both academia and industry in a state-of-art facility, the BLiSC campus has set up a service pipeline. Dr. Varadharajan Sundaramurthy was also key to this effort. SARS-CoV-2 virus cultures along with a panel of assays have been set up in the contained Biosafety category III facility with appropriate safety and regulatory compliances in place. So far, the campus has received and processed about 20 requests for in vitro infection assays both from academics and industry. Learn more about our efforts to establish a state-of-the-art ABSL-3 facility on page 98 that will meet national and international standards, to further test these modalities in vivo models, and provide integrated solutions for antiviral testing in the country.



Biosafety Level 3 Animal Facility for Enabling Animal Model Use for Infectious Disease Research

Hiyaa Ghosh

During the COVID-19 pandemic the Indian scientific community collectively put its efforts for diagnostics and drug development. It was quickly realised that animal facilities where model organisms could be tested for drug development and infectious disease studies were not available readily to researchers in India. To this end, NCBS in partnership with inStem, proposed to build an animal facility that will follow biosafety level 3 (ABSL3) standards to enable safe generation and use of mouse-models for COVID-19 research. In addition, this facility would provide services for engineering disease-models for prospective infectious diseases, access to state-of-the-art equipment for disease research, and trained staff to facilitate infection and disease study in rodent models. NCBS was granted a generous funding from BIRAC to enable the ABSL3 facility. As part of this, we established validity of COVID-infection in novel transgenic mouse lines that were generated on campus. Several state-of-the art equipment, including multimodal live-imaging system for small animals, is being established. In addition, we have also developed a *fee-for-service* model for sustainability and scalability of this facility to meet future needs for infectious disease research.



Wastewater Surveillance to Understand Community Health

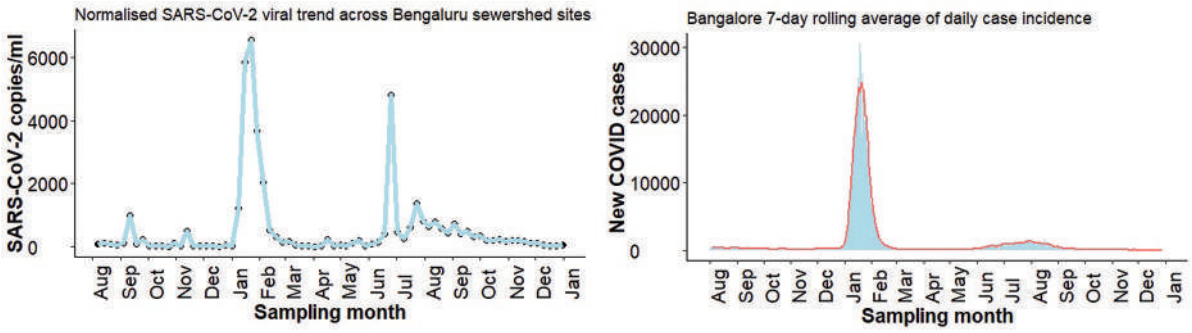
Farah Ishtiaq
TIGS

Uma Ramakrishnan
NCBS

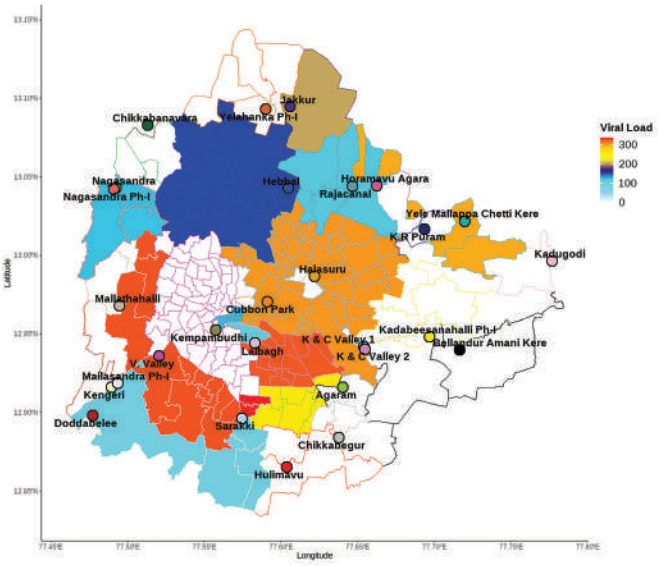
What comes to mind when you think of Bangalore? Probably traffic, gardens, great weather, tech companies. But did you know that Bangalore also has a pretty unique sewage system? More than 90% of Bangalore's wastewater is treated in sewage treatment plants (STP) across the city. This makes it an ideal place for environmental surveillance, where we use sewage wastewater to assess the health of people in Bangalore city.

Wastewater surveillance to monitor health at a community level has been around for a while, but the COVID-19 pandemic saw an invigoration of these approaches. Funded initially by the Bangalore sustainability forum, Uma and Ansil from NCBS worked with Vishwanath, Bangalore's water man (Biome Trust), to understand whether COVID-19 could be detected in wastewater in Jakkur and Yelahanka STPs. Thanks to a memorandum of understanding with the Bangalore Water Supply and Sewage Board, Farah Ishtiaq and team from TIGS, together with Vishwanath, expanded this effort across active 28 STPs in Bangalore city. Over the past year and a half, all STPs have been sampled weekly and 14 STPs on a biweekly basis to monitor trends in SARS-CoV-2 positivity, and sequencing of positive samples to understand diversity of SARS-CoV-2 variants in community samples. Because infected individuals start shedding the virus several days before symptoms show up (or not) and only select individuals get tested for COVID-19, wastewater can provide an early warning detection system for upcoming waves of infection. Funded by the Rockefeller foundation, the team at the Bangalore Life Sciences Cluster was able to analyze early warning trends and variants of concern and have been in regular contact about these results with the local authorities, in this case the BBMP so the data can be used for making informed policy decision. Results of their work are soon to be published in the Lancet Regional Health Southeast Asia.

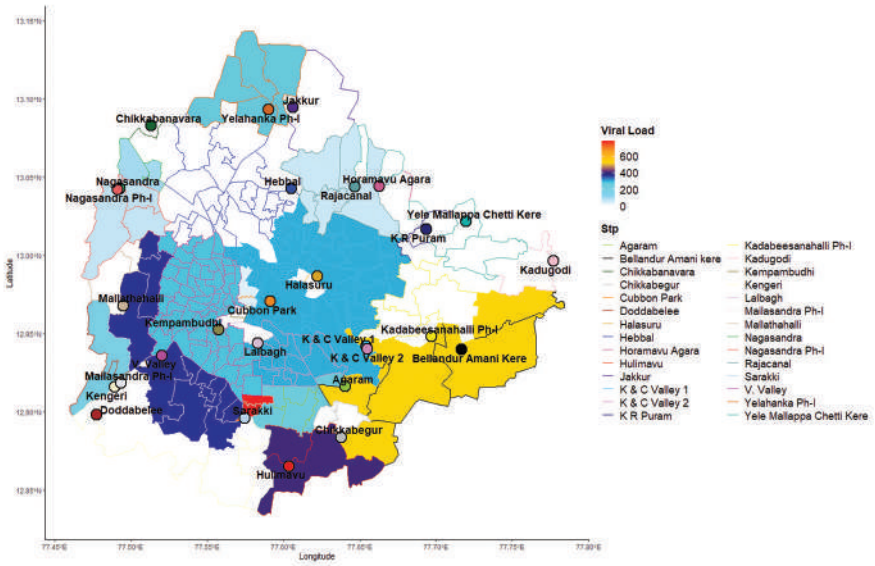
The wastewater surveillance went hand in hand with clinical sequencing, also funded by the Rockefellar Foundation. The Bangalore Life Sciences Cluster, with its excellent facilities and diverse institutions fostered these organic and critical collaborations. In the future, we hope to expand the diseases surveyed through wastewater, and integrate our efforts into the One Health city Bengaluru theme within the Principle Scientific Advisor *(PSA, Government of India)* sanctioned Bangalore Science and Technology Cluster (BeST).

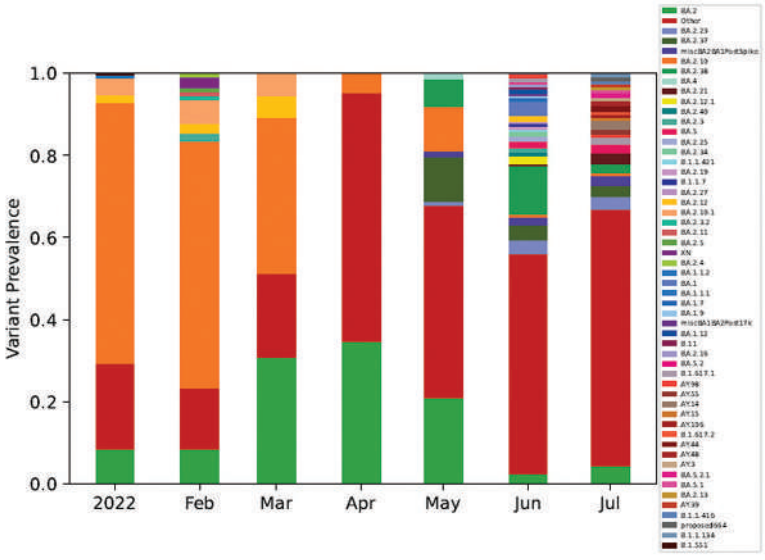


Last week (19 Dec - 24 Dec) **Total Positive = 13**
Total samples = 28



Present week (26 Dec - 31 Dec) **Total Positive = 14**
Total samples = 28





NCBS COMMUNICATIONS OFFICE

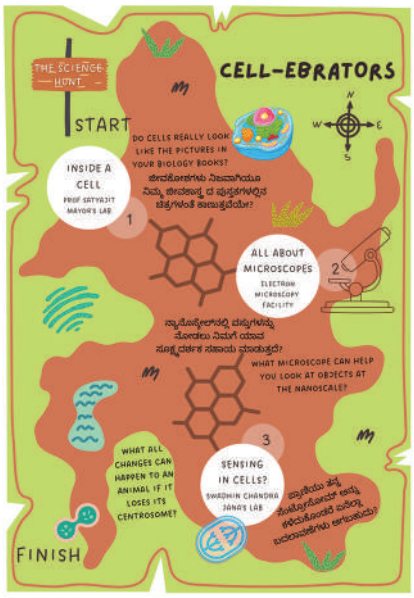
Building Impact-Driven Engagement

Sonal Katyal

The dawn of 2022 saw an independent communications office for NCBS, which I got the opportunity to lead as the Communications Officer along with Prof. Uma Ramakrishnan, the Head of Outreach & Development. Moumita Mazumdar and Raghul MR continued helping us with the creatives till June. To add to the office skill set, two enthusiastic interns, Harsh Srivastava and Surender Ponnalagar joined us in the latter half of the year. This year was about transitioning from pandemic-driven online engagement to opening our doors to curious minds again.

Our outcomes this year ranged from diverse communication to outreach initiatives. These included press releases, social media campaigns, articles, student and teacher visits, talks and exhibits. However, I would like to highlight the new initiatives we kickstarted in 2022.

We launched the NCBS Instagram account, focusing on communication through visual stories. We ran a themed photo campaign called ***'World Under My Microscope'*** to engage our online audience with research the microscopy facilities are assisting with. While the world was cautiously dawdling towards pre-COVID normality, we knew we needed to offer online knowledge-exchange platforms. With these thoughts, Surender organised online Tweet-a-thons on Global Tiger Day and World Alzheimer's Day to allow people to connect with our scientists through Q&As and Twitter-based discussions. We were able to reach 42.6k people within a week *(both events combined)!*



We continued with press releases and tweets about the latest publications; however, the work was not reaching a wider community yet. To address this, Harsh delivered a new series of posts, ***'NCBS Blurbs'***, which are banner-style posters covering the latest research in about 100 words!

The next hurdle was keeping people outside NCBS connected to the life in our labs; despite the impossibility of on-campus visits. I found the solution by delivering a Facebook LIVE series of lab tours called ***'Lab-o-reporting'***. Here I adopted informal VLOG-style conversations to bring the wonders hidden in a lab to people's mobile screens. The reach went upto 1.6 k and is still growing.

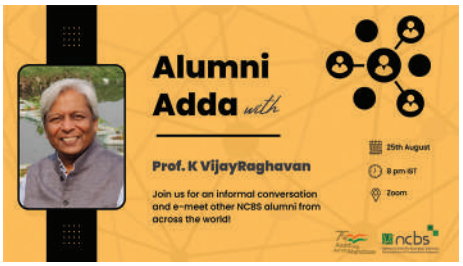
When we could finally host students on campus, we aimed to make their visit impactful. The best model we delivered this year was a curated visit where students explored the labs at the BLiSC campus like a treasure hunt. With trail maps in their hands and divided into thematic groups, they went on a mission to find solutions to specific questions. In this particular visit, we engaged 19 labs for 68 visitors.

We also took our research outside the campus boundaries. Keeping all inhibitions aside, our researchers set up stalls at the streetside gallery of the Rangoli Metro Art Center to interact with people from all walks of life! We also screened a documentary film by Rajani Mani, ***'Colonies in Conflict'***, at the Bangalore International Centre (BIC), which concluded with a riveting discussion with the audience. This film focused on human-bee conflict and was made in consultation with two of our faculty, Dr. Axel Brockmann and Dr. Shannon Olsson. This was the beginning of strengthening our relations with BIC. We collaborated with them for another public talk titled ***'Excavating the Human Molecular Past'***, given by Dr Maanasa Raghavan, Professor of Human Genetics at the University of Chicago, with a discussion by Prof. Uma Ramakrishnan. We look forward to delivering more activities at BIC, and other public spaces in Bangalore and beyond in the coming year.

We collaborated with the echonetwork for social media campaigns and a much-required panel discussion on building climate-resilient communities. We continued supporting the online public discussions ***'Life Science Across the Globe',*** which brings together scientists and scholars worldwide.

NCBS communications office also partnered with Intel India for their initiative ***'Vriddhi'***. Through this channel, our researchers mentored 30 young girls to explore STEM fields and helped them understand a researcher's life. Moreover, they empowered young students to believe that science is a subject for all genders.

Our current objective is to research building better public engagement platforms, to enable two-way dialogues and reach a diverse audience. Next year we will also aim to be more accessible and enhance our inclusion.



Siddharth Kankaria, Communications and Program Coordinator at the Simons Centre at NCBS, also developed and taught a 2-credit graduate course in Fall 2022 called the ***'Fundamentals of Science Communication'***. The course trained researchers in effectively designing, implementing and evaluating their science communication efforts.

Our outputs continue to ensure that people outside the NCBS community see our institute as a place with open doors and not as an ivory tower - an image synonymous with scientific institutes. We hope that in the coming years, we will keep building NCBS as *a resource for learning, a place to satiate curiosity, and a safe forum to discuss and ask questions.*

Highlights of the Year

Meetings and Workshops Calendar

Research Integrity Office
Raj Ladher

The Tata Institute for Genetics and Society
M K Sham Bharadwaj

Early Career Researchers' Council
Raj Ladher and Satyajit Mayor

BLiSC-Q

HIGHLIGHTS OF THE YEAR

Meetings & Workshops 2022

Each year, NCBS hosts a range of meetings and workshops aimed at providing our faculty and students with national and international exposure to cutting-edge research and developments.

January

10–13

Annual Talks - Facets of Biology

February

18–19

Origins of Life and Evolving Chemical Systems Meeting

April

6

Brain Ultrasound Meeting

May

16–20

Hands-on workshop: Stem cell techniques

June

15–17

Soft Matter Young Investigators Meet

July

4–8
Training Workshop on Basic Bio-Methodology of Laboratory Mice and Rats

12–18
MGEF workshop on Crispr/Cas technology and Genome Editing

16
Biodiversity Collaborative - Retreat

23 July – 7 August
Computational Approaches to Memory and Plasticity

August

20
ONE Conference: Ocean Networking and Ecosystem Development

September

19–23
Hands on Workshop on "Integrated OMICS-III" (Genomics, Proteomics and Bioinformatics)

October

16–21
EMBO Practical Course: Metabolite and Species Dynamics in Microbial Communities

18
Viral Translational Network

November

1–4
Cellular Lineages and Development: from Single Cells to Landscapes

14–18
EMBO Workshop: "Inositol Lipids: Signaling Platforms for Organizing Cellular Architecture and Physiology"

18–22
4th ACRC Training Workshop on Basic Bio-Methodology of Laboratory Mice and Rats

21–22
Genetics of Adaptation

December

12–17
MGEF Mouse CryoBiology and IVF workshop

Research Integrity Office

Raj Ladher

Our exploration of nature, our motivation to understand us and our surroundings, is what drives our research. However, the way we do research must be methodical, transparent, documented and reproducible: This is our promise to society, returning the trust that they put in us. We also have a responsibility to incorporate integrity in the training we give to our students. In fact, the University Grants Commission (UGC) that regulates our degree programmes recognised this, mandating the provision of a Research Ethics course for all graduate students. To systematise both our integrity training, and introduce best practices into our data management, NCBS, together with our neighbours at inStem have established a Research Integrity Office (RIO). This office, the first of its kind in India, has been set up to develop processes that let us proactively put in place procedures that alert our researchers on common problems that could result in misconduct. It has also streamlined our processes in reacting to research misconduct and will liaise with Institute heads to investigate any complaints. Importantly, it has played an active role in training students and staff, running a monthly ethic orientation for all new joinees, and teaching the mandatory Ethics course. Biswa and Sabuj have been busy reaching out to all labs to understand their data management processes, and adapting this to the requirement journals and granting agencies have. As the RIO grows, our hope is that it becomes a template for educating and managing issues around research integrity throughout India.

Biswa Bhusana Mahapatra

Sabuj Bhattacharya

The Tata Institute for Genetics and Society (TIGS)

M K Sham Bharadwaj

The Tata Institute for Genetics and Society (TIGS), founded in 2017 and an integral part of the Bangalore Life Science Cluster (BLiSC), is a non-profit research institute that tackles challenges in human health and agriculture. A program-driven institution, TIGS is focused on developing solutions based on cutting-edge science and technology across three principal areas i.e., Infectious diseases, Rare Genetic Diseases, and Crop Improvement.

During this period, TIGS has developed a model for the environmental surveillance of infectious diseases from wastewater which has been crucial for monitoring the extent and spread of COVID-19 infections in Bengaluru. In partnership with the city's administrative and municipal authorities, all the 28 sewage treatment plants (STPs) across the city are sampled routinely to analyze SARS-CoV-2 viral loads. High throughput genomic sequencing, in collaboration with NCBS, identifies emerging viral variants, and their distribution in the catchment areas of these STPs. The city-wide data trends are

shared with the municipal corporation, the Bruhat Bengaluru Mahanagara Palike (BBMP) to help flag areas of concern. This system of wastewater-based epidemiology can provide timely warning of disease spread, and we are adapting the same under a One Health approach to track the emergence of various infectious pathogens, and bacterial species resistant to antibiotics and drugs, etc.

TIGS is also taking multiple approaches to reduce the burden of rare genetic disorders (RGDs) which are far from rare in India, owing to the high population density in the country and social practices. We are working towards improving access to affordable and quality diagnostics and therapeutics for RGDs to help foster health equity in the country. We are also focused on innovation and implementation of different approaches to improve the nutritional quality of food grains and develop varieties that can tolerate the changing environment. Using our expertise across a gamut of tools such as conventional plant breeding, mutation breeding, and genome editing technologies, we are working on multiple aspects of crop improvement, as well as novel methods to reduce the effects of agricultural pests, helping reduce crop losses due to diseases and pests.

As part of campus visits, several students and other researchers have visited TIGS and its facilities to know more about the research activities carried out. As part of our outreach and community engagement programs, we organize several webinars, invited talks and panel discussions to learn and inform the campus of varied activities. To know more about the research and outreach programs at TIGS scan the QR code.

The day TIGS became an official part of the Bangalore Life Sciences Cluster (BLiSC)

From R to L:

Dr. K Thangaraj, Director DBT -CDFD

Dr. Aravind Ramanathan, Head of Research, DBT – inStem

Dr. Rakesh K Mishra, Director TIGS India

Dr. Taslimarif Saiyed, CEO C-CAMP

Mr. Manoj Kumar, CEO Social Alpha

Prof. Satyajit Mayor, Director NCBS

Prof. Uma Ramakrishnan, Head, Outreach & Development, NCBS

Mr. L C Das, MD Social Alpha

A batch of MSc Biotechnology students from Azim Premji University visited the facilities and labs to learn about the research activities at TIGS

Early Career Researchers' Council ECRC

Raj Ladher and Satyajit Mayor

At the end of 2021, Jitu, Das *(inStem's academic coordinator)* and I started a series of conversations with all early career researchers on campus. The early career researchers *(that is graduate students, junior research fellows, project assistants and postdoctoral associates)* are the engines of research at NCBS. It is this group that generates the vibrancy and dynamism that is NCBS, and forms a major part of the innovators, creators, thinkers and great researchers that the centre is renowned for. These are also the group that we felt it was important to connect with: The third COVID wave had passed, as had the south-west monsoon, and with the more pleasant weather we thought that it would be valuable for us to hear how our colleagues were doing. Over the span of two months, and around 25 separate meetings, we spoke to slightly over 400 ECRs, split into groups of 10-15. The chats took place on the terrace close to the fly facility, and were held at the end of the day, around 5 pm so that they did not overly interrupt the day.

A number of takeaways from the terrace chats prompted the need to come up with a way to structure ECRs engagement with faculty, management, staff and indeed other ECRs. ECRs are an important constituent on the campus, and their views need to be heard and responded to. As the campus grows, counterintuitively, connections and opportunities to meet, develop new friendships, exchanges ideas, and ferment new collaborations become more limited. Developing fora that break down barriers and enable this kind of exchange is important and should become an enduring facet of the culture of our campus.

When ECRs suggested the formation of an early career researcher's council (ECRC), we encouraged it. This group represents the views of the ECR body, with representation on many key committees that manage aspects of campus life. With a direct means to effect changes in their environment, the hope is that not only will it lead to positive changes in the way ECRs can maintain the scientific excellence of the centre, but it also provides insights into management that may equip some ECRs a perspective on administration, and some of the nuances and trade-offs that need to be considered. The ECRC has been driving social events, with *Happy Fridays*, a get-together once a month, and a meet-a-faculty session, the *'Faculty-ECR Mixer Series'* being especially popular events.

As Director and Dean of Academics, we welcome the ECRC. As an important component in the culture of the centre, ECRs are part of any vision of research excellence. Their success is our success, and these successes will be an enduring legacy of NCBS.

BLiSC-Q

BLiSC-Q is a queer + allies collective at the Bangalore Life Science Cluster (BLiSC) that was officially launched in June 2022 *(also internationally celebrated as Pride Month)*. The collective aims to create an inclusive and safe space for everybody on campus, irrespective of their sexual orientation, gender identity or expression.

BLiSC-Q hopes to acknowledge, support and celebrate the presence of LGBTQIA+ individuals spread across the student, faculty, staff and alumni communities on campus. It hopes to build networks and connections among and across queer individuals and allies in a bid to create community, allyship and safe spaces on campus.

The collective also aims to engage with the larger campus community to help raise awareness, enhance sensitivity and build support for issues faced by LGBTQIA+ individuals on campus. In 2022, BLiSC-Q organised several events, including a queer-themed movie screening and discussion, a Pride Month-themed 'Happy Priday' networking event, and a closed-door potluck lunch for queer folks on campus. The collective further hopes to engage with queer individuals, allies and the larger campus community through many more interactive events and programmes in the upcoming year.

If you would be interested in joining the BLiSC-Q collective as a queer individual or an ally, please reach out to us at ***bliscq@ncbs.res.in***

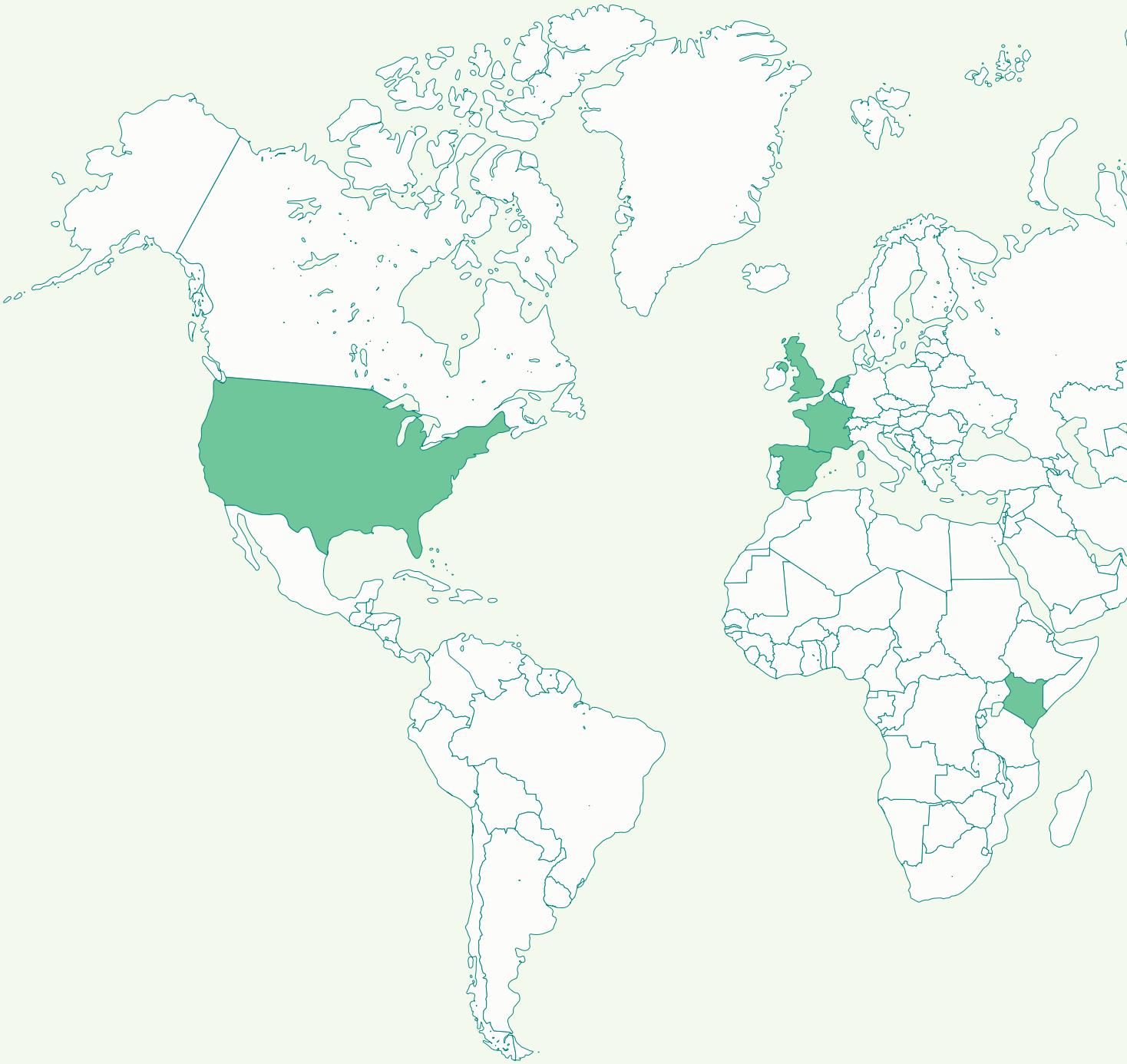
From streaking plates to finding colourful colonies, being passionate about science is all about the joy in little things.
Photo credit: Sonal Katyal

NCBS Collaborations

International Collaborations

National Collaborations

NCBS International Collaborations



Broad Institute
Boston, USA

Centre National de la Recherche Scientifique
Paris, France

Erasmus University Medical Centre
Rotterdam, Netherlands

Kings College
London, UK

National University of Singapore
Singapore, Singapore

Panthera
New York, USA

RIKEN
Hirosawa, Japan

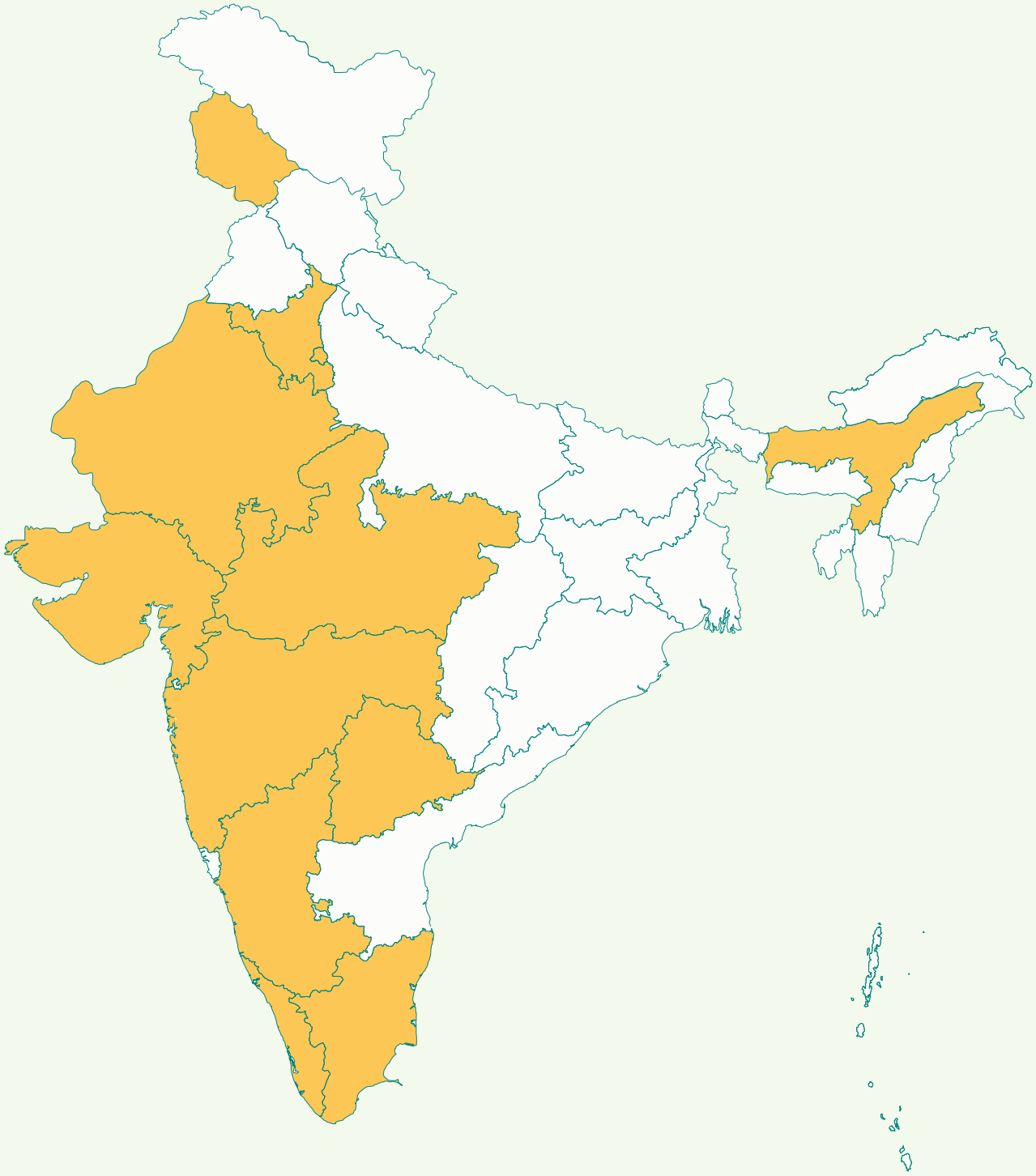
Socidad Espanola de Dessorrollos Quimicos
Barcelona, Spain

University of Dundee
Dundee, Scotland, UK

University of Nairobi
Nairobi, Kenya

Wildlife Conservation Society
New York, USA

NCBS National Collaborations



Abu Paryavan Samiti
Mt. Abu, Rajasthan

Advance Centre for Treatment, Research and Education in Cancer
Mumbai, Maharashtra

Apollo Hospital
Bangalore, Karnataka

Ashok Trust for Research in Ecology and the Environment
Bangalore, Karnataka

Ashoka University
Sonipat, Haryana

Bangalore Baptist Hospital
Bangalore, Karnataka

Bangalore Medical Services Trust
Bangalore, Karnataka

CBCI Society for Medical Education
(St. John's National Academy of Health Sciences)
Bangalore, Karnataka

Centre for Cellular & Molecular Platforms
Bangalore, Karnataka

Christian Medical College
Vellore, Tamil Nadu

CSIR-Centre for Cellular & Molecular Biology
Hyderabad, Telangana

Cytecare Hospitals Pvt. Ltd.
Bangalore, Karnataka

Feather Library
Ahmedabad, Gujrat

Goethe Institute
Bangalore, Karnataka

Govt. of Rajasthan
Jaipur, Rajasthan

Indian Institute for Science Education and Research Pune
Pune, Maharashtra

Indian Institute of Forest Management
Bhopal, Madhya Pradesh

Indian Institute of Science
Bangalore, Karnataka

Indian Institute of Technology, Mumbai
Mumbai, Maharashtra

Indian Malabar Cancer Centre
Thalaserry, Kerala

Institute for Stem Cell Science and Regenerative Medicine
Bangalore, Karnataka

Kadamane Estates Company
Chennai, Tamil Nadu

Karnataka State Forest Department
Bangalore, Karnataka

Lakeshore Hospital & Research Centre
Kochi, Kerala

Manipal Academy for Higher Education
Manipal, Karnataka

Manomanian Sundaranar University
Thirunveli, Tamil Nadu

Nature Conservation Foundation
Mysore, Karnataka

National Institute for Mental Health and Neurosciences
Bangalore, Karnataka

Pune Knowledge Cluster
Pune, Maharashtra

Rajiv Gandhi University of Health Sciences
Bangalore, Karnataka

Tadoba - Andhari Tiger Reserve
Chandrapur, Maharashtra

Tamil Nadu Agricultural University
Coimbatore, Tamil Nadu

Tata Institute for Genetics & Society
Bangalore, Karnataka

Tata Memorial Centre
Mumbai, Maharashtra

Tezpur University
Tezpur, Assam

Thackeray Wildlife Foundation
Mumbai, Maharashtra

Translational Health Science and Technology Institute
Faridabad, Haryana

University of Agricultural Sciences-Bengaluru
Bangalore, Karnataka

University of Kashmir
Srinagar, Jammu & Kashmir

University School of Environment Management
New Delhi, Delhi

Wildlife Conservation Society
Bangalore, Karnataka

Wipro Foundation
Bangalore, Karnataka

Scientific and Management Board

Management Board

The Management Board is in charge of the overall management of NCBS, and also functions as a research council.

- Prof. Jayaram N. Chengalur, *Director, TIFR, Mumbai -Chairperson*
- Prof. Mary Beckerle, *University of Utah, USA*
- Prof. Thomas Daniel, *University of Washington, USA*
- Prof. Gagandeep Kang, *Christian Medical College, Vellore*
- Dr. Anurag Behar, *Azim Premji Foundation, Bangalore*
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- Prof. Raghu Padinjat, Dean of Research, *NCBS, Bangalore, (ex-officio)*
- Prof. Sanjay Sane, Dean of Faculty, *NCBS, Bangalore, (ex-officio)*
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- Dr. Satyajit Rath, *Indian Institute of Science Education and Research, Pune*
- Prof. Benny Shilo, *Weizmann Institute of Science, Israel*
- Director, *inStem, Bangalore, (ex-officio)*
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- Prof. Vidita. A. Vaidya, *TIFR, Mumbai*
- Prof. Rajesh Kumar Ladher, Dean of Academics, *NCBS, Bangalore, (ex-officio)*
- Prof. Mukund Thattai, *NCBS, Bangalore*
- Registrar, *TIFR, Mumbai, (ex-officio)*
- Head, Administration and Finance, *NCBS, (ex-officio) - Non Member Secretary*

Scientific Advisors

- Prof. Kamal Bawa, *University of Massachusetts, USA*
- Prof. Albert J Libchaber, *Rockefeller University, USA*
- Prof. Venkatraman Ramakrishnan, *MRC Laboratory for Molecular Biology, Cambridge, U.K*
- Prof. Joan E. Strassmann, *Washington University in St Louis, USA*
- Prof. Jan Marino (Nino) Ramirez, *University of Washington, Seattle, USA*

Funders
NCBS-TIFR

National Funding Agencies

- DBT/Wellcome Trust India Alliance
- Department of Science and Technology (DST)
- Department of Biotechnology (DBT)
- Science and Engineering Research Board (SERB)
- Council of Scientific and Industrial Research (CSIR)
- Indian Council of Medical Research (ICMR)
- Department of Health Research (DHR)
- University Grants Commission (UGC)
- Ministry of Environment, Forest and Climate Change (MOEFCC)
- Biotechnology Industry Research Assistance Council (BIRAC)
- Indo-French Centre for the Promotion of Advanced Research (IFCPAR/CEFIPRA)

International Funding Agencies

- Human Frontier Science Program (HFSP)
- European Molecular Biology Organization (EMBO)
- National Geographic Society
- Air Force Office of Scientific Research (AFOSR/AOARD)
- Max Planck Group (MPG)
- Simons Foundation

Private/Philanthropy/ Corporate Sources

- Infosys Foundation
- Kiran Mazumdar Shaw
- Pratiksha Trust
- TNQ Technologies
- Wildlife Conservation Trust (WCT)
- Tata Trust
- Narayana Murthy
- DeFries-Bajapi Foundation
- Panthera Corporation, New York, USA
- Hindustan Unilever Limited and Unilever Industries P Ltd.
- Rockefeller Foundation
- On the EDGE Conservation, UK
- Wildlife Conservation Society (WCS, NY)
- Arcadia Philanthropic Trust
- Global Partnerships Fund. International Relations and Partnerships Team, Newcastle University, UK
- Conservation, Food and Health Foundation, USA (CFH)
- International Council on Archives Fund (FIDA)
- Tadoba Andheri Tiger Reserve Conservation Foundation
- Nature Conservation Foundation (NCF)
- The Habitats Trust

Nature is incredible!

Uma Ramakrishnan

Professor, Head, Outreach and Development, NCBS

Scientists at NCBS work tirelessly everyday to reveal hidden facets of nature. This journey of discovery and learning begins as a graduate student, and goes on for as long as we are able to wonder, question and understand living systems. This issue is dedicated to learning, and our early career researchers without whom this journey would not be possible, and frankly no fun at all! Thanks to Sonal and Sumita, co-creating this annual report with them was a great experience. We hope you enjoy learning about our year, and what motivates us as we move towards the future.

Design note

Sumita Nanda

Designer www.superpixel.in

This edition of the NCBS annual report is dedicated to *students and learning*. I worked closely with ***Uma Ramakrishnan*** and ***Sonal Katyal*** on this project and we picked an illustrative approach ***showcasing the different aspects of the life of a research student.***

A scientist is a student for life. Along their journey as a PhD student at NCBS, they spend a significant amount of time reading and learning, conducting research and experiments, analyzing data, writing reports and papers, and collaborating with other scientists to find solutions to the complex mysteries that surround us. Their passion for their work is infectious and that's the energy you feel being at NCBS. They can also be seen enjoying the beautiful nature that the NCBS campus offers - out for a walk, discussing science with the PIs, or just having a cup of coffee in their favourite corner. They are eager to bridge the gap between science and the general public, participating in initiatives and events that help increase awareness and spread knowledge. While science and academia are a major part of their lives, they also know how to maintain a balance with more relaxing activities and can be seen participating in *dance, music, theatre,* and *book clubs,* playing a variety of indoor and outdoor sports including *cricket, frisbee, volleyball, foosball, carrom, etc.*

These various facets of their lives are illustrated on the front and back covers of the report and also extended to the inner pages where they make appearances in between. In keeping with the overall design theme of the report, we have used faculty sketches instead of photographs, and these were done by the very talented ***Alissa Barnes*** *(NCBS).*

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