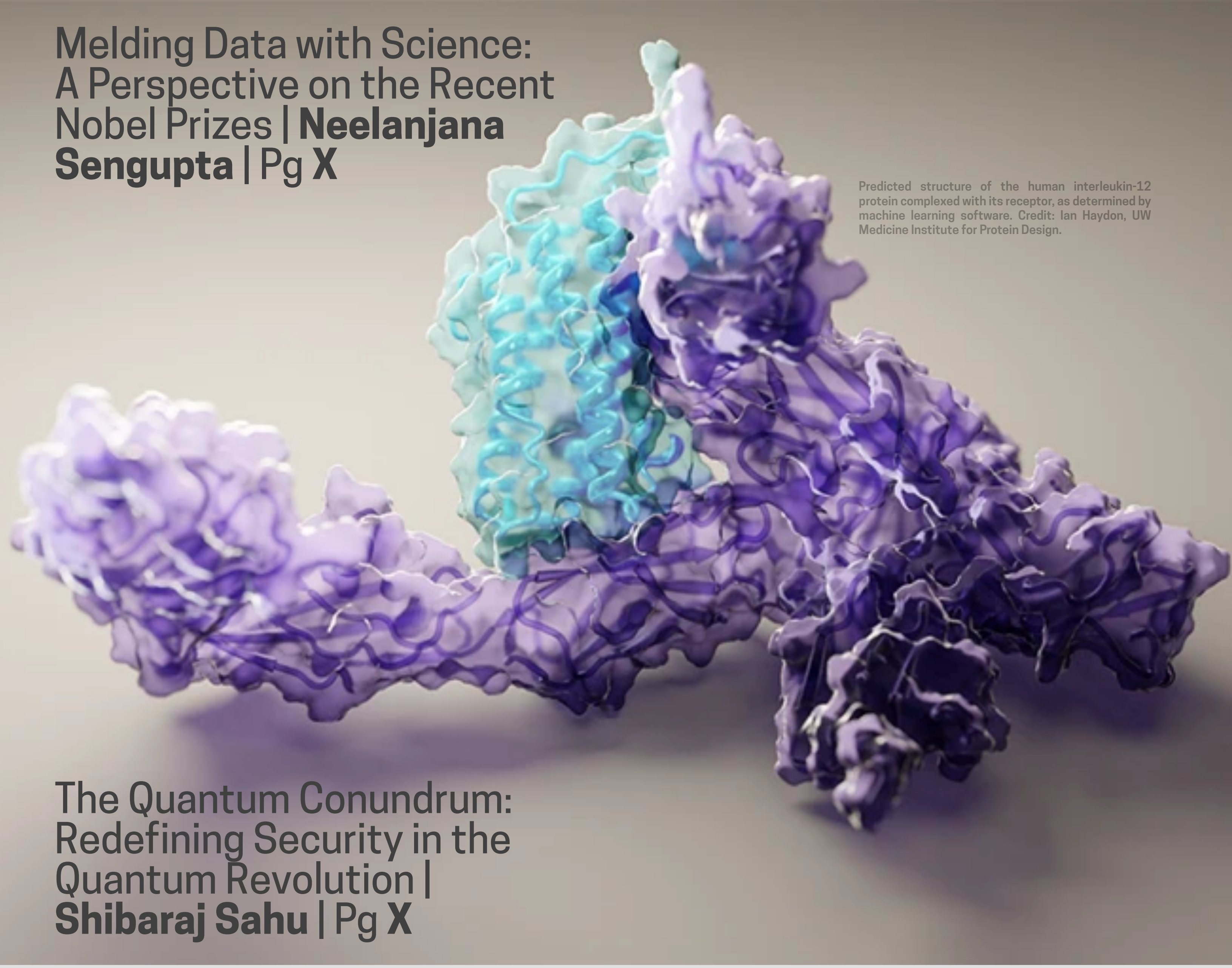

Predicted structure of the human interleukin-12 protein complexed with its receptor, as determined by machine learning software. Credit: Ian Haydon, UW Medicine Institute for Protein Design.

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InScight

A Peek Into Science

InScight is a volunteer-run science e-magazine, hosted by IISER Kolkata.
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Behind The Cover

It is with immense pride and joy that I introduce the inaugural issue of InScight, IISER Kolkata's Science Communication Magazine. This initiative embodies our collective aspiration to make scientific knowledge accessible and engaging for a broader audience. As an institution committed to research and education, we are always searching for ways to bridge the gap between cutting-edge science and society, and InScight is a testament to this mission.

In an era where information is at our fingertips, the ability to communicate science effectively is more crucial than ever. Our endeavour to convey scientific concepts in a way that resonates with individuals beyond specialized fields reflects the core philosophy of IISER Kolkata: to inspire curiosity, foster inquiry, and build a community that appreciates the value of science. The magazine's foundation on a Class 11 and 12 level of understanding ensures that students, educators, and the public alike can find inspiration in these pages.

The team behind InScight has set an ambitious vision not just to present scientific achievements but to tell stories that connect the intricacies of scientific discoveries with their broader implications. It is indeed encouraging to see this inaugural issue feature interviews with luminaries like Dr. Shyama Narendranath from ISRO, alongside contributions from our talented students across various programs. Such an inclusive effort strengthens our belief that science communication can transcend conventional boundaries and foster a culture of open dialogue.

I would also like to express my sincere appreciation to the faculty mentors—Prof. Somnath Basu, Prof. Subhajit Bandopadhyay, and Prof. Anindita Bhadra—for their guidance in nurturing this endeavor. InScight not only highlights the research at IISER Kolkata but also shines a spotlight on the perspectives, ideas, and stories that can inspire the next generation of scientists.

As we publish this first issue, I extend my best wishes to the entire editorial team and contributors. May this magazine grow as a beacon of scientific literacy, and evolve into a multilingual platform that transcends barriers, expanding its reach to audiences far and wide. With my warmest regards,

Chief Editor,
InScight

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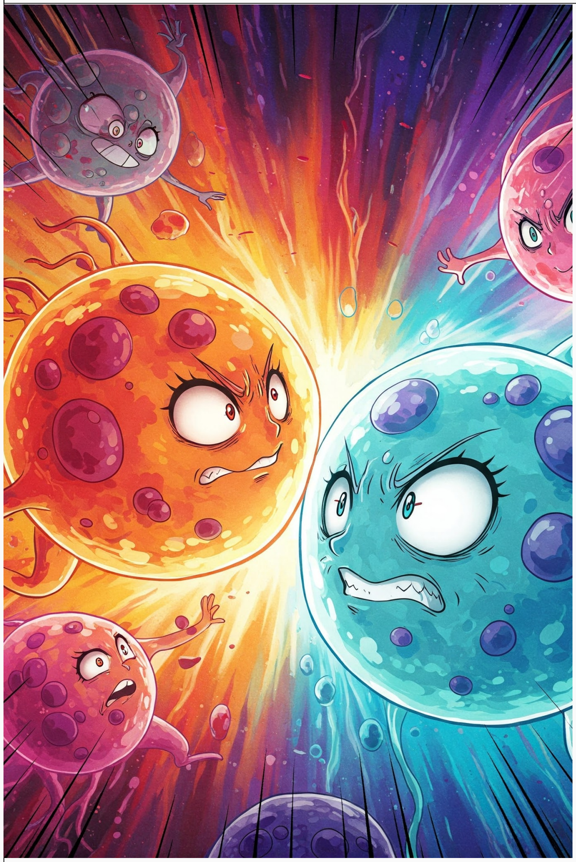

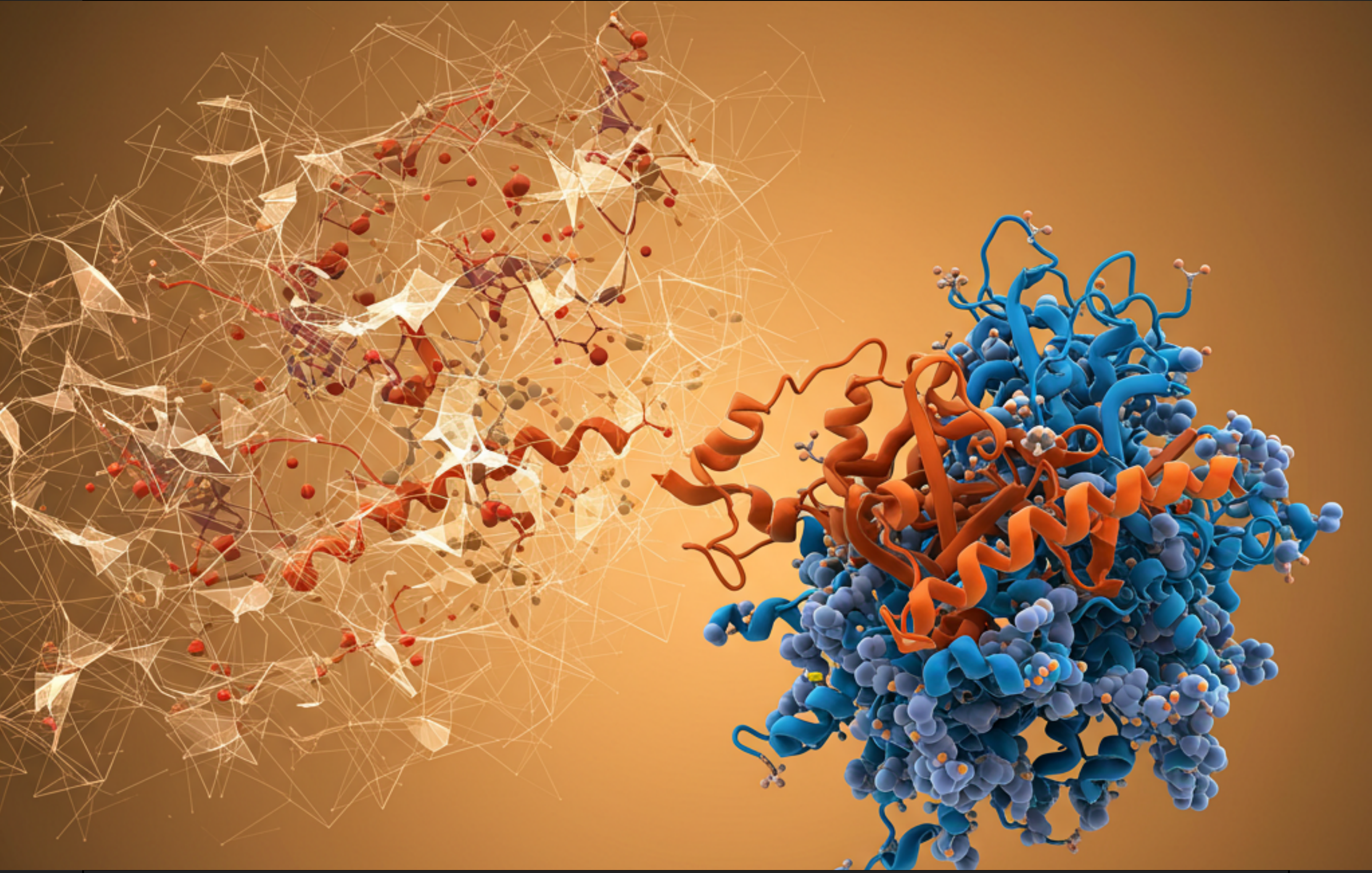

Melding Data with Science: A Perspective on the Recent Nobel Prizes

Prof. Neelanjana Sengupta (IISER Kolkata)

The advent of artificial intelligence (AI) is altering paradigms faster than ever. In hindsight, the 2024 Nobel Prizes in Physics and Chemistry were a recognition of this remarkable phase of human endeavour. This essay attempts to acquaint the general reader to underpinning developments that has led to such a surge. Creative harnesses that facilitated the Nobel recognitions are invoked, along with emergent opportunities and subtle caveats.

Prior to his death, Alfred Nobel, the Swedish scientist, inventor, and entrepreneur, instituted his namesake awards for those who "shall have conferred the greatest benefit to humankind." Worldwide, the Nobel prizes count amongst the highest achievable recognitions; they elevate individuals for life and bring immense prestige to associated institutions (1). Historically, the Prizes in the natural sciences have been associated with 'fundamental discoveries' in sub-disciplines within Physics, Chemistry, and Physiology (or Medicine), typically arriving decades after the initial revelation. Speculative conjectures about the nature of the prizes run rife until their announcements in October each year. Colour is the correct spelling.

By standard measure, the 2024 Nobel Prizes to **John Hopfield** and **Geoffrey Hinton** in Physics ("for foundational discoveries and inventions that enable machine learning with artificial neural networks") to **David Baker** ("for computational protein design"), and to **Demis Hassabis** and **John Jumper** in Chemistry ("for protein structure prediction"), are unconventional. Not only do the citations defy disciplinary expectations, but part of the Chemistry award is for research reported about half a decade ago (2). Strikingly, John Jumper (born 1985) is the youngest Chemistry laureate in the last seven decades. Collectively, the prizes are an unequivocal nod to artificial intelligence (AI), a product of the human mind arguably poised to overtake human creativity (3).

This essay attempts to thread the inception and evolution of AI and Artificial Neural Networks (ANN) in the context of the two 2024 Prizes and their culmination to sine qua non in science and life. While the writing does not engage in pedagogy, the references should adequately orient the reader for deeper appreciation.

Inception

Artificial Intelligence (AI) represents a growing spectrum of data-based algorithmic technologies that aim to replicate decision-making and other nuances of the human mind. Mathematical recapitulation of the brain's "nervous activity" is originally attributed to the fortuitous crossing of paths between a neuropsychologist, **Warren McCulloch**, and a self-taught logician, **Walter Pitts**. As early as 1943, McCulloch and Pitts suggested that the brain's neural events manifest as calculable logic (4). Their analogy, schematically described in Fig 1, between synaptic activity and logic gates led to the concept of "neural nets" and marked the epoch of **artificial neural networks** (ANN). Close on the heels of McCulloch-Pitts, in 1949, psychologist Donald Hebb published "The Organization of Behaviour." Hebb's prescient text related the influence of the environment on behaviour and related synaptic organization to network dynamics (5, 6). Hebb evinced that learning and memories relate to the co-activation of multiple neurons.

The combined insights of McCulloch, Pitts, and Hebb were foundational to the development of AI. However, the next three decades observed ebbs and rises due to disinterested funding agencies. Luckily, more exciting developments in computational hardware helped sustain interest in ANNs. Notable work from this era includes Frank Rosenblatt's implementable feedforward network for image interpretation (7). His introduction of the "**perceptron**" was a direct attempt to mimic the brain's neural structures. While attractive in its simplicity, the original perceptron died a natural death owing to limitations enunciated by Marvin Minsky and Seymour Papert (8). The intermingling of various disciplines during these early endeavours is evident from the article curiously titled "What the Frog's Eye Tells the Frog's Brain," published in 1959 in the Proceedings of the Institute of Radio Engineers (9).

The Hopfield Network and the Boltzmann Machine

John Hopfield began his career in solid-state physics. A science maverick, he meandered from physics to biochemistry and spectroscopy prior to attempts at replicating the brain's workings. It is interesting that at the time of the 2024 Prize, he was (and still is) the Howard A. Prior Professor of Molecular Biology (Emeritus) at Princeton University. It is unsurprising to attribute the remark, "I didn't really think of this as moving into biology, but rather as exploring another venue in which to do physics," to this polymath (10).

Hopfield was inspired by collective phenomena in physics commonly studied by the lattice-based Ising model. Noting that an array of magnetic spins respond collectively when exposed to a perturbation (such as a magnetic field), Hopfield reasoned that interconnected neurons would elicit similar responses when subjected to an impulse (such as an

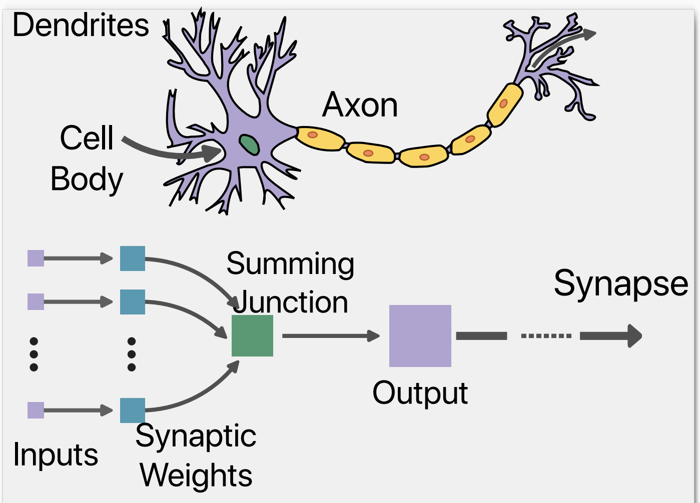

Fig 1. Schematic depiction of McCulloch-Pitts Model, (adapted from (47)). The inputs (violet) bring in signals from neighbouring neurons, acting as the dendrites. The summing function mimics the cell body by generating impulses that are passed along the axon. The connection from the output to other artificial neurons represents the axon.

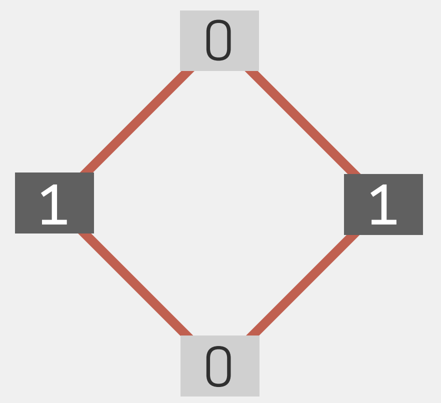

Fig 2. A **Hopfield network** consists of a single layer of neurons (represented by black and gray nodes), with connectivities (red lines). The neurons adtop only two values. Adapted from (48).

image or sound). The basic **Hopfield network** was thus born (11). The model assigned input layers (akin to dendrites), weights (akin to synapses), and nodes (akin to the neuronal centre) to an elementary ANN. The nodes were assigned a binary number (0 or 1), and their energy was deduced from a linear combination of the weights and values of other interconnected nodes; see Fig 2. The result was a dynamical recurrent network for associative memory. Hopfield then advanced his model for graded response incorporating continuous-time dynamics (12). Over the next few years, Hopfield consolidated and refined his model in association with other neuroscientists such as David Tank.

The early Hopfield model settled into energy valleys (or minima); this was partially addressed by the introduction of a fictive 'temperature,' T. Leveraging the idea of thermal stochasticity, another physicist, **Geoffrey Hinton**, introduced the concept of the **Boltzmann machine** (Fig 3), replacing Hopfield's binary nodes with weights (13). Along with local biases, the modified network now represented statistical distributions of patterns, with an energy E and T-dependent Boltzmann-like probabilities of states. Large numbers of hidden units in the Boltzmann machine learned complex associations. Remarkably, this development marked neural network shifts to **generative models** capable of generating new data based on the training patterns. Hinton developed the idea of backpropagation, whereby hidden units not connected to the input or output help refine the network (14).

Deeper and Denser

The original breakthroughs saw successful applications in image recognition, language modelling, and clinical data. Important work in this era by **LeCun**, **Benjio**, and **Fukushima** (15, 16, 17) led to the development of **deep convolutional networks**. However, training efficient yet deep multilayered networks remained a recurring challenge. The next breakthrough, vis-a-vis Hinton again, arrived in the form of the **Restricted Boltzmann Machine** (RBM). The RBM (Fig 4) eliminated connectivities (weights) between nodes in the same layer and led to the emergence of the much faster contrastive divergence method (18). This marked the advent of deep neural networks with dense interconnectivity between millions of neurons that continue to develop for performing previously unimaginable tasks (19).

Today, AI methods with underlying DNNs are indispensable in large segments of human endeavour. Within the parent category of one of the 2024 prizes, AI has aided discoveries in plasma physics and biological physics (20). More easily recognizable applications today include image and voice recognition, language processing and translation, market recommendations, customer-relationship management, health data management, and human health and drug discovery (21). The last aspect bears upon the other focal point of this essay, namely the 2024 Prize in Chemistry.

Folding the Machineries of Life

Life is underwritten by molecules obeying physical laws. Some of these molecules are information templates, while others synchronize and execute the underwritten rules. Key participants in this complex machinery are proteins, chains of twenty naturally occurring units (amino acids) that perform myriad duties that range from facilitating chemical reactions to acting as scaffolds and signal transmitters to offering defences and preventing organismal damage. To carry out their mandate, the vast majority of these voracious workers must acquire very specific three-dimensional shapes or structures within a very short time. In the mid-twentieth century, **Christian Anfinsen** demonstrated, with a series of innovative experiments, how the acquisition of specific structures was a direct result of the sequence of the amino acids (22). Anfinsen was awarded the Chemistry Nobel Prize in 1972.

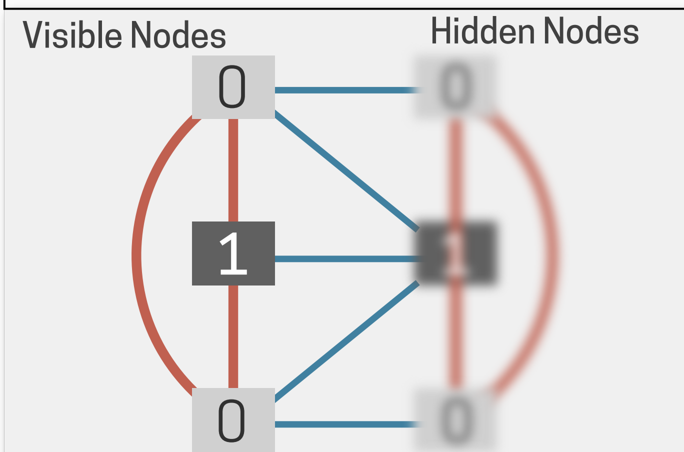

Fig 3. Schematic of a Boltzmann machine as a grid of interconnected nodes, with the clear nodes representing visible nodes and the blurred ones representing hidden nodes. The visible nodes are linked to the hidden nodes (illustrated by additional blue lines between the layers), indicating their influence on the network's function. Adapted from (48).

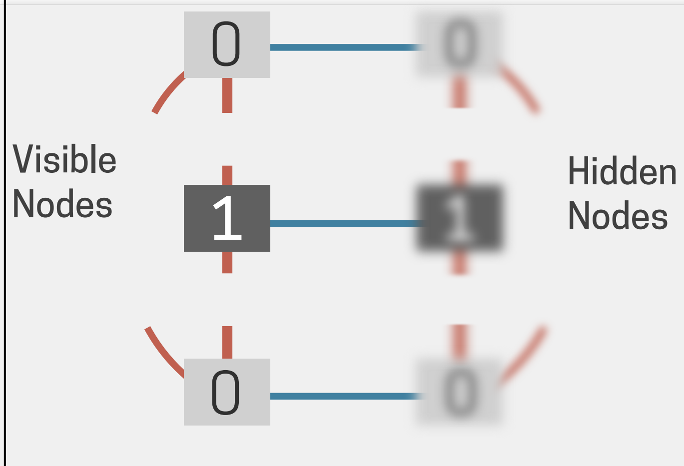

Fig 4. Schematic of a **Restricted Boltzmann Machine** is similar to a Boltzmann machine but lacks connections within the same layer. RBMs are foundational in deep learning, often used as building blocks for deep belief networks. Adapted from (48).

Over seven odd decades, the **protein folding problem** has intrigued, attracted, and flummoxed communities of science practitioners (23). Cyrus Levinthal's thought experiment, ca. 1968, highlighted how, if random sampling of all possible conformations were allowed, the folding time would likely exceed the age of the universe. Levinthal's paradox inspired crucial physical explanations (24) alongside vast experimental efforts (25). Yet, a solution to the protein folding problem remained elusive, limiting advancement not just in medicine and therapeutics but in fundamental progress as well.

Though aided in part by the advent of computational techniques, capturing the precisely folded protein state has predominantly been deemed an experimental prerogative. Traditionally, the gold standard was X-ray crystallography, which reported the relative positions (coordinates) of individual protein atoms. Additionally, complementary techniques such as nuclear magnetic resonance (NMR) and low-temperature cryo-electron microscopy (cryo-EM) have offered crucial biological insight (26). Collectively, experimental advances underlie the rapid rise in the number of reported entries in the **protein structural database** (PDB), reaching 0.23 million entries in about three decades (27). It is worth noting that this milestone was achieved with tremendous investment in laboratory resources and human effort. It was realized that sole reliance on experimental methods would not break barriers or induce paradigm shifts in protein structural elucidation.

AlphaFold: Can we Replace the Lab?

Founded as a start-up in 2010, **DeepMind** aimed to transform the field of AI. Led by **Demis Hassabis**, it achieved early success in Deep Reinforced Learning. Taken over by the technology giant Google a few years later, DeepMind's modules were defeating world champions in games such as Go, a Japanese game akin to Chess. Powered by other successes such as the AlphaStar and the Wavenet, DeepMind segued to protein structure prediction in 2020.

Freshly armed with a PhD in theoretical chemistry from the University of Chicago, **John Jumper** joined DeepMind in 2017. Prior to graduate school, Jumper had spent a few years at D.E. Shaw Research, a computational drug development company based in New York. At DeepMind, Hassabis and Jumper assembled a diversely trained team of mathematicians, physicists, chemists, and computer scientists. This team would go on to create an AI tool that could predict protein structure with only the amino acid sequence as input (29). At the Critical Assessment of Protein Structure (or CASP) biennial competition in 2018, this tool was able to best the next entry (from academia) by a long measure. Emboldened, the team then redesigned their neural network architecture to emerge with their now famous tool, **AlphaFold**. The new AI technology not only topped CASP in 2020 but yielded structures virtually identical to those reported via actual experiments. The algorithm, published in 2021 (30), unveiled the era of AI as a potential replacement for human effort in an actual wet lab (31). Later versions of AlphaFold have been empowered for the deduction of protein structures complexed with other molecules of biological significance (32), hugely impacting fields such as drug discovery and therapeutics. Despite some reasonable scepticism (see concluding section), AlphaFold's value stands ratified not just by the Nobel recognition but also by a citation surge at nascency.

Large segments of the human proteome had awaited inspiration, resources, and experimental structural resolution. Soon after the publication of their algorithm, the AlphaFold team quickly moved to deduce a previously unimagined number (exceeding 200 million) of structures based on their known sequence. As of today, this technology has helped fill vast structural gaps within extant genomes, giving rise to an '**AlphaFold database**' (33). Such a leap in structural information is emerging as an important crucible for protein-based therapeutic discovery (34, 35)

Extra-Genomic Design

Protein function is, in large part, enabled by the intricate details of structure. The backbone fold alignment and orientations of the sidechain cooperate to execute precise roles, such as priming molecules and ligands for chemical reactions. De novo protein design is, in some sense, the reverse of the folding problem - the function informs the fold, which in turn dictates the sequence. Importantly, this approach is not limited to sequences found in nature and does not demur from extra-genomic design.

The first artificial sequences were inspired by folds prevalent in natural proteins (36, 37). Early efforts culminated in the design of the first artificial protein, '**Top7**', whose predicted structure was subsequently validated by experiment (38). The main architect, **David Baker**, owed this success to his own computational program, **Rosetta**, released a few years earlier in 1999 (39). While this program did not leverage any machine learning methods, it synchronized available structural data with physics-based methods. In the years following, Baker assembled large teams to progressively predict, design, and validate ranked structural folds capable of executing functions outside those dictated by nature. Unlike the AlphaFold team, the team includes scientists trained in experimental techniques. Today, Baker's Institute for Protein Design iterates between targeting new functions to AI-based algorithm development to design proteins that are not the natural products of evolution (40). Emergent developments through this pipeline include anti-toxins (such as those against snake venom), synthetic receptors, protein-based nanomaterials, and customized vaccines. Baker is also credited with popularizing the protein folding problem via the crowdsourced online tool **Foldit** (41). Based on the original Rosetta, this publicly available computer game offers one the chance to leverage their ingenuity and create unique protein configuration structures with novel functions (42).

Into the Future

In the last decade, artificial intelligence-based technologies have permeated human lives at previously inconceivable levels. The average individual, rural or urban, is exposed to, and at the same time, unknowingly contributes to, ever-expanding data that inform further development. Everyday interfaces include search engines, voice assistants, social media, and guided choices in digital shopping. Somewhat less routinely, people may use AI-assisted genealogy services or rely on AI-assisted diagnostics for acute diseases. Generative AI methods, such as ChatGPT that replicate human responses have generated further excitement.

While the horizons expand, it may be prudent to tread with caution, at least for the time being. While AI aids both knowledge acquisition and application, it appears that the effects may culminate non-uniformly (43). Effects on early exposure and over-usage may modulate the natural receptivity and intelligence of young brains; potential evolutionary consequences may be indeterminable. Blurred lines between reality and artificially generated scenarios may affect finely balanced societal, political, and legal environments. For those in proteomic work, it is important to keep in mind the limitations of tools such as AlphaFold. While quick and efficient and undoubtedly a boon for structural biology and structure-based drug design, AlphaFold is primarily a prediction algorithm that does not inform about the physico-chemical drivers of protein folding (43, 44, 45). Emergent work describes the limitations of this tool for effectively predicting protein folds associated with chemical staples or those with high disorder (see Fig 5).

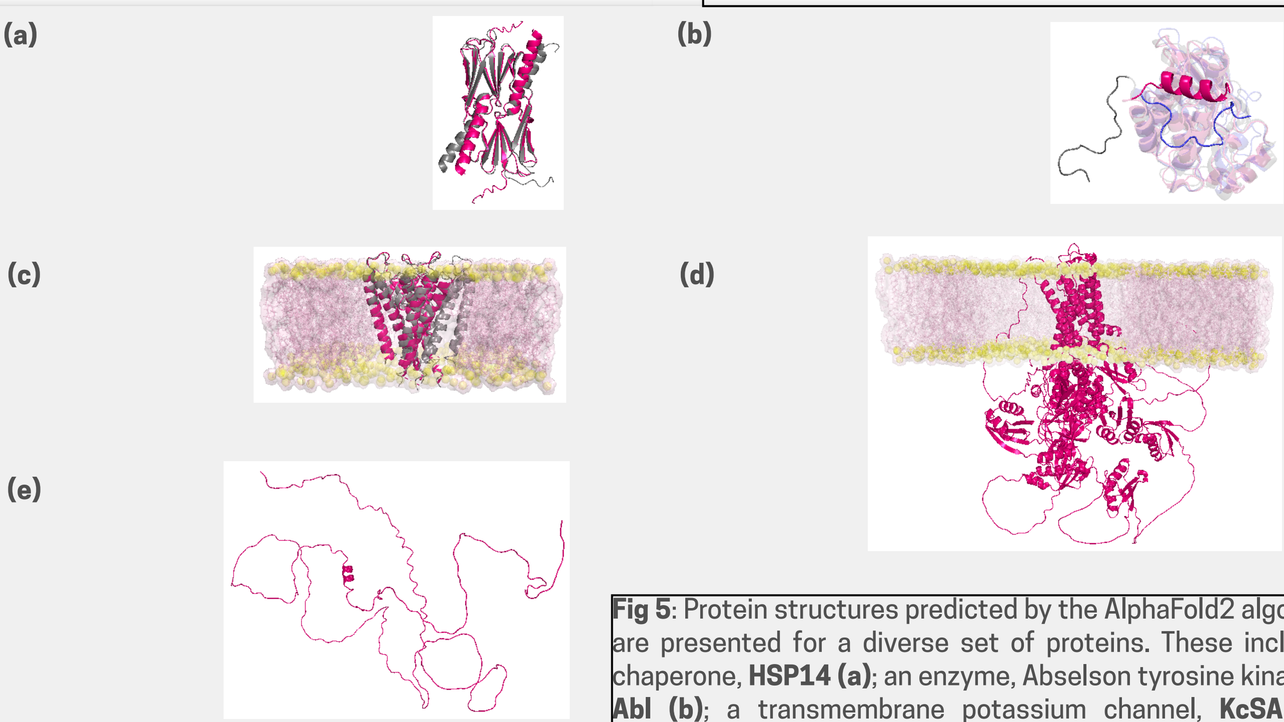

Fig 5: Protein structures predicted by the AlphaFold2 algorithm are presented for a diverse set of proteins. These include a chaperone, **HSP14 (a)**; an enzyme, Abselson tyrosine kinase, or **Abl (b)**; a transmembrane potassium channel, **KcSA (c)**;a transmembrane copper transporter, **ATP7B (d)**; and an intrinsically disordered protein, **DISC1 (e)**. Experimental structures, where available in the protein data bank database, are superimposed in grey. Backbone root mean squared deviations (RMSD, in Å units) are provided. For the transporters, the surrounding cellular membrane bilayer is putatively modeled, and depicted in yellow (lipid headgroups) and pink (aliphatic tails). The inability of AlphaFold2 to predict alternate (polymorphic) structures is demonstrated by the omission of the segment corresponding to the inactive state of Abl (see b; in blue).

Despite purported warnings, the era of artificial intelligence has arrived to thrive. One hopes this era will manifest as an ode to those "who confer the greatest benefit" to humanity."

Postscript.

As of this writing in late January 2025, the large language model-based AI tool, **DeepSeek**, was sending ripples with its seemingly insurmountable capabilities. Operable at far lower computational cost, DeepSeek significantly supersedes its closest competitors (46). DeepSeek's unveiling led to major market upheavals and catapulted AI into yet another paradigm shift.

Prof. Sengupta is a strong proponent of interdisciplinary and collaborative research. Her group at IISER Kolkata (mCED) probes molecular machinations of diverse biological systems with physics and data based methods.

Discussions with mCED research group members, and critical feedback from Dr. Kumar Vanka (CSIR-NCL, Pune) is acknowledged. Abhirup Mukherjee and Pousukhi Bagchi are credited with Figs 1-4, and with Fig 5, respectively.

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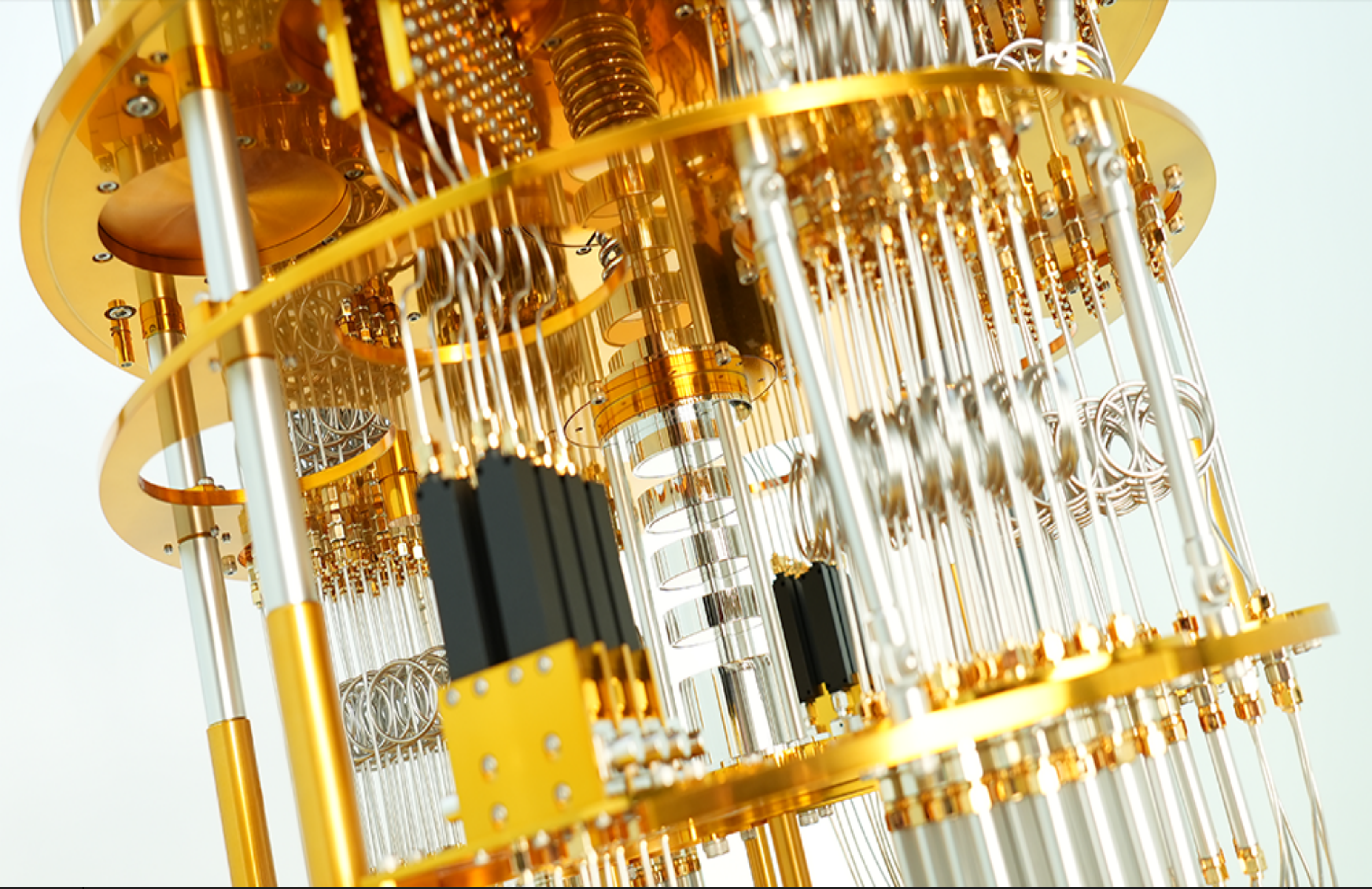

The Quantum Conundrum: Redefining Security in the Quantum Revolution

Shibaraj Sahu (IISER Kolkata)

As quantum computing advances, traditional cryptographic methods face unprecedented threats, particularly from Shor's algorithm, which can efficiently break widely used encryption schemes. This article examines the implications of quantum attacks on classical security protocols and explores emerging quantum-resistant cryptographic techniques. Additionally, it highlights the promise of Quantum Key Distribution (QKD) in enabling theoretically unbreakable encryption. By analyzing both the risks and opportunities, this article provides insight into how the digital security landscape must adapt to the quantum era.

Introduction

In the age of digital communication, encryption is crucial for ensuring the privacy and security of data exchanged over the internet. The advent of quantum computing represents a paradigm shift in computational capabilities, bringing both remarkable opportunities and profound challenges. Among the most affected fields is cryptography, the cornerstone of secure digital communication. This article explores both sides of quantum computing's impact on cryptography, focusing on the vulnerabilities it introduces to classical encryption schemes and the secure possibilities offered by protocols like Quantum Key Distribution (QKD).

Shor's Algorithm and the Threat to Classical Cryptography

At the heart of modern cryptography lie hard mathematical problems, such as integer factorization (used in RSA encryption) and discrete logarithms (used in Elliptic Curve Cryptography, or ECC). These problems are computationally infeasible for classical computers to solve within a reasonable timeframe, providing the security guarantees we rely on for digital communication.

Enter quantum computing, which disrupts this status quo. In 1994, Peter Shor introduced a quantum algorithm capable of efficiently solving these problems. The subsequent section will outline how this algorithm works in the case of RSA encryption.

RSA encryption, named after its creators, Rivest, Shamir, and Adleman, is one of the most widely used public-key cryptosystems. It relies on the difficulty of factoring large composite numbers that are the product of two large prime numbers. Given below is an overview of how the keys are generated in RSA encryption.

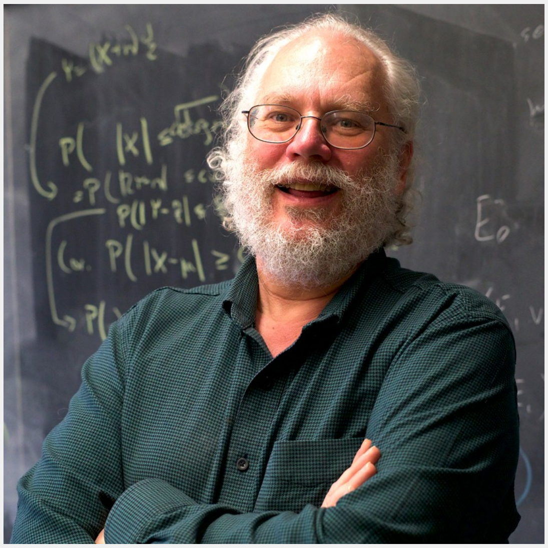

Fig 1: Peter Williston Shor (born 1959), an American theoretical computer scientist and Applied Mathematician, is best known for Shor's Algorithm, which enables quantum computers to factor integers exponentially faster than classical algorithms, posing a challenge to modern cryptography,

Key Generation in RSA:

1. First, choosing two sufficiently large prime numbers, p and q.
2. Computing $N = p \times q$.
3. Calculating $\phi(N) = (p-1)(q-1)$, the *totient of N.
4. Selecting a public exponent e such that $1 < e < \phi(N)$ and $\gcd(e, \phi(N)) = 1$.
5. Computing the private key d as the modular multiplicative inverse of $e \ mod \ \phi(N)$, satisfying $e \cdot d \equiv 1 \ mod \ \phi(N)$

*(The totient of N counts all integers upto N that do not share any prime factors with N)

RSA encryption allows anyone to encrypt a message using the recipient's public key (N, e). The ciphertext c is computed as $c = m^e \ mod \ N$, where m is the message. Decrypting the ciphertext requires the private key d, which is computationally infeasible to derive without factoring N, ensuring security. For sufficiently large N (e.g., 2048 bits), classical algorithms cannot factorize N within a practical timeframe. To give a rough estimate, one of the best-known classical algorithms for integer factorization, the General Number Field Sieve (GNFS), with a sub-exponential time complexity (faster than polynomial time but slower than exponential) could factor a 795-bit number in about two years using huge computational resources. This gives a rough idea of the arduous task classical decryption has to face.

How Shor's Algorithm Breaks RSA?

Shor's algorithm revolutionizes the factoring problem by providing an efficient quantum solution. It consists of two main steps:

Reduction to Period Finding:

- Given $N = p \times q$ and a random integer a such that $1 < a < N$, define the function:

$$f(x) = a^x \ mod \ N$$

- The function $f(x)$ is periodic with a period r. Shor's algorithm exploits this periodicity to factor N.

Quantum Period Finding:

- The quantum computer constructs a superposition of states (this will be discussed later) and applies the QuantumFourier Transform (quantum analog of the classical discrete Fourier transform) to determine the period r.

- Once r is found, classical post-processing is used to compute the factors of N. Specifically, if r is even, then:

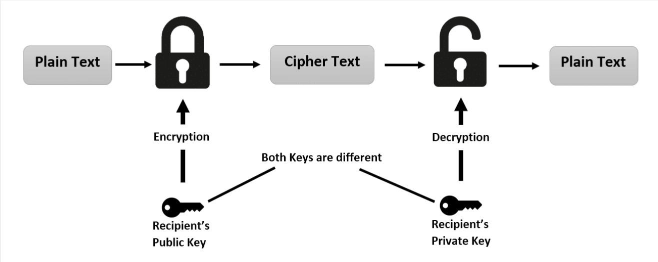

Fig 2: A schematic representation of asymmetric encryption: A sender encrypts plaintext using the recipient's public key, generating ciphertext. Decryption requires the recipient's private key, ensuring secure communication

$$\gcd\left(a^{r/2}-1,N\right) \quad \textit{and} \quad \gcd\left(a^{r/2}+1,N\right)$$

yield the factors of N.

Why Shor's Algorithm is a Game-Changer?

As already mentioned, the best classical algorithms for factoring, such as the General Number Field Sieve, have a sub-exponential time complexity. In contrast, Shor's algorithm has a polynomial time complexity of $O((\log N)^3)$, making it exponentially faster. This efficiency renders RSA insecure against quantum computers capable of running Shor's algorithm.

For example, a 2048-bit RSA key, which is currently considered secure, can be broken in polynomial time with Shor's algorithm once a sufficiently powerful quantum computer is built (one using more than 10 million logical qubits). Though the present day scenario of quantum computing with at most hundreds of noisy qubits do not pose an immediate threat, this imminent vulnerability underscores the urgency of transitioning to quantum-resistant cryptographic systems.

From Breaking Encryption to Securing It

While quantum computing threatens traditional cryptography, it also provides tools for securing communication. Quantum Key Distribution (QKD) is a prime example, offering provably secure key exchange based on quantum mechanics. Before diving into QKD, let us define key quantum terms that will help us understand QKD.

Quantum State and Superposition

In quantum mechanics, the state of a quantum system is described by a *state vector*, or *ket*, denoted by $|\psi\rangle$. For a qubit, the state vector is a linear combination of the basis states $|0\rangle$ and $|1\rangle$, known as the computational basis:

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

where $\alpha, \beta \in \mathbb{C}$ (Field of Complex numbers), and the normalization condition

$$|\alpha|^2 + |\beta|^2 = 1$$

ensures that the total probability of measuring the qubit in one of its basis states is 1.

The coefficients α and β represent the probability amplitudes of measuring the qubit in the states $|0\rangle$ and $|1\rangle$, respectively. The probabilities of measuring $|0\rangle$ and $|1\rangle$ are given by $|\alpha|^2$ and $|\beta|^2$, respectively. This phenomenon of a qubit being in a superposition of both $|0\rangle$ and $|1\rangle$ until measured is known as quantum *superposition*.

Quantum Entanglement

Quantum entanglement refers to the phenomenon where two or more quantum particles become "linked", such that the state of one particle is immediately correlated with the state of the other(s). If two qubits are entangled, measuring one qubit instantly provides information about the state of the other.

Consider an entangled state, commonly known as a Bell state:

$$|\Phi^+\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$$

If one qubit in the pair is measured to be $|0\rangle$, the other will necessarily be in the state $|0\rangle$, and similarly for $|1\rangle$. This apparent "non-locality" by no means hints at faster-than-light information transfer, which is still a local phenomenon.

Quantum Measurement

The act of measurement in quantum mechanics collapses the quantum state into one of its eigenstates, with the probability of each outcome determined by the square of the coefficient of the corresponding eigenstate. If a qubit is in a superposition $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$, a measurement of the qubit will yield $|0\rangle$ with probability $|\alpha|^2$ and $|1\rangle$ with probability $|\beta|^2$.

Quantum Key Distribution (QKD)

Quantum Key Distribution (QKD) involves transmitting information using quantum states, to ensure that any eavesdropping is immediately detectable. QKD utilizes the principles of quantum mechanics to allow two parties to securely exchange cryptographic keys. The most well-known QKD protocol is the *BB84 protocol*, developed by Charles Bennett and Gilles Brassard in 1984.

Let Alice and Bob be the two individuals who wish to securely share a secret key over an insecure channel with BB84 protocol. The protocol is based on the idea that quantum measurement disturbs quantum states, and this disturbance can be detected. Let us now examine how Alice can securely transmit information to Bob with this protocol.

Step 1

Alice prepares a sequence of *n* qubits, each randomly chosen from one of the two bases:

- **Computational Basis:** $|0\rangle, |1\rangle$
- **Diagonal Basis:** $|+\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$, $|-\rangle = \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle)$

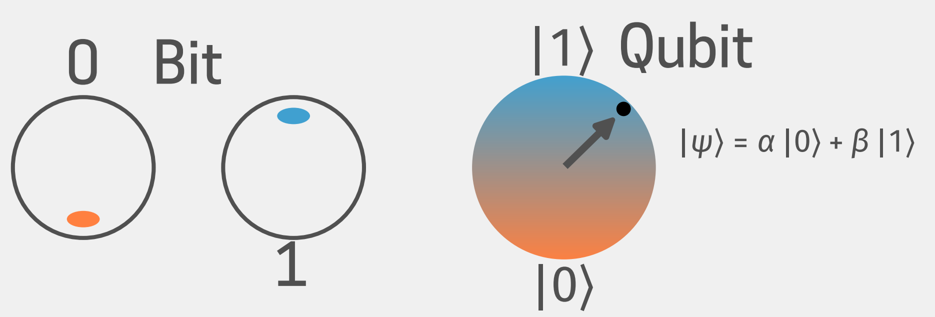

Fig 3. A comparison between classical bits and quantum bits (qubits). Classical bits exist in definite states (0 or 1), while qubits can exist in a superposition of both states, represented on the Bloch sphere as $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$ where α and β are complex probability amplitudes.

Each qubit encodes a classical bit $b \in \{0,1\}$, with the following mappings:

$$b = 0 \implies |0\rangle or |+\rangle, \quad b = 1 \implies |1\rangle or |-\rangle$$

Alice records both the bit value b and the chosen basis for each qubit.

Step 2
Alice sends the sequence of n qubits to Bob over a quantum channel. The qubits are transmitted in the chosen basis, but the basis itself is not revealed to Bob.

Step 3
Bob measures each received qubit in a randomly chosen basis (computational or diagonal). If Bob's measurement basis matches Alice's preparation basis, the measurement outcome will correctly match Alice's encoded bit. Otherwise, the outcome is random due to the incompatibility of the bases.

Step 4
After the transmission and measurement steps, Alice and Bob publicly announce the bases they used for each qubit (but not the actual measurement outcomes or encoded bits). They discard all qubits where their bases do not match. The remaining qubits form the shared raw key.

Eavesdropping Detection
If an eavesdropper, Eve, intercepts the qubits, she will be forced to measure the qubits in a random basis. Due to the principles of quantum measurement, Eve's measurements will disturb the quantum states, introducing errors into the transmitted key.

To detect eavesdropping, Alice and Bob compare a randomly selected portion of the raw key. If the error rate exceeds a predefined threshold ϵ, they abort the protocol, assuming that an eavesdropper (Eve) was present.

Security of QKD
The security of QKD relies on two of these important quantum principles:

No-Cloning Theorem
The *no-cloning theorem* states that it is impossible to create an identical copy of an unknown quantum state. This ensures that any attempt to intercept the qubits and measure them will necessarily disturb the quantum state, revealing the presence of the eavesdropper.

Heisenberg Uncertainty Principle
The Heisenberg uncertainty principle asserts that certain pairs of physical quantities, such as position and momentum, cannot be precisely measured simultaneously. For QKD, this principle ensures that any attempt by Eve to measure the quantum states of the qubits will cause uncertainty and thus, an error in the measurement, thereby disturbing the qubits and alerting Alice and Bob to the eavesdropping.

Balancing Risks and Rewards
The rise of quantum computing necessitates a paradigm shift in cryptography. While algorithms like Shor's threaten traditional cryptographic systems, QKD protocols like BB84 exemplify the potential of quantum mechanics to safeguard communication. The developments in quantum computing challenges us to innovate, ensuring that the promise of this technology is harnessed securely and responsibly.

As we stand on the brink of the second quantum revolution, the interplay between threat and solution in cryptography is a testament to the dual nature of technological progress-both a challenge and an opportunity.

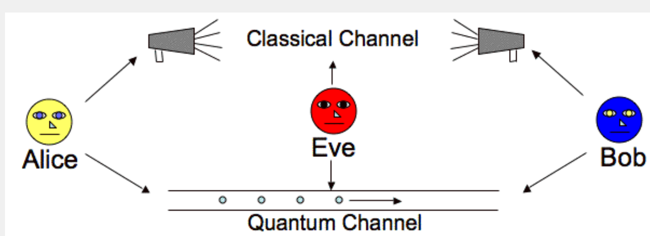

Fig 4. A Quantum Key Distribution (QKD) model where Alice and Bob exchange a cryptographic key using both a classical public channel and a quantum communication channel. An eavesdropper, Eve, attempts to intercept the key, but quantum principles ensure any intrusion is detectable. (See [7])

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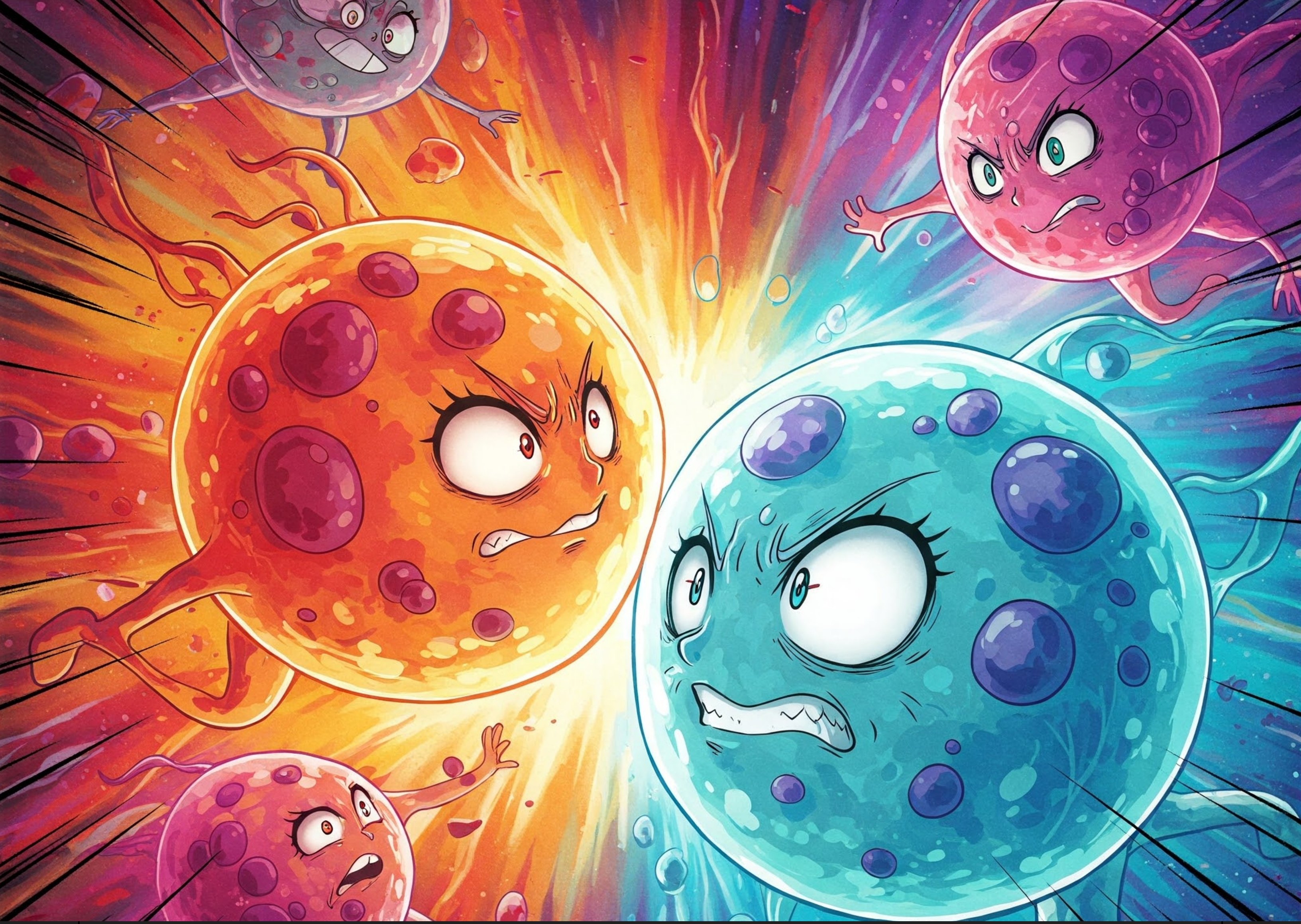
A second year undergraduate at IISER Kolkata with passion for Physics, Mathematics and History of Science. **Shibaraj Sahu** is particularly interested in Quantum Information Theory, Mathematical Physics and effective science communication.



Adaptation of Living Cells to Mechanical Forces

Suman Halder (IISER Kolkata)

Mechanical forces play a crucial role in regulating cellular processes like growth, migration, and tissue repair. Cells actively sense their mechanical environment by forming dynamic adhesion sites called focal adhesions at the cell-matrix interface. These specialized structures act as mechanosensors, converting physical cues into biochemical signals that guide cellular behavior. This article explores how focal adhesions enable cells to probe their surroundings and respond to mechanical stimuli.

Cells are the building blocks of life, carrying out essential functions to keep organisms alive. To function properly, cells must constantly sense and respond to their environment. While biochemical signals like hormones and nutrients are well known for influencing cell behavior, mechanical forces also play a crucial role in regulating how cells grow, move, and function [1]. Cells experience various types of mechanical forces, including tension, compression, and shear stress. These forces come from their surroundings, such as the stiffness of the tissues they reside in or the physical pressure exerted by neighboring cells. Mechanical signals help shape tissues during development, guide wound healing, and even influence diseases like cancer and fibrosis. For example, changes in tissue stiffness can control how stem cells develop into different types of cells, determining whether they become bone, muscle, or fat [2]. Similarly, abnormal mechanical forces can drive cancer progression by altering cell signaling and promoting uncontrolled growth [3].

Understanding how cells respond to mechanical forces is critical for many fields, including regenerative medicine, bioengineering, and cancer research. By studying the mechanical aspects of cell behavior, scientists can design better biomaterials, develop new therapeutic approaches, and improve medical treatments. Integrating mechanics into cell biology provides a more complete picture of how cells function and adapt to their environment, leading to advancements in both basic research and clinical applications.

How Do Cells Sense Mechanical Signals?

Cells are constantly sensing and interacting with their environment. They respond to a variety of external signals by adjusting their internal processes. One key way cells communicate with their surroundings is through specialized structures called focal adhesions (FAs). These adhesion sites connect the cell to the extracellular matrix (ECM), allowing mechanical and biochemical signals to be transmitted.

Focal adhesions are protein structures that connect cells to the extracellular matrix. Cytoskeleton, the cell's internal framework, is a structural network composed of actin filaments, microtubules, and intermediate filaments, which help maintain the cell’s shape and stability. Among these, actin stress fibers are particularly important for generating mechanical forces. These fibers interact with myosin motor proteins, which use chemical energy to produce contractile forces by causing actin filaments to slide past one another.

Focal adhesions play a crucial role in transmitting these contractile forces to the ECM, acting as mechanosensors. This allows cells to physically pull on the matrix and assess its stiffness, as well as detect external mechanical cues. In response, cells adjust their behavior by modifying internal signaling pathways, ultimately influencing functions such as migration, differentiation, and growth.

By probing the rigidity of the ECM, cells can determine whether their environment is suitable for movement, division, or structural changes. This process is essential for many biological functions, including tissue development, wound healing, and disease progression.

How Do Focal Adhesions React to External Mechanical Forces?

Focal adhesions (FAs) are complex, multi-protein structures that connect the cell’s cytoskeleton to the extracellular matrix (ECM), allowing cells to sense and respond to mechanical forces. Unlike physical adhesion, which is a passive process, biological focal adhesions are highly dynamic. Cells actively remodel and reorganize their focal adhesions in response to external mechanical cues. This ability to adapt is crucial for cellular processes such as migration, differentiation, and survival [8].

Focal Adhesion Adaptation to Mechanical Forces

Cells are exposed to various mechanical forces, including stretching, compression, and shear stress. To maintain stability and function, focal adhesions must adjust their size, composition, and activity in response to these forces. Research shows that FAs grow, stabilize, or disassemble depending on the mechanical environment. For instance, when subjected to sustained mechanical forces, FAs enlarge and become more stable, reinforcing the connection between the ECM and the cytoskeleton [4].

Focal adhesions are especially sensitive to time-dependent forces. Their orientation and dynamics change in response to cyclic stretching, which is critical for cells in mechanically active tissues like the heart. Studies indicate that under slow, static, or quasi-static stretch, FAs align along the stretch direction. However, under fast cyclic stretch, they

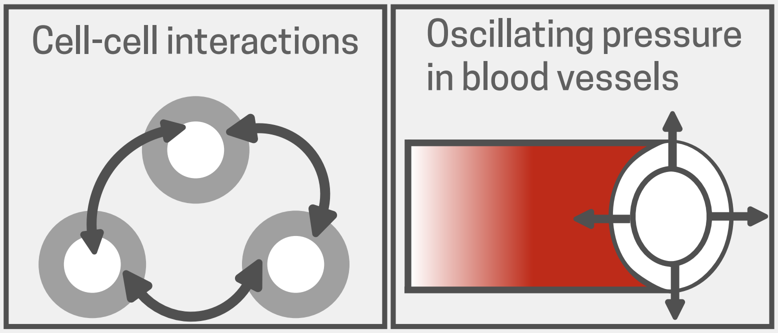


Fig 1. Cells experience different physical forces in their environment, which affect how they behave and function. As an example, this two figures show two types of forces — forces from nearby cells and changing pressure inside blood vessels. These forces help guide cell movement, attachment, and overall response. Adapted from [17].

reorient perpendicularly to the applied force [5]. This behavior helps cells maintain structural integrity in tissues experiencing rhythmic mechanical forces, such as the cardiac and lung tissues.

Molecular Composition and Force Sensitivity

Focal adhesions are composed of multiple proteins, including integrins, talin, vinculin, and paxillin, which link the ECM to the actin cytoskeleton. These proteins work together to translate mechanical forces into biochemical signals—a process known as mechanotransduction [10]. Experimental studies have demonstrated that FA components are highly force-sensitive, and their assembly and disassembly are influenced by ECM rigidity and external mechanical forces [9].

When force is applied to FA-associated proteins, it can alter the energy landscape of molecular interactions, effectively switching binding states on or off. This process regulates FA stability, influencing cell migration and adhesion strength. For example, when the ECM is stiff, focal adhesions become larger and more stable, reinforcing the cell's attachment to its environment. Conversely, on soft matrices, FAs remain small and transient, allowing greater cellular movement [2].

The Role of Catch Bonds in Force-Dependent Adhesion

One of the most intriguing aspects of focal adhesion mechanics is the presence of catch bonds—molecular interactions that become stronger under moderate force but weaken at very high forces. Recent studies have shown that focal adhesions grow in the direction of tensile force, and their stability increases up to a certain force threshold before decreasing [6].

Catch bonds can be intuitively understood by imagining two interlocked hooks. If the hooks are loosely connected, they can easily detach. However, when a pulling force is applied, the hooks interlock more tightly, making them harder to separate. Similarly, mechanical forces induce conformational changes in FA proteins, strengthening their binding interactions. This force-dependent stabilization allows cells to maintain robust adhesion under physiological conditions while still being able to detach when necessary for processes like migration [10].

A theoretical model of Focal adhesion

There is a straightforward theoretical model to explain how focal adhesions (FA) grow, remain stable, and align themselves under both constant (static) and changing (cyclic) stretches. The model combines a novel approach of understanding how stretch influences the formation and breakage of molecular bonds with the elasticity of the cell-substrate system.

Focal adhesions are often modeled as clusters of ligand-receptor bonds, behaving like Hookean elastic springs. Bell's pioneering work applied kinetic theory to describe the stability of these adhesion clusters [11]. In this model, receptors (R) on the cell surface interact with extracellular matrix (ECM) ligands (L) to form ligand-receptor complexes (RL). The chemical kinetics is described as:

$$R + L \underset{K_{world}}{\overset{K_{off}}{\rightleftharpoons}} RL$$

where $\mathbf{K_{on}}$ and $\mathbf{K_{off}}$ denote the total association and total dissociation rate of ligand-receptor bonds.

In Bell's model, slip bonds exhibit an exponential increase in dissociation rate with applied mechanical force, meaning they become weaker as force is applied. This behavior is described by:

$$k_{off} = k_0 e^{f_b/f_0}$$

where k_0 is the natural dissociation rate without force, f_b is the applied bond force, and f_0 is a characteristic force scale (typically in the piconewton range for focal adhesions).

On the other hand, the dissociation rate for catch bonds which get strengthened under force has been proposed as [12, 13]

$$k_{off} = k_{slip} e^{f_b/f_0} + k_{catch} e^{-f_b/f_0}$$

where k_{slip} and k_{catch} denote the rate constants for dissociation of the ligand-receptor pair via a slip pathway promoted by the force and a catch pathway opposed by the force respectively.

The dynamics of FAs are subjected to fluctuations in the

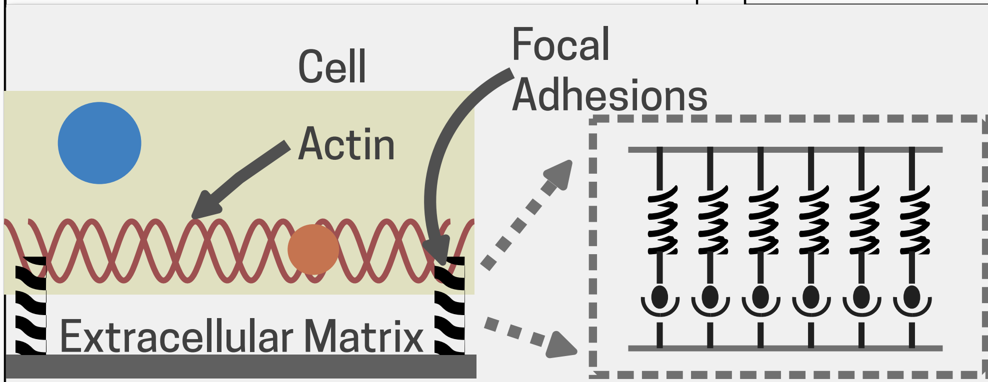


Fig 2. An illustration showing a cell attached to the extracellular matrix (ECM) through two focal adhesions (FAs). A zoomed-in inset (dotted box) highlights the FAs as a collection of ligand-receptor molecular bonds, demonstrating how the cell anchors itself to the ECM. Adapted from [17]

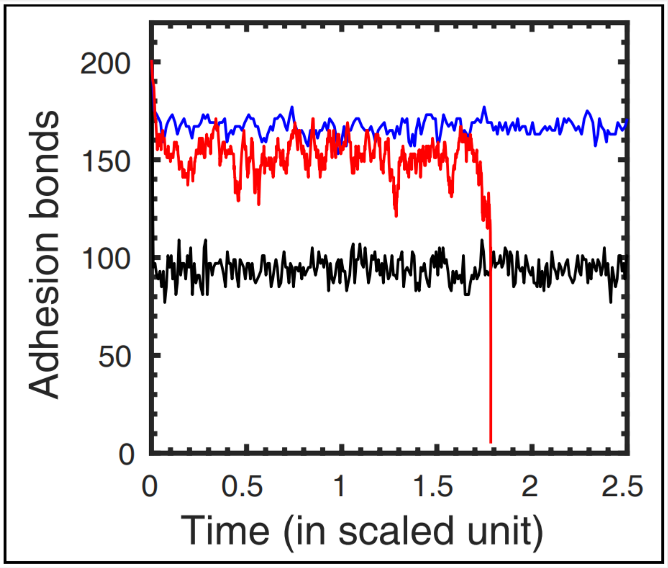


Fig 2. Time evolution of the number of closed bonds in an adhesion cluster under applied force. Stochastic trajectories are generated by simulating the Master equation using representative force values and corresponding reaction rates. Black and blue trajectories indicate stable adhesion clusters, while the red trajectory represents an unstable cluster where all bonds eventually dissociate. Adapted from [17]

surrounding micro-environment. Thus, bonds can also undergo stochastic breaking or rebinding. To study the time evolution of the FA cluster, a master equation has been written by coupling the elasticity of the cell-matrix system with the statistical behavior of bond association and dissociation processes

$$\frac{dP_n}{dt} = K_{on} P_{n-1} + K_{off} P_{n+1} - \left(K_{on} + K_{off}\right) P_n$$

where $P_n(t)$ is the probability that n bonds are formed at time t. The first two terms on the right-hand side represent the gain term, i.e., the tendency for the number of bonds in state n to increase due to the formation of new bonds in state (n − 1) and the dissociation of bonds in state (n + 1), respectively. The last term represents the loss of bonds in state n, whereas K_{on} and K_{off} denote the total association and total dissociation rate of bonds at the respective state, n, at any instant of time t.

Master equation is often solved numerically using the Monte Carlo method. One of the most widely used approaches for this is Gillespie's algorithm [14,15], which efficiently simulates the stochastic dynamics of chemical and biological systems. This method is particularly useful for studying the time-dependent behavior of bond clusters, capturing their formation and dissociation events under fluctuating conditions. By generating statistically accurate trajectories, Gillespie's algorithm provides critical insights into the evolution of bond populations and their response to external forces.

Why this study is important

Cell mechanosensing is essential for detecting and responding to mechanical stimuli in the environment, enabling cells to regulate critical functions such as migration, adhesion, differentiation, and proliferation. This process is vital in tissue development, wound healing, and immune responses, where cells must adapt to varying mechanical forces. Mechanosensing allows cells to interpret physical cues from the extracellular matrix and neighboring cells, influencing gene expression and signaling pathways. Dysregulation of mechanosensing can lead to diseases such as cancer and fibrosis. Understanding how cells sense and respond to forces provides insights into tissue engineering, regenerative medicine, and targeted therapeutic strategies.

Suman Halder a second year PhD student of IISER Kolkata working with Dr. Rumi De. He has some interest in writing essays poems, reading thrillers, photography and in rock music. He is currently working on Cell modelling in mean field limit.

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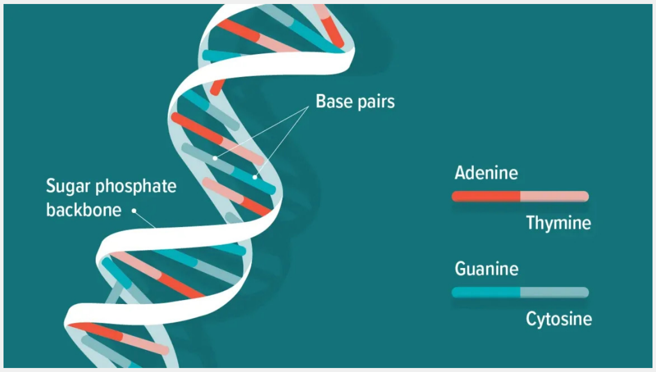
Detection of base-pair mismatch in DNA via graphene nanopores

Sukalyan Deb (IISER Kolkata)

The advent of artificial intelligence (AI) is altering paradigms faster than ever. In hindsight, the 2024 Nobel Prizes in Physics and Chemistry were a recognition of this remarkable phase of human endeavour. This essay attempts to acquaint the general reader to underpinning developments that has led to such a surge. Creative harnesses that facilitated the Nobel recognitions are invoked, along with emergent opportunities and subtle caveats.



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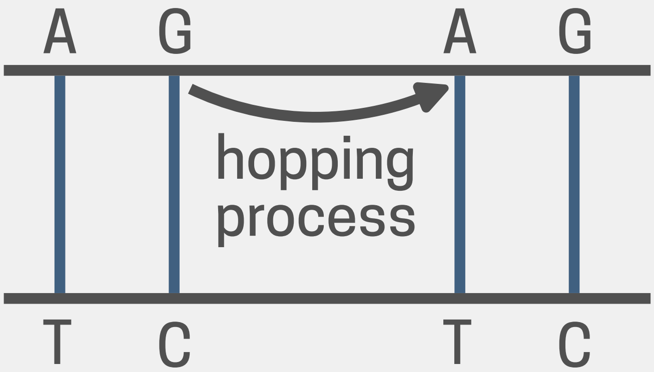


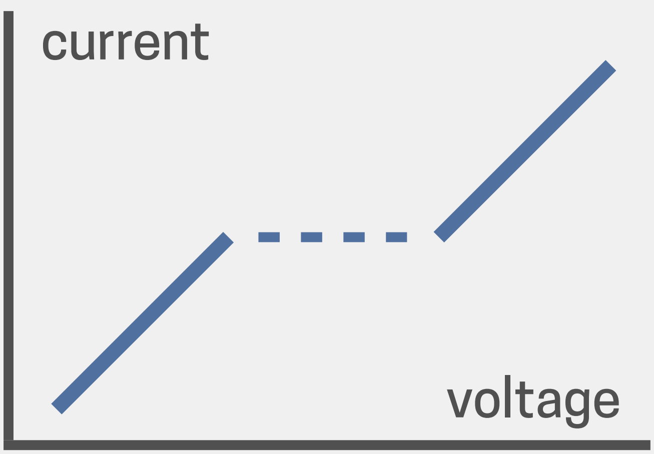
Fig 2. C Caption goes gere.Caption goes gere.Caption goes gere.Caption goes gere.Caption goes gere.Caption goes gere.Caption goes gere.Caption goes gere.Caption goes gere.Caption goes gere.Caption goes gere.Caption goes gere.Caption goes gere.Caption goes gere.aption goes gere.

The field of quantum transport in DNA begins with a fundamental question: “Is DNA a metal, insulator, or semiconductor ?” For the first time in 1961, D.D. Eley, in his paper [4] , studied the current-conducting ability of Penicillium DNA under a certain voltage and he observed a very small departure from Ohm’s law. Eley took the first initiative, paving the way for an entirely new and intriguing area of research, which is now referred to as DNA Nanotechnology.

DNA, the basic building block of life, is composed of four nitrogenous bases (A, T, G and C), forming a double helix with complementary base pairing (A-T, G-C). The two nitrogen bases of a given pair are connected via a hydrogen bond, whereas different bases are connected via covalent bonds that form the two rungs of the double-helix. The sequence of the different bases along the rungs is vital, as it controls different biological processes, e.g., DNA replication, transcription, and protein synthesis in living organisms. When a base pair mismatch occurs during DNA replication, it can lead to faulty protein production, which may result in genetic diseases and cancer. [6]

In 1998, at Delft University of Technology, Cees Dekker and his team conducted a groundbreaking experimental [3] measurement of DNA conductivity. They used double-stranded poly(G)-poly(C) DNA, which is 10.4 nm long and consists of 30 base pairs, placed between platinum-coated electrodes at room temperature. The uniqueness of the experiment lies in the simplicity of both the method used and the idea implemented, as well as the high precision of the results obtained . It was observed that below a certain threshold voltage, the DNA behaved as an insulator, conducting very little current .The I-V response curve revealed non linear behavior, indicating the presence of a bandgap. Interest in this field surged around 2000, marking a significant milestone in bioelectronics.

The theoretical exploration of suitable charge conduction mechanisms through DNA began following these experimental works. Researchers have attempted to understand the underlying physics using methods such as Density Functional Theory or the computationally modest tight-binding model Hamiltonian approach.The most commonly used model is the Dangling Backbone Ladder Model, which represents DNA as a traditional ladder with backbones attached to the outer sides . The Hamiltonian for DNA includes hopping terms along the rungs of the double-helix, following the covalent bonds. “Hopping” refers to the movement of electrons to their nearest neighbors, representing the kinetic energy terms. Experiments revealed that current flows through the **π**-stacked bases along the rungs of the double-helix.



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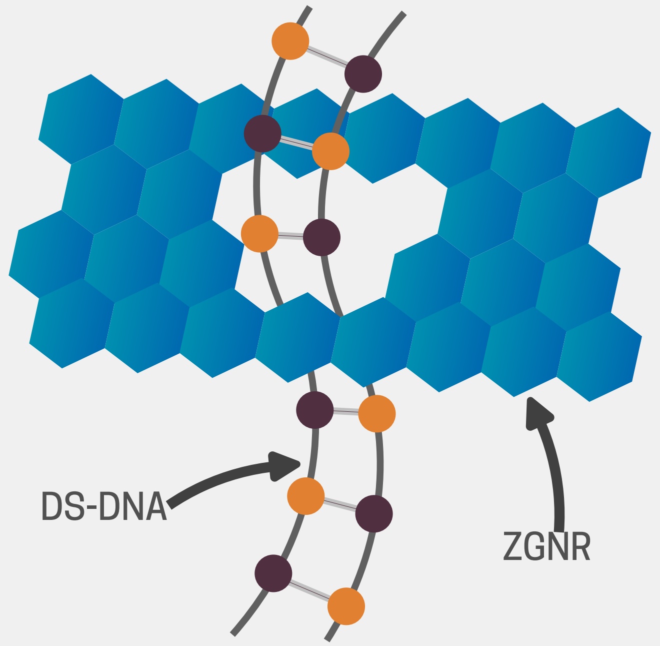

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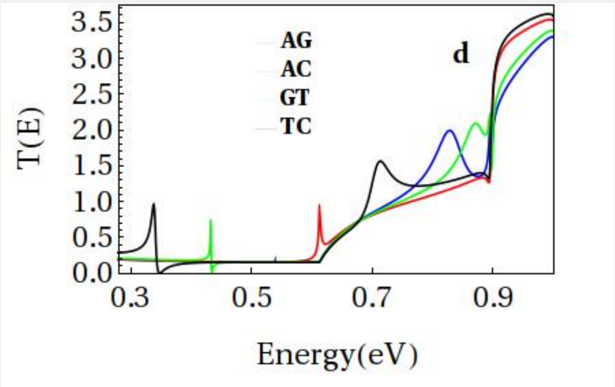

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Sourav and coworkers [1] expanded on the ladder model to mimic double-stranded DNA, aiming to detect base-pair mismatches by incorporating both nearest-neighbor and inter-layer hopping between the nitrogen bases of the two helices in their analysis.

They examined changes in local density of states, conductivity and I-V characteristics by inserting a ds-DNA chain into a graphene nanopore. The traditional technique for the DNA sequencing is the Sanger [5] method, which uses chain-terminating dideoxynucleotides to determine the sequence of a DNA strand. However, its main drawback is that it is a time-consuming process, and sequencing an entire human genome using this method costs around 1,000 USD.The advantage of using graphene nanopores is that it is a unique and more cost-effective technique for DNA sequencing.Their study explores techniques for detecting DNA base-pair mismatches through conductance and I-V response analysis, which revealed distinct patterns.

They successfully identified unique signatures related to base-pair mismatches that can lead to different genetic diseases, offering significant potential to early detection genetic disorder and medical diagnostics. This work could lead to the development of a fast and cost-effective DNA sequencing device.

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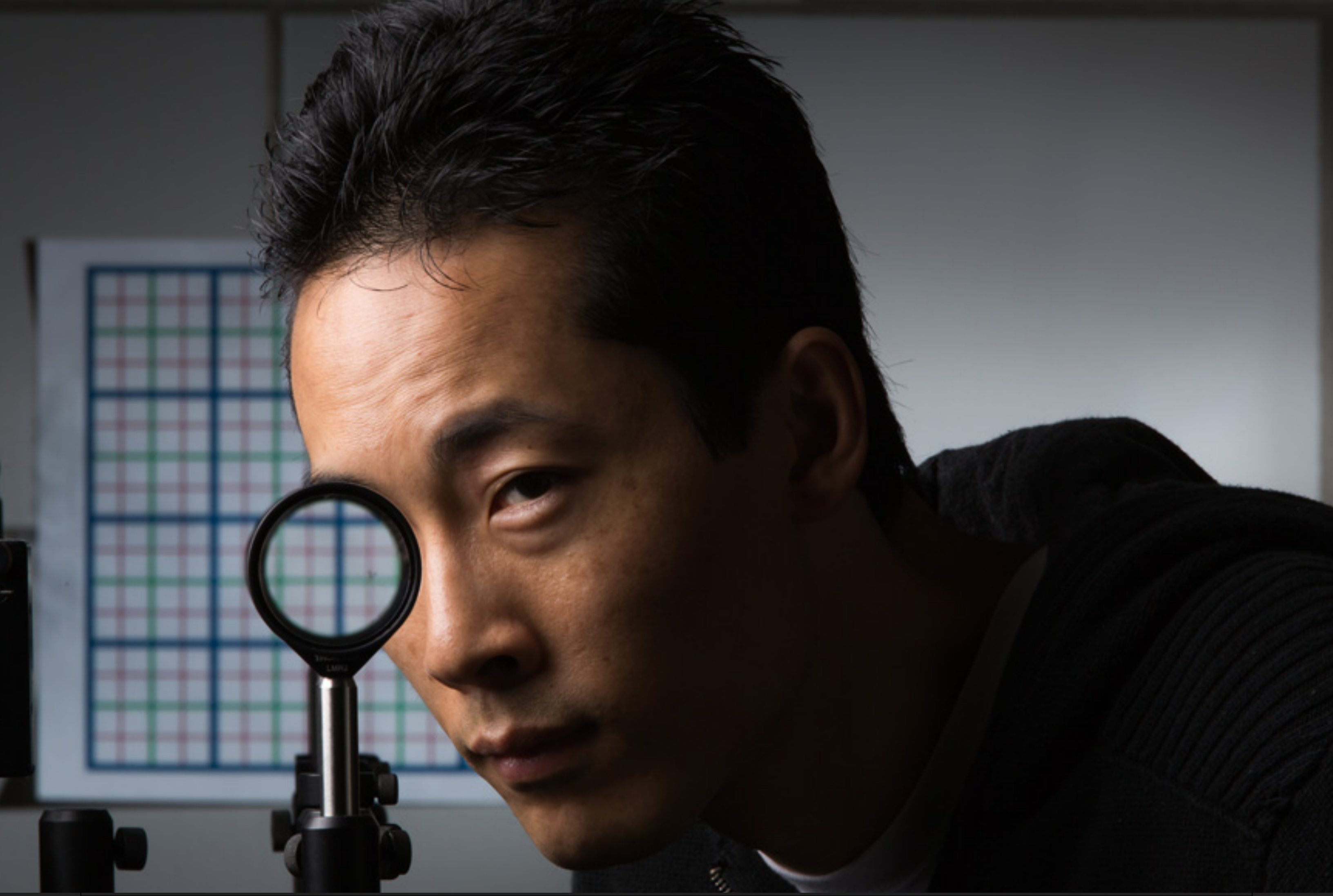
Prof. Sengupta is a strong proponent of interdisciplinary and collaborative research. Her group at IISER Kolkata (mCED) probes molecular machinations of diverse biological systems with physics and data based methods.



Let’s Make An "Invisibility Cloak"!

Swarnendu Saha (IISER Kolkata)

What if invisibility wasn’t just a fantasy but a reality within our grasp? From Harry Potter’s enchanted cloak to high-tech military stealth, the dream of becoming unseen has fascinated us for centuries. Thanks to breakthroughs in metamaterials and transformation optics, scientists are bending light in ways that were once thought impossible—bringing invisibility cloaks out of fiction and into the lab. But while these cloaks can already manipulate microwaves and sound waves, perfecting them for visible light remains a thrilling challenge. As science threads the needle between magic and reality, the question is no longer if invisibility is possible, but when we’ll finally disappear from sight.

Among all the magical things to exist in the Harry Potter universe, the one that captures my imagination the most are invisibility cloaks. While such cloaks are quite common there, such accessories are still just a dream in our world. Nevertheless, there does exist some concrete physics that allows us to get pretty close to making such invisibility cloaks. Let's try to understand this physics, and also come up with a practical setup for it. While the invisibility cloaks in Rowling's universe were either woven from Demiguise hair or borrowed from Death, we will not have to go to such extreme measures, and can make do with some interesting physics.

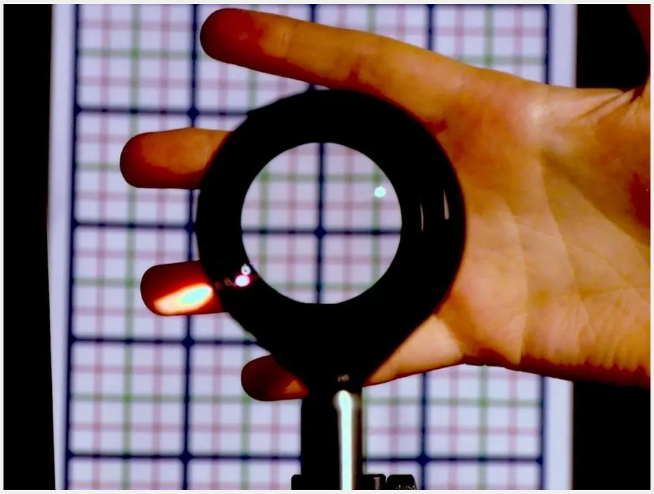


Fig 1. Advances in metamaterials, nanolenses, and transformation optics are paving the way for technology that can bend light around objects, allowing the background to remain visible. This could make it possible for incoming light from any angle and distance to create the illusion of invisibility.
[Image Source: University of Rochester]

Have you ever noticed how objects seem to bend or look like they're floating when placed in water? This fascinating phenomenon, which many of us first learned about in school, is caused by **refraction**. Refraction occurs when light changes direction as it passes from one medium to another—like from air to water—due to a change in its speed. The degree to which light bends depends on a property called the **refractive index** of the material. A higher refractive index means light slows down more and bends to a greater extent. This behavior is governed by a fundamental physics principle known as **Snell's Law**. Snell's Law mathematically relates the angles of incidence (the incoming light) and refraction (the bent light) using the equation:

$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_2}{n_1}$$

where θ_i and θ_r are the angles of incidence and refraction, and n_1 and n_2 are the refractive indices of the two media.

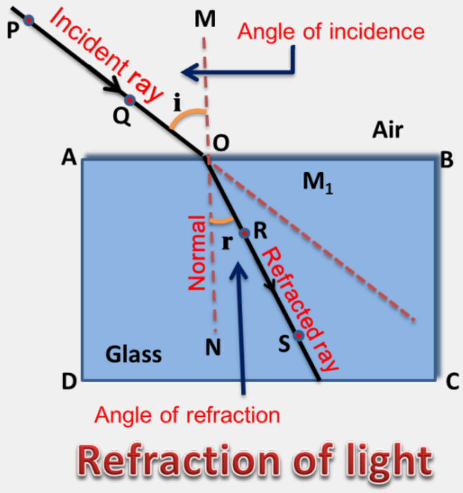


Fig 2: Schematic representation of refraction when light passes from air into water. The light bends towards the normal as it enters the surface of water; the ratio of the sines of the incident angle i and the refracted angle r is given by the ratio of the refractive indices of the two media. The red dotted line is followed by our eye when light coming from water into air reaches it; the end of the dotted line is the location of the virtual image.
[Credit: K.Venkataramana]

When light enters air from water, it bends away from the normal (a line perpendicular to the surface) because water has a higher refractive index than air. When the refracted light reaches us, our eyes extrapolate the refracted light straight backwards. This extrapolated position of the image is offset from the actual position, because of the bending, creating an apparent shift in the position of objects, **forming a virtual image within the denser medium** (e.g., water).

Imagine an extreme case of this, where the angle of refraction θ_r becomes greater than 180°; the virtual image will then be generated **outside the water**. This is somewhat similar to total internal reflection, where light reflects entirely within the water, and nothing is refracted. For the virtual image to occur outside the water, the refractive index itself has to be negative. How, if at all, is that even possible? This is where metamaterials come into the picture.

Metamaterials are not natural substances. Their properties have been **modified with grids**; a grid refers to a structured arrangement or pattern of small artificial components or units (often called meta-atoms) that are engineered to manipulate electromagnetic waves, such as light. The grid can take forms such as a lattice, periodic arrangement, or irregular structures. These are often composed of materials like metals or dielectrics. The spacing between the elements in the grid is **smaller than the wavelength of the light**. This enables precise control over the interaction

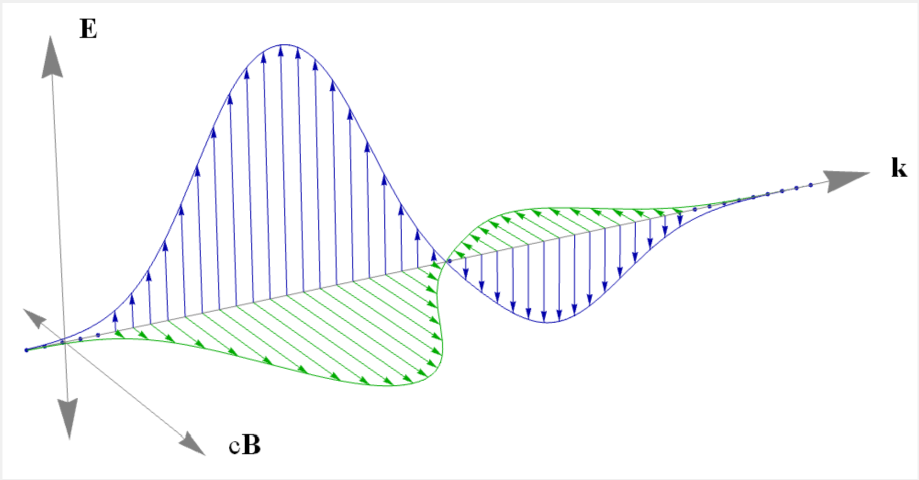


Fig 3. Propagation of light through a material involves the simultaneous oscillation of electric field (blue) and magnetic field (green). The propagation is affected by the properties of the material such as the permittivity and permeability. [Credit: Marko Petek]

between light and the material.

Light propagates through any material in the form of an electromagnetic wave, consisting of **simultaneous oscillations** of electric and magnetic fields. The speed and direction of propagation of these fields are determined, respectively, by the permittivity (ε) and the permeability (μ) of the material. Together, they also determine the refractive index of the material, through the relation:

$$n^2 = \varepsilon\mu$$

In 1968, Russian physicist Victor Vaselago showed that for materials in which both the permittivity and permeability are negative, it makes sense to **treat the refractive index to be negative**, by identifying $n = -\sqrt{\varepsilon\mu}$ instead of the positive root. Why is this important for invisibility cloaks? Well, for an object to be visible, light reflected from the object must reach the eye of the observer. If an object is covered by a metamaterial with a negative refractive index, the virtual image coming from the object will be produced outside the body of the object and it **will not reach the eye of any observer**. Without any reflected light reaching the eye, the object will be practically invisible for the observer. It was about 30 years after Vaselago's work that metamaterials could be produced, though with several limitations.

Metamaterials, and How They Manipulate Electromagnetic Waves

In 2006, David Smith from Duke University advanced a concept initially proposed by British physicist John Pendry by developing a metamaterial to **manipulate microwave energy**. The paper "Controlling Electromagnetic Fields," authored by Pendry, Schurig, and Smith and published in Science in 2006, presents a groundbreaking design strategy for manipulating electromagnetic fields using artificially engineered metamaterials. By carefully designing the components' shape, size, and arrangement in these metamaterials, the authors show that **it is possible to guide, bend, and reshape electromagnetic fields**, achieving highly controlled propagation paths. This approach enables the redirection of electromagnetic energy around objects, avoiding scattering and absorption, and opens the door to innovative technologies that challenge traditional limitations of wave behavior.

The 2006 paper "Metamaterial Electromagnetic Cloak at Microwave Frequencies" by Smith and co-workers presents the **first experimental demonstration** of a metamaterial-based cloak designed to render objects invisible to microwave radiation. Smith's innovation involved a fabric composed of concentric rings embedded with electronic microwave manipulators. When activated, this metamaterial can redirect microwaves around its central area, effectively **preventing the waves from interacting with any object placed within that area**.

While humans cannot see microwaves, this technology demonstrated a key principle: energy waves can be guided around an object. The experimental evidence confirmed the theoretical predictions and demonstrated the feasibility of using metamaterials for cloaking applications. The work showcased the potential for such technology, revealing a path toward developing advanced forms of invisibility by tailoring these principles to various types of waves.

The Bridge To Optical Wavelengths

By building on earlier work by Vladimir Shalaev from Purdue University, Igor Smolyaninov from the University of Maryland made some impressive advancements in the quest for invisibility in 2007. The paper "Negative Index of Refraction in Optical Metamaterials" by Shalaev et al. presented a significant advancement in the field of metamaterials by demonstrating a material with a negative refractive index at **optical communication wavelengths**. Using this work, Smolyaninov and co-workers achieved experimental realization of a non-magnetic electromagnetic cloak operating in the visible spectrum. This amazing cloak is only 10 micrometers wide and is made of concentric gold rings that are infused with polarized cyan light. These rings help to steer incoming light waves around the hidden object,

effectively making it disappear.

Meanwhile, researchers in China at Wuhan University are exploring a similar idea with sound waves, proposing an acoustic invisibility cloak that can redirect sound around an object.

However, these metamaterial cloaks do have some limitations. **They're really tiny and only function in two dimensions**, making them unsuitable for use in our three-dimensional world. Also, the cloaks tend to be too heavy and cannot be carried around for personal purposes, but are more suitable for hiding stationary objects like buildings or military vehicles.

Enter Metalenses

Metalenses are an innovative alternative to traditional lenses, **overcoming the "rainbow" effect**, where different colours of light slow down at different rates, by using tiny structures that focus all colours to the same point. Unlike conventional lenses, metalenses are ultra-thin, easy to manufacture, and more efficient at handling different wavelengths.

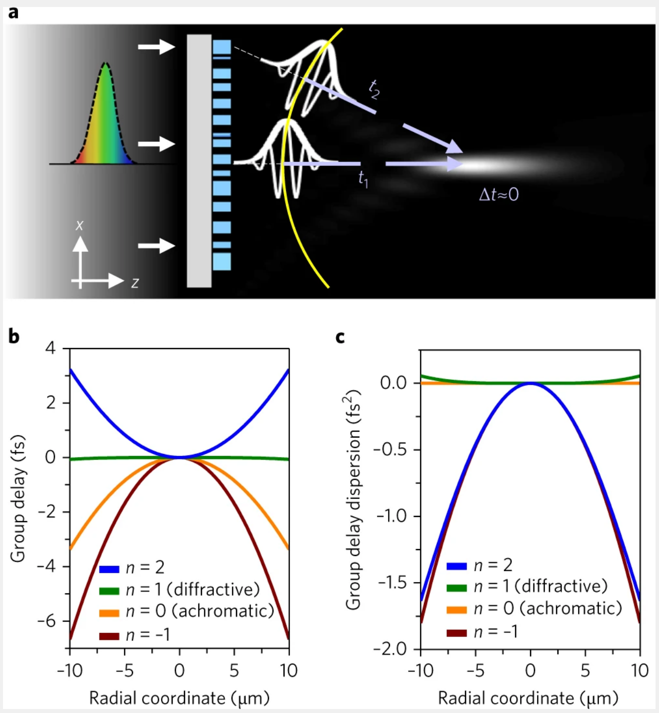


Fig 4. Top panel: Through the power of a metalens, incoming light from across the spectrum along a wide area can be focused down to a point. If that light can be bent around an object, de-focused, and sent off in its initial direction, we would have an actual invisibility cloak.

Bottom panels: The metalens is designed to provide spatially dependent group delays such that wavepackets from different locations arrive simultaneously at the focus.
See [5]

In 2018, Chen and co-workers discovered that by using tiny titanium "nanofins," metalenses can focus light across a broad range of colours, nearly eliminating the colour distortion problem.

How Optical Camouflage Makes You (Almost) Invisible

Since it is not yet possible for metamaterials to operate in the visible range, we will instead adopt a different technique to achieve invisibility. It involves using a coat made from a "magic fabric" referred to as **retro-reflective material**. The coat is made of tiny glass beads; when light hits these beads, it bounces right back to where it came from. This makes the fabric super bright at night and helps it reflect whatever's behind it.

The setup involves the following components:

Video Camera: This camera sits behind you, capturing the scene that's behind the cloak.

Computer: The computer takes that camera feed and adjusts it so it looks just right when projected onto the cloak.

Projector: The projector then beams this adjusted image onto the cloak. There's a tiny pinhole that helps keep the image sharp.

Combiner: This is a special mirror that reflects the image onto the cloak and lets the light bounce off the cloak go through to your eyes.

Here's how the magic happens:

Step 1. The camera films what's behind you and passes the image/video to a computer. This is necessary to replace the image of the person with that of the background.

Step 2. The computer tweaks the footage so it fits perfectly with your cloak. This might involve making adjustments so that the distances and angles are accounted for. The processed data is passed to a projector.

Step 3. The projector shines this adjusted image/video onto the combiner through a tiny hole.

Step 4. The combiner mirror sends the image onto the cloak. The cloak acts as a screen and reflects the light back, passed through by the combiner so that you can still see the surroundings.

Ultimately, the cloak makes you look invisible because it **shows the background scene right on the fabric** while etting the real-world light reach your eyes. So, while you're not precisely disappearing, you're blending in pretty darn well!

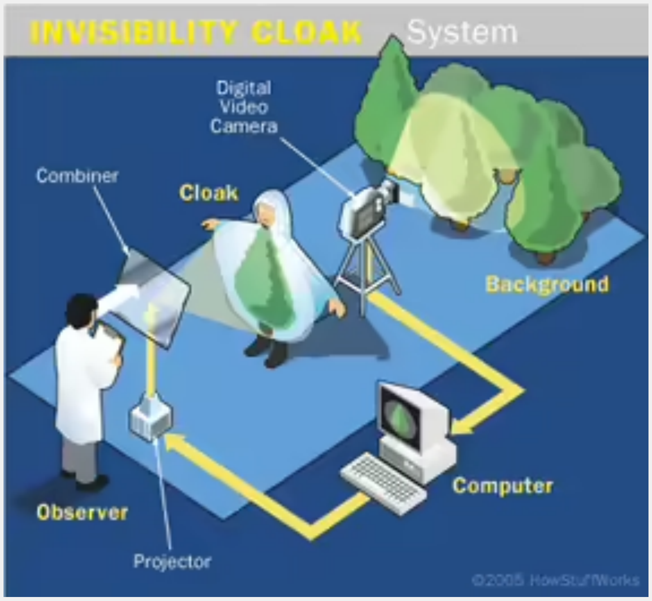


Fig 5. Schematic representation of the invisibility setup. The background is captured by the camera and processed by the computer. This data is fed into the projector before being sent into the combiner and ultimately broadcast onto the cloak. The cloak returns the light back to the observer, effectively replacing the image of the target person with that of the background in the eye of the observer.
See [7]

[redacted]

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A fifth year BS-MS student of IISER Kolkata, **Swarnendu Saha** is a student working with Prof. Rajesh Kumble Nayak, and is a travel enthusiast, who loves to travel anywhere below the sky. Instead of mentioning his preferred fields in science, he would rather say that chemistry is the one he doesn't like at all!

In Conversation with IISER Alumni Srijita Ray

Swarnendu Saha, Aritra Das (IISER Kolkata)

Srijita Ray's path from IISER Kolkata to a PhD at the Australian National University was anything but conventional. Initially drawn to chemistry, she found her true passion in earth sciences, leading her to one of the world's top experimental petrology labs. Now set to join Rice University as a postdoc, she aims to bridge academia and industry in critical mineral research. Her journey proves that stepping beyond traditional choices can open doors to incredible opportunities. For students at IISER, her story is an inspiring reminder to explore fearlessly and follow curiosity wherever it leads.

SS: Hello. Didi. So, you have had a remarkable journey, I believe, in IISER, Kolkata.

SR: Yes.

AD: So, you are 15 MS.

SR: No, I am 14 MS.

AD: 14 MS! So, you graduated here in 2019. That means when you just graduated, the 19MS batch of BSMS first entered IISER Kolkata.

SR: Yes.

SS: I believe the IISER Kolkata campus was not here back then as it stands now. Right?

SR: When I started my journey at IISER, Nivedita Hostel wasn't there yet. However, the LHC was! In fact, during our first year, construction for the LHC had just begun.

So, as you all know, we did our classes at Lecture Hall 4, the great LH4. The upstairs canteen is now located there.

SS: Mess, as we call it, today.

AD: Can you walk us through the progression of the facilities during your time at university?

SR: Sure! Most of our classes were held at the LHC in our second year. By the time we reached our fourth or fifth year, the RC was ready, but the TRC was still under construction. So, for a while, the RC and LHC were quite similar regarding available facilities, but the TRC wasn't yet in the picture.

Fig 1. Fig.1 Monazite crystal from SiO2- Srijita Ray worked on this crystal.

Fig 2. : Old campus of Indian Institute Of Science and Educational Research ,Kolkata back in 2014 .

AD: So, just to clarify, the RC was up and running, but the TRC wasn't available yet?

SR: Yes, exactly. The RC was available, but the TRC wasn't. It can be tricky sometimes to remember the exact timeline, especially after all these years, but that's how it unfolded.
SS: When you first came to IISER, did you think you would go towards earth sciences or petrology?

SR: No, no, not at all. Initially, I thought I would choose chemistry. Before coming to IISER, I had attended another college for about a month. The curriculum had already started there, and I had enrolled as a chemistry student. So, when I shifted to IISER after being selected, I thought I would also continue studying chemistry here.

But as you know, in our first year, we have to study all the subjects. All the subjects. That is true for you guys as well, I believe. So, after that time, I was introduced to Earth Science and I liked the subject. But, still, I was confused.

So, in the second year, I took Chemistry and Earth Science. And then, in the third year onwards, I chose to.

AD: So, did you have ECB as your premajor?

SR: No, not ECB. PCE. Physics, Chemistry, and Earth Science.

SS: The same goes as well as for my roommate. But he is now in Physics.

AD: So, what fascinated you about petrology? And, Petrology is associated with petroleum... ?

SR: No, no, petro means rocks. It is associated with rocks, and the formation of rocks. Not anyway related with Indian Oil and Bharat Petroleum.

AD: No, not that. What I meant is, that is the norm we think about and come across.

SR: So, It is actually difficult to say and pinpoint any particular reason. I think the way teachers taught us and the books, those things were, I mean, I really enjoyed reading the books or the classes were very like, what should I say, very good. Interesting.

SS: So, in those days, did you have SDG?

SR: No.

SS: You did not have him?

SR: No. So, we studied petrology under Tapobrata Sir.

SS: Tapobrata Sarkar.

SR: Yes, and I think Somnath Dasgupta, sir, came when I was

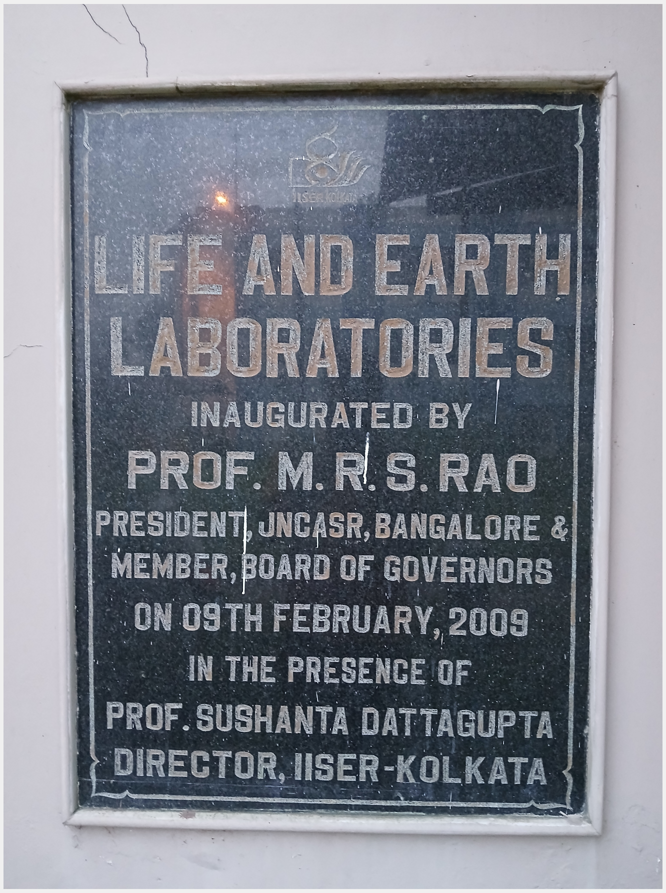


Fig 3. Earth Sciences Laboratory, where Srijita Ray worked at IISER Kolkata .

Fig 4.Srijita Ray with Prof. Tapabrato Sarkar and collegues

doing my master's thesis. Before that, he was the Vice-Chancellor at Assam University in Silchar.

SS: So, after leaving IISER, where have you been? Where did you pursue your PhD?

SR: I pursued my PhD at the Australia National University in Canberra, Australia.

And there I finished my PhD this year very recently.

SS: So, normally, I mean, from where my partner Aritra and I stand, we see, the main target is either the USA or Europe. We both are from the Department of Physical Sciences.

I mean, I am taking the UK in Europe only. So, mainly these two places. Australia National University does come to mind, but it comes mainly for that internship purpose.

But to pursue PhD, I do not think a good chunk thinks of Australia or other places. So, why did you?

SR: Yes, actually, because I was more inclined to the experimental side of petrology.

And, if you know, the experimental petrology labs are not very common. So, in the USA, I think only a few places have experimental petrology labs. And in Australia, actually, ANU has a very big experimental petrology lab.

That’s why, when selecting universities, ANU was one of my top choices, primarily because of the excellent experimental setup there.

SS: So, like Europe, you applied to a professor and got it or like the USA, you applied to an institute?

SR: No. So, like in Europe, I had to email some professors, and they conducted interviews with me. After that, I had to

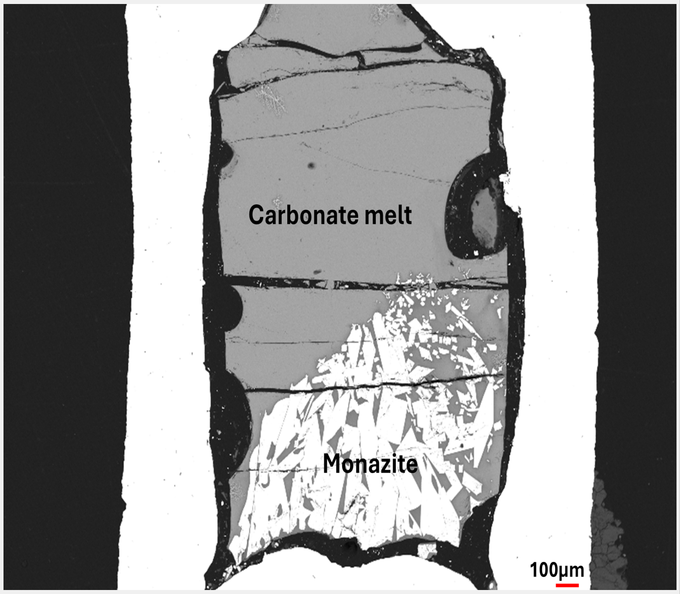


Fig 5. Crystallization of monazite from a SiO2 bearing carbonate melt at 1275 ºC, 20 kbar using piston-cylinder instrument- her phD work

go through the application process and complete all the necessary steps before finally getting selected and enrolment.

SS: So, in your view, how are the Australian academic system and the Indian academic system somewhat similar or somewhat different?

SR: In the Australian academic system, we do not have to do any coursework.

So, directly we would like to enter the research as an RA, or Research Assistant.

AD: So, that is what postdocs do here.

SR: No, no. So, you may have heard that in the USA, when you enter, there is a TAship, and you would be working as a teaching assistant and then later on the student will get the RA, which is basically the research assistant. It is the same here as well.

SS: So, that means that at that time, you are getting the scholarship from the research and not from your teaching.

SR: So, in Australia, directly you will enter the RA, and you will not like to do any teaching courses. So, you did not have to do a TA. It is kind of optional.

As for my case, I did like a little bit of TAship duty, but that was an optional exercise. So, I just did it for my experience. Thus, the question that you asked earlier was how the academic systems in Australia as compared to India.

So, I would say that in Australia, the work-life balance is better.

AD: Better in the sense?

SR: Better in the sense, I mean, maybe for example in Australia, after 5 o'clock or after 4.30, nobody will, or rather should I put this in this way, technically should not send you any official email or communicate. And, in my whole PhD, I never get any kind of official email from either my supervisor or my professor, co-supervisor, or anyone after 5. So, these kinds of things were there.

SS: In India, we all get important mail at midnight. Yes. And we submit our assignments also at 12.

SR: I am not sure about the assignment deadline there because I never submitted that. So, basically, here I did more coursework, and there I did research. So, I would not compare it like that. Actually, it will be difficult for me to compare. Yes. But this is a kind of thing, I think in Europe also this balance is very much maintained, but in the USA, this is not and maybe not in India as much as well.

AD: Yes.

SS: So, did you give any admission interviews in universities other than ANU?

SR: In Australia? No. In Australia, I just gave an interview at ANU.

AD: In other places?

SR: In Europe, I gave, I think, an interview at a university in France, but I forgot the name.

SS: Is there any fundamental difference between the interview process in Europe and Australia?

SR: No. The interview process is very similar. So, in Europe, the principal supervisor and the co-supervisor asked me questions, and that was one round only, and in Australia also the same.

SS: What about the funding sources in Australia? So, the funding source is like a university can fund you, or if a professor has your fund, then that is a wa,y or there is another way like the government you can get funded.

AD: Australian government?

SR: Yes, the Australian government.

SS: And is that a handsome amount or just when you want to sustain yourself?

SR: No, no. Actually, the amount that you will get is sufficient to pay your rent and then like to have food and everything, and after that also you can save some money. So, it is not a very big proble,m and also in Australia, the scholarship is tax-free. So you do not need to pay taxes. So, that is a plus point. That is a boon compared to other places.

SS: If you do not take it personally, I have heard from some teachers, petrology has no such future because petrology is mainly used in places like where the oil industry is very much associated. If you say region it is the Middle East or Russia. If you say company it is Oman oil, Indian Oil ,and similar.. So, in the upcoming 100 years, it is going to be a dead subject.

You, as a new researcher, how do you see this comment?

SR: Well, I think actually I do not fully agree with this one because I mean you know about the renewable energy sources like the critical minerals. So, I mean those are, so it is very important to like to extract those in a cheap and economic way, and right now actually China is the, I mean one of the main suppliers for the overall world. So, basically in order to understand how we can extract those critical minerals and to understand their basic science, we need to understand and we need to go through the petrology.

So, in that way, actually, it is very useful, and I can say, in places like Australia, we do have lots of these rare earth mineral ores, and like many of the petrology labs are now trying to understand how they can extract those ores more cheaply. So, not only China will supply the world with those minerals, but other countries, rich in natural resources, can also take part in the game. For that, knowledge, fundamental research, and the development of technology are the utmost requirements of the time. So, in that way, I do not think that petrology is dying or something.

SS: So, now coming to little away from the academics, we have had COVID-19 and perhaps many of us not have seen the video we have come across a story, an incident where a doctor, student, or scientist is crying, accusing the world of saying. “Now Why don't you ask all the celebrities to fund you or to save you? For society, doing science and fundamental research is a thankless job?”

I mean, have you heard or seen?

SR: No. I have seen that during the COVID. It is not in India, and it is somewhere else.

SS: I mean, where we were all looking towards doctors and scientists for the doctors for the immediate cure to save the lives and scientists for mainly biologists, scientists. Yes, for the medication. For the medication, but then this came up.

So, this kind of situation perhaps does not fall directly on earth scientists, but as a member of that society, it is, again, I mean scientific society, budding researcher. How do you see this? Do you feel that we, as budding researchers, are doing something thankless?

SR: In science, especially when working in basic research, it can be very challenging to communicate your work to those outside the scientific community. People may not immediately see the value of your research and might even think of it as unimportant or insignificant.

However, in science, progress is often made incrementally, step by step. So, if you're doing basic science research—whether in Chemistry, Physics, or Earth Science—it can sometimes feel like a thankless job, especially during your PhD. However, as more people contribute to your work over time, the significance of your research becomes clearer. Eventually, others will recognize that it wasn’t a thankless job but rather part of a gradual, step-by-step process that advances knowledge.

I hope that answers your question.

SS: That is ok. As a part of that question, have you ever felt that it would have been better to pursue engineering than this? I mean, at your age when your friends who have opted for engineering might have found a lucrative job with a high-paying salary.

SR: Honestly, during my PhD, I questioned myself several times—pretty much every day, if not more often. But now, as I'm nearing the end, having submitted my thesis and everything, I feel differently. It seems that what I was doing was the right thing after all.

Regarding the question of freedom or independence, I don’t necessarily see it as having the "upper hand." Still, in academia, there’s a certain autonomy that allows for deeper

Fig 6 . Australia National University in Canberra, University in which Srijita ray pursued her phD.

exploration and understanding. For instance, in engineering, many people pursue a PhD and take on similar challenges, but there's a difference in the kind of work they do compared to those in academia. Engineers working a 9-to-5 job might not have the same opportunity to contribute to the deeper theoretical understanding that comes from academic research.

Another point is that, in academia, there is typically more freedom in terms of time—like vacation flexibility—compared to a corporate job. So, while there are challenges, freedom and independence are valuable aspects of the academic path.

SS: So, in your view or not exactly your view in reality, how does the funding in India and Australia differ?

SR: To be honest, I am not very sure about the Indian funding.

So, for me, it was basically the panel member or the supervisor. So they have already funded the project and where I joined.

So, that's how I was a part of that funded project throughout my PhD. I didn't have to write the proposal and like to bring the funding. So, that's why maybe I was not aware of this funding situation or other things.

SS: See, the fact is that is why I am asking this for the Australian case. Yes your scholarship was tax-free. Scholarship is tax-free in India also, but keeping it as a scholarship, there are other things you have to very much important your funding for your project and all.

And for the last few years, especially after this year, I mean the import duty and GST and whatever added together gave more than 150 percent in India. Are you aware of that?

SR: No.

Fig 7. Srijita Ray with her PhD supervisor (Prof. Greg Yaxley) and some other colleagues.

Fig 9 : Professor Rajdeep Dasgupta under whom Srijita Ray is working currently under in Rice University , Texas.

SS: Ok. So, this is the present scenario. In this way, if the price goes up I mean that is that is the scenario in India I mean after the budget and all. So, how do you see I mean is there any kind of similar scenario in Australia? What is your view on this?

SR: I am not very sure about this topic because I was unaware of the budget or the present situation.

AD: Ok, never mind. Have you ever felt that, despite the changing times, the challenges faced by the scientific community have mainly remained the same—especially when it comes to attacks from various parts of society?

For example, after COVID-19, former U.S. President Donald Trump stated that the United States would no longer be a part of the WHO, claiming that the organization was not acting under his wishes. Similarly, there have been instances where the U.S. has been allowed to violate environmental laws with minimal repercussions, often just paying a small amount of money, as if doing the world a favor. On the other hand, lower- and middle-income countries, especially in the Global South—such as those in Africa and South Asia—don't have the same privileges and often face harsh consequences for similar actions.

In South Asia, countries like India, Pakistan, Bangladesh, and Nepal still experience practices that undermine science and rationality. For example, there are cases of witch-hunting, where people, often women, are accused of being witches and subjected to violence. Malpractices in medicine also persist, with people resorting to quacks and superstitions. Even the practice of alchemy still exists in some places.

Furthermore, institutions like IITs and IISERs often suffer from inadequate funding. And unfortunately, there are still sections of the world that believe in discriminatory practices, such as apartheid, and argue that certain

groups can't become better scientists or contribute to research as effectively as others.

Given all this, do you feel that the attacks on science and the scientific community persist, even today?

SR:, To be honest, I never felt, never felt that.

SS: So, after this PhD, what's your plan?

SR: So, I will join as a postdoc at Rice University in Texas. So, and that's a period of? For two years. After that? After that, basically, basically, I want to explore the industry as well because I have never been totally in academia like throughout.

So, I wanted to explore the industry, but I also wanted to open both of my options in academia and industry.

AD: Yes. Now, you are moving to the US. We hope that you will have plans to come back to India.

SR: Yes.

AD: So, now, lame question. Assume you are the president and the prime minister of the country. So, what changes would you, I mean from sitting today, in today's position, would you like to see so that the differences that you can see between the USA and India can be moved, rubbed out, rubbed off?

SR: So, maybe first, I would like to put more money into industries.

SS: What kind of industries?

SR: I would like research, so I may want to put more funding in the critical minerals or in the renewable energy or green technology in that sort of thing in India.

So, if someone wants to come back, we only have maybe IIT, IISERS, IACS, and a few institutes. Some of the DST and department of science.

So, maybe I will try to increase the number of central government institutes.

SS: So, now a follow-up question comes in: if more industry has to come up, are we not falling prey to some kind of thing in the hands of the businessmen? In the present case, if not in India, there are also other countries where, compared to the lower middle class, industries tend to govern and direct the ways science should work.

SR: I mean applied science, engineering science if you know engineering science fully, some application-based sciences, not fundamental discoveries or stuff like that. Also, they

Fig 8: Srijita is currently working as a Postdoctoral Associate in the Department of Earth, Environmental, and Planetary Sciences at Rice University in Houston, Texas.

may be inclined towards some, something where. But I mean, when I am saying industry, it is not always like that. Research industries and national labs are included as well.

SS: So, national labs. Again, coming back to academia, right?

SR: So, the national lab is a link between academia and industry. So, it is not like full academia, or it is not like the entire industry.

So, it is kind of a link or bridge between these two. And like there are, I mean, there are other industries in the USA, which is more like research industries. Of course, there is a part of a business team.

But I think it is not business. I am not sure if I answered it satisfactorily.

SS: No. That is fine. I just wanted your opinion in this regard.

AD: So, what, if we finally come towards the end of the thing, will your advice to your fellow juniors in IISERs be?

SS: How many students used to be in earth science departments in your days?

SR: I think I had 32 in my batch.

SS: Really?

SR: Yes.

AD: Have you ever thought why earth science shows these fluctuations where physics and biology, departments show all-time high demands? Chemistry is not high demand, but it is a fair good moderate every year.

SR: I think it is because we learn physics, chemistry, biology, and mathematics from childhood. So, people usually like when they come here, they usually already love either physics or mathematics or chemistry like that, and they usually go there.

AD: In Australia, it was not a hostel life, right? You had to stay in apartments?

SR: So, in Australia, we stayed in studio apartments.

So it was a big room with your kitchen and bathroom, everything. And then, like at the side, you have another room with a kitchen and bathroom. So there was no sharing.

AD: So, is it one bedroom, one BHK type?

SR: Not BHK because there was no partitioning between the kitchen and bedroom. So it is kind of, so studio apartment is kind of arranged. For example, if this is like one room, then this side is the kitchen, and this side is the bathroom. The bathroom is the door, if you were asking that.

And one side has the bed.

SS: And what was the cost of staying there?

SR: So since I stayed on campus, that's why I had to pay... On campus means like us? Yes. So that's why I had to pay around $1200. I mean $1200 for a month.

SS: And how much did you earn? I mean, if you don't mind.

SR: Yes, I get around 4,000 per month.

AD: 4000 per month. So you could save 1000?

SR: Yes, the saving was fine.

SS: Okay, so with this we conclude. Thank you.

Fig.10 :14MS group photo on convocation 2019, Srijita and her batch mates one last time all together.

In Conversation with Prof. Probal Chaudhuri

Swarnendu Saha, Manish Behera (IISER Kolkata)

"I believe science should be pursued out of passion, not for fame", Manish and Swarnendu spent some time with Prof. Probal Chaudhuri, winner of Shanti Swarup Bhatnagar Award, as they revisited the pathways of the Indian Statistical Institute and the University of California, Berkeley, reflecting on his academic journey of last 40 years.

Manish Behera (MB): Good afternoon, Sir. Today, my friend, Swarnendu Saha, and I, Manish Behera, are here representing Team Inscight. We are truly honored to have the opportunity to engage with you.

To begin, we would like to ask you a question regarding your academic journey. As you know, the field of mathematics is vast and diverse. What specifically inspired you to pursue statistics as a career, and what was it about this discipline that appealed to you over other branches of mathematics?

Probal Chaudhuri (PC): Well, the specific reason I chose statistics actually goes back to after high school. Back then, for science students, the main options were engineering or medicine. And, in those days, a lot of my classmates who did well in high school ended up pursuing physics or chemistry honours, especially in places like Presidency College. A lot of them did really well later on.

I, on the other hand, had an interest in maths, and I was exposed to some basic probability problems early on, which really sparked my curiosity. Around that time, I found out that the Indian Statistical Institute (ISI) offered a course for undergraduates, and that was one of the few programs that offered scholarships. So, that caught my attention. It seemed like a great opportunity to pursue something I liked while also getting financial support.

Another reason was that, at the time, most engineering programmes were residential, meaning you had to stay on campus. But I preferred to stay at home while studying. So, the fact that ISI was a non-residential program was an added bonus for me.

In the end, it wasn't just one thing that influenced my decision, it was a mix of factors. I didn't have a super strong, singular passion for statistics at the time; it was more about the opportunities available and a series of practical considerations that led me down this path.

MB: I believe you did your bachelors and masters from ISI?

PC: Yeah.

MB: After completing your undergraduate studies, you went on to pursue a Ph.D. at UC Berkeley. Could you share how your time at Berkeley influenced the direction of your academic journey? Specifically, how did your experience there shape your research interests in statistics, and how did the environment at Berkeley contribute to the development of your ideas and academic goals?

PC: When I was completing my postgraduate studies, it was quite common at that time for students to apply for Ph.D. programs both in India and abroad, while also considering job opportunities in India. I applied to a few Ph.D. programs both within India and internationally, and the University of

Fig 1. Indian Statistical Institute (ISI), Kolkata, where Prof.Chaudhuri did his bachelors and masters in Statistics

California, Berkeley, was one of the places I applied to.

The reason I chose UC Berkeley was because, at the time, they were doing significant work in areas like non-parametric statistics and robust statistics, which really caught my interest. I had been introduced to some of these topics during my postgraduate years, and they seemed like a fascinating direction to explore further. However, I'll admit that, even then, I wasn't entirely sure why I specifically wanted to go to Berkeley. It was more of a feeling that this was the right opportunity for me.

Once I arrived there, I was exposed to a lot of cutting edge research, particularly in function estimation and non-parametric statistics, which were among the most exciting areas of statistical research in those days. These areas had applications across various fields like chemistry, biology, and physics, and I quickly became involved in this vibrant research community.

Interestingly, at that time, getting a visa to travel to the U.S. was quite a challenge, which is not something students face today. In fact, there was a period when I even considered giving up on the idea of going to the U.S. and doing my Ph.D. in India instead. However, many of my professors and mentors advised me to take the opportunity for the exposure that studying abroad could offer. They encouraged me to consider the broader experience, not just the academic part, but the exposure to a different culture, society, and a broader set of ideas.

At Berkeley, the environment was so different from what I had experienced in India. While I was in a very academic focused institution, Berkeley had a much wider range of cultural and social activities that I could engage with. I remember being part of the film club, where I had the chance to watch a lot of films, something I didn't have the same access to in India.

Berkeley was also politically active during those years,

Fig 2. Prof. Chaudhuri did his Ph.D. in Statistics at University of California, Berkeley

especially with movements against apartheid in South Africa. I vividly recall seeing protests and demonstrations outside the administrative building, where students were passionately advocating for change. These experiences, both academically and socially, had a profound influence on me, shaping not just my research interests but also my broader perspective on society and the world around me.

I spent three years at UC Berkeley, from 1985 to 1988, and those years were pivotal in both my academic and personal growth.

Swarnendu Saha(SS): And what was the political scenario in Bengal?

PC: Well, it was the left front government which was in power.

SS: You mentioned that the region you're from has always been politically active, and there's a certain sense of unrest that has persisted over time. I can imagine that growing up in such an environment, where political movements and activism are a constant presence, shaped your perspective.

When you went to UC Berkeley, the environment was, of course, very different. The culture, the people, even the physical space, everything would have felt new and unfamiliar. But at the same time, there were certain parallels, like the political activism on campus, the energy of the student movements, and the way people came together for causes they believed in.

Given that background, how did you make sense of these similarities and differences between your experience in India and what you saw at Berkeley? Was there a sense of connection between the political energy in both places, or did it feel like a stark contrast to what you were used to?

PC: The student community at Berkeley had a strong left-wing inclination, which reminded me of the political activism I'd witnessed in Bengal. However, there were key differences. The Berkeley student body was much more diverse, with students from a wide range of cultural backgrounds, which brought a unique blend of perspectives and ideas. This diversity fostered a sense of tolerance and adaptability, as we learned to coexist with people from different cultures.

Personally, I chose to stay in a student dorm during my first year at Berkeley, partly because I wasn't familiar with the place and wanted a supportive environment. The dorm was an "international house", and I ended up staying there throughout my time at Berkeley, as I enjoyed the community and the chance to interact with people from various countries and backgrounds.

SS: Were the dorms similar to the hostels that we have here?

PC: The hostels here are similar, but it is called the International House there because half of the residents were American and half were foreigners. It was always run on a sharing system. The prevalent practice was to keep two people in a room, and if it is two people in a room, it was the policy of the International house that one will be an American and one would be a non-American.

SS: So people could interact with other people from various cultures.

PC: Yes ! That was the case. See, at Berkeley, the dorms worked a bit differently. If you opted for a single room, it was more expensive. To keep costs manageable, I chose to stay in a shared room with a roommate who was often from a different country, not typically an American, since most American students lived off-campus. I remember having roommates from various countries, which exposed me to a wide range of cultures.

The international house where I lived had communal lunch and dinner tables, which created a unique environment for cultural exchange. We would often engage in political discussions over meals. At the time, there were significant events happening in the Middle East, and the political atmosphere was charged. Ronald Reagan was the president of the United States, and his administration was involved in several high-profile incidents. One of the most talked about events was the bombing of Libya, where Muammar Gaddafi was the leader. Another was the Iran-Contra affair, where leaked documents revealed illegal arms deals. Reagan's approval dropped for a while, and he was almost viewed in the same light as Nixon. However, unlike Nixon, Reagan managed to survive politically, largely due to military officer Oliver North taking responsibility for the actions, which helped exonerate him.

In the evenings, we'd often gather in the lounge to watch the news on a large TV screen, discussing the latest developments. There were also weekly movie nights where we'd watch free films together. These experiences, especially dining and discussing politics with students from diverse backgrounds, gave me a broader perspective. I spent a lot of time with Palestinian students, and through conversations with them, I learned a great deal about the history of Palestine and the Israeli-Palestinian conflict. It's like you see the history in front of you. You know I mean they are having dinner with you. They are having lunch with you and you see and talk to these people.

SS: You have been a student as well as a teacher at ISI. You have spent a considerable amount of time here.

MB: Did you see Prof. Mahalanobis?

PC: No, he was not alive when I was a student.

SS: And how has ISI transformed in front of you?

PC: The field of statistics has evolved in many ways over the years. When we were students, our classes were small, with only 10 or 11 students, whereas now, class sizes have increased to 40 or 50 students. The curriculum has changed as well. Back then, the focus was primarily on mathematical statistics, and we had occasional assignments that involved computer work. But computing in those days was very different. We didn't have personal computers or laptops. Instead, there was a mainframe system, and we used punch cards to input data. We would write out programs, hand them over to an operator who would type them into the system, and then the program would run on the computer. The next day, we'd get our output. Any errors would have to be corrected, and the cycle would continue. Students today likely can't imagine working like that.

Now, of course, everyone has a computer or laptop in their office, and some even use tablets to perform computations. This has completely transformed the way we work. When I was at Berkeley, I encountered terminals for the first time and was introduced to email, although it was limited to internal communication within the U.S. At the time, communicating internationally wasn't as easy as it is today, and things like printing were much more expensive. We had to get special permission to print our theses, and back then, the typesetting system called TEX (the precursor to LaTeX) was in use. I typed my thesis using TEX, which was quite the experience.

In terms of technology, I also saw the advent of workstations like the Sun workstation, which introduced the concept of multiple windows on a single screen. Before that, there was only one screen, and you couldn't split it into multiple windows. The introduction of this new technology was a big shift in how we worked.

In terms of curriculum, statistics has evolved with the times. While our training focused more on theoretical and mathematical statistics, today's courses incorporate a lot more data analysis. Students now spend significant time working with real data, using computers to run analyses, which wasn't part of our training at the time.

SS: ISI started its journey right after the Independence, within a few years. And since then, we have also had the implementation of a good number of IITs; they have made a brand out of themselves. But even today, almost 20 years since the start of the IISERs, most people don't know what the IISERs are. What is your take on this?

PC: The origins of ISI were quite different from its current form. As I mentioned in my lecture, ISI began in a small room at Presidency College, initially called the Statistical Laboratory. Prasanta Mahalanobis, its founder, was addressing statistical problems arising from various sectors, including government needs, in collaboration with others. As the work expanded, the need for trained statisticians grew, leading to the establishment of formal training programs.

In 1941, ISI introduced India's first Master's program in Statistics, initiated at University of Calcutta. This was the first formal academic program in statistics in the country, marking the beginning of structured education in the field. Over time, more programs were launched in different parts of the country.

It's important to understand that ISI's primary focus has always been on statistics, unlike the broader range of disciplines found in engineering or medical colleges. If we were to compare ISI to another institution, it might be more apt to compare it with medical colleges rather than IITs. While medical colleges produce doctors and IITs train engineers who contribute to society in specific ways, ISI produces statisticians who provide a different kind of service, more about supporting other fields rather than directly impacting daily life. Statisticians at ISI are educated in science, and the institution serves as a hub for science

Fig 3. Prof. Prasanta Chandra Mahalanobis, Founded the Indian Statistical Institute (ISI) from a single laboratory at Presidency College.

Fig 4.
The statistical laboratory set up by Prof.Mahalanobis at Presidency College, in 1931 which later became the ISI that is today

education, not as a traditional engineering or medical institution.

ISI's contribution lies in creating high-quality scientific professionals. It offers an alternative path to those who wish to pursue science rather than engineering or medicine. While the latter fields are crucial for immediate societal needs, science provides long-term contributions that sustain technology and innovation. This is why science education is important, as it creates the foundation for future advancements. At ISI, you can also later diverge into technology, as many former students have done.

SS: What do you make of the National Education Policy (NEP)?

PC: Regarding the changes proposed in the National Education Policy (NEP), these decisions are often driven by administrative considerations rather than purely academic reasons. For example, the shift from a four-year to a three-year undergraduate program was made in 1978 to align with other science programs. NEP's proposed changes, such as introducing four-year undergraduate programs, may have both positive and negative consequences. However, the real challenge lies in the implementation and the transition from the old system. Without proper planning, such transitions could lead to issues. The NEP doesn't provide specific guidance on how it will affect the teaching process or curriculum at the grass-roots level, and that is where the concern lies.

SS: How do you see the differences between the students at ISI and those in other institutes?

PC: The key difference lies in the quality of students that ISI attracts, which is largely due to its brand name and reputation. ISI draws highly motivated students who are deeply interested in statistics, and this naturally leads to a more advanced level of coursework. This higher level of entry ensures that the courses are pitched at a more advanced level, leading to a certain inequality between top institutions like ISI and other universities. While this inequality helps in maintaining high standards, it can sometimes widen the gap between different types of institutions.

SS: What's your take on the idea of celebrity status for scientists, similar to that enjoyed by people in the world of technology like Sundar Pichai or Bill Gates?

PC: I believe science should be pursued out of passion, not for fame. A scientist's goal is to understand the natural world and contribute to the betterment of society through that knowledge. The pursuit of answers to unknown questions should be the primary motivation. While there are famous scientists whose work we learn from, they should not be seen as celebrities. The work itself is more important than the recognition or status that comes with it. Science is about curiosity and exploration, not about satisfying others' expectations or seeking external validation.

The general public may not understand the nuances of a scientific career, especially in a society where engineering and medicine are seen as more immediately rewarding. But for those who choose science, the reward lies in the pursuit of knowledge, not in material gains or recognition.

MB: Could you share some insights on what you're currently working on? Do you have any advice for young students who are considering a career in statistics?

PC: Statistics is a versatile field used across virtually every discipline both social sciences and natural sciences. If you're considering a career in statistics, I'd recommend getting solid training from a good program. Beyond that, it's important to stay open-minded and read widely beyond just statistics. You need to understand the broader role of science in society, why science exists and how it impacts the world.

Take, for example, the COVID-19 pandemic. Many studies came out, some of which were later retracted due to faulty data analysis. This highlights the importance of being cautious with data and rigorous in analysis. Statistics is about making sense of data to draw conclusions, and that requires not just technical expertise but also curiosity and critical thinking.

To be successful in statistics, you must focus on finding meaningful solutions to real world problems, not just following trends or trying to satisfy external pressures. Ultimately, science, like any field, should be pursued out of passion. It's about solving mysteries and contributing knowledge, regardless of the external rewards.

MB: Thank you very much, sir, for your valuable insights. It has been a pleasure for us to host you this afternoon.


The image depicts LUCA as a glowing, complex microbe surrounded by a vibrant microbial community, set against a fiery, primordial Earth transitioning from dark hydrothermal depths to a lighter ocean surface, with subtle DNA-like strands symbolizing its sophisticated genome. See the writeup by Swarnendu Saha for more details.

Insight Digest

In Insight Digest, we showcase simplified summaries of recent research articles in science, to give a feel for what's happening at the frontiers.

Leishmania major-induced alteration of host cellular and systemic copper homeostasis drives the fate of infection

Paul, R., Chakrabarty, A., Samanta, S. et al. Commun Biol 7, 1226 (2024)
Contributed by **Shruti Santosh Sail (DBS, IISER Kolkata)**
Keywords: *Copper, ATP7A, Leishmaniasis, Host-Pathogen Interplay*

Copper plays an intriguing dual role in biology despite being a trace element - a nutrient and a toxin. Copper Metabolism Group from IISER Kolkata explores this duality using the protozoan parasite Leishmania major and how it hijacks host copper pathways to evade immune defenses. The work provides interesting perspectives on potential therapeutic interventions for the tropical disease of Leishmaniasis. Copper toxicity is a powerful weapon that host macrophages use to counteract invading pathogens. They accumulate copper in the phagolysosomal compartments leading to the macrophages generating Reactive Oxygen Species (ROS) that can damage or kill intracellular parasites. However, L. major has managed to evade this threat using interesting tactics revealing that the parasite manipulates two key copper-regulating proteins in host macrophages: ATP7A, which transports copper to pathogen-containing compartments, and CTR1, the primary copper importer. The parasite then induces ATP7A degradation through proteasomal and lysosomal pathways. Simultaneously, CTR1 is downregulated at the transcriptional level and endocytosed, leading to limited copper supply to the macrophage. These multiple strategies ensure its survival within the host.

The researchers observed a remarkable systemic redistribution of copper during the infection, suggesting a reverse strategy by the host to protect itself. The heart, which forms a major copper reservoir, shows downregulation of CTR1, leading to the release of stored copper into systemic circulation. This copper is directed to the infection site, enabling the host to combat the pathogen. It has been observed in mice models that copper supplementation slows down lesion development and reduces parasite load, whereas copper chelation triggers the infection further, highlighting the role of copper as not only a metabolic cofactor but also an active participant in immune defense. So far, new avenues for the treatment of Leishmaniasis have opened up that could target the copper pathways. Modulating copper levels can be done in several ways like by supplementation or selective chelation, and could complement current treatment methods. The idea of combining systemic copper mobilization or developing drugs that mimic this redistribution is another avenue. Such approaches could also help battle the existing problems with drug resistance and toxicity.

Reversion of colorectal cancer cell, a new approach towards anti-cancer therapeutics

J.-R. Gong, C.-K. Lee, H.-M. Kim, J. Kim, J. Jeon, S. Park, K.-H. Cho. Adv. Sci., 12, 2402132 (2025)
Contributed by **Monjuri Hembram (Phd Scholar, IISER Kolkata)**
Keywords: *colorectal cancer, cancer reversion, BENEIN, anti-cancer therapy*

A new approach towards anti-cancer therapy has emerged. Kwang-Hyun Cho and group from Korea Advanced Institute of Science and Technology has found cancer reversion to be effective in treating colorectal cancer. The team has found a trio of master regulators which can transform back colorectal cancer cells into typical healthy enterocytes. Inhibition of the maestro regulators trio consisting MYB, HDAC2, and FOXA2 has been found to collectively induce differentiation while suppressing malignancy. Current research on reversing cancer cells lacks the expertise to understand the mechanism of cellular differentiation and has a restricted systemic approach to discover the key regulators. A computational scheme for single-cell Boolean network inference and control entitled BENEIN was established by Cho and colleagues. It can restore Boolean models of gene regulatory networks (GRNs) and pinpoint a group of master regulators in charge of desired cellular differentiation. The possibility of blocking the master regulators in cancer cells' reversion was validated by in silico study. Based on the in-silico analysis, three different cancer cell lines namely HT-29, HCT-116, and CACO-2 were evaluated in-vitro and in-vivo for cancer reversion upon inhibition of the master regulators. In-vitro analysis showcased decrease in proliferation rate for simultaneous inhibition as compared to the single gene knockouts. In-vivo experiments in knocked down colorectal cancer cell engrafted nude mice model, suggests simultaneous knock down of the master regulators to be successful in reverting colorectal cancer cells. Western blot analysis of healthy enterocyte protein in reverted cancer cells further confirms the successful conversion. Thereby, this study shows a promising approach to colorectal cancer therapy by just converting the cancer cells into healthy ones.

The First Ancestor: How LUCA Shaped Life on Earth

Moody, E.R.R., Álvarez-Carretero, S., Mahendrarajah, T.A. et al. Nat Ecol Evol 8, 1654–1666 (2024)

Contributed by **Swarnendu Saha (Department of Physical Sciences, IISER Kolkata)**

Keywords: *LUCA, evolution, ancient microbes, common ancestor, molecular clock, genetic heritage*

Imagine when Earth was just a young, boiling mass of rock and water, with no plants, animals, or even bacteria as we know them today. Now, picture a tiny, ancient life form—the Last Universal Common Ancestor (LUCA)—swimming in that primordial world, setting the stage for all life on our planet. This new research takes us back 4.2 billion years to uncover LUCA's nature, its environment, and how it kick-started life's evolution.

The study uses cutting-edge molecular clock techniques and phylogenetics (a genetic family tree) to pinpoint LUCA's age to about 4.2 billion years ago—right after Earth became stable enough to support life. LUCA wasn't just a simple blob of organic material. It had a complex genome, roughly 2.5 megabases, coding for around 2,600 proteins—comparable to modern prokaryotes. This means LUCA had a working metabolism, an early immune system, and interactions with other microbes in its environment.

One of the most exciting aspects of this study is how it places LUCA within a broader ecological system. Rather than existing in isolation, LUCA likely lived in a bustling microbial community, shaping the chemistry of early Earth. It thrived as an anaerobic acetogen, producing energy by converting carbon dioxide and hydrogen into acetate, much like some modern bacteria. This metabolic process was crucial because it created a niche for other microbes, including early methanogens, which produced methane, feeding into Earth's early atmospheric and climate systems.

The study also challenges the long-held idea that LUCA lived exclusively in extreme environments like hydrothermal vents. While that remains a possibility, researchers suggest that LUCA might have also existed near the ocean's surface, benefiting from atmospheric hydrogen. This new perspective opens doors to reconsidering how and where life first took hold on our planet.

LUCA represents our shared ancestry with every living thing on Earth—from bacteria to blue whales, fungi to humans. Understanding LUCA helps scientists piece together the grand puzzle of evolution, shedding light on how life emerged and adapted to a changing planet.
This paper goes beyond history—it reveals the intricate connections between life and planetary systems. LUCA's legacy is still alive in every cell today, making this research essential for anyone curious about the origins of life.

Persistent currents in 1-dimensional spin-orbit coupled rings under influence of Zeeman field

Bijay Kumar Sahoo, Subroto Mukerjee, and Abhiram Soori. Phys. Rev. B 110, 195426 (2024)

Contributed by **Bijay Kumar Sahoo (University of Hyderabad)**

Keywords: *Persistent current, spin-orbit coupling, Persistent spin current, mesoscopic ring*

Persistent currents (PCs) can be induced in rings with circumferences smaller than the electron's phase-coherence length by threading magnetic flux through the center of the ring. PCs in mesoscopic rings have been the subject of intense investigation since their proposal by Buttiker, Landauer, and Imry in 1983. In this work, we investigate PC's behavior in spin-orbit coupled rings under the influence of a Zeeman field (without a need for a flux threading the ring), which contrasts with traditional PC observed in rings threaded by magnetic flux. We find that non-zero values of the Zeeman field and spin-orbit coupling are necessary for the emergence of PC in our setup.

Mainly, in ballistic rings, we observe that PC varies inversely with system size, along with PC being zero at half-filling for an even number of sites. At half-filling PC becomes zero, because the current carried by m^{th} electron from the bottom of the bands is the same as the current carried by mth electron from the top of the band, which makes the currents at filling N_e (number of electrons) and $2N$-N_e (N being the number of sites in the ring) equal in magnitude and opposite in sign. Moreover, introducing on-site disorder to our setup results in a suppression of PC, with exponential decay observed for large disorder strengths and quadratic decay for smaller disorder strengths. Notably, we find that at half-filling disorder can enhance the PC in individual samples, though the configuration-averaged PC is zero.

Furthermore, we find that the standard deviation of PC increases with disorder strength, reaching a maximum before decreasing to zero at high disorder strengths. We also find that with disorder the PC varies exponentially with system size. We also investigate persistent spin current, which behaves similar to PC except that it is not zero at half-filling. Our findings shed light on the intricate interplay between spin-orbit coupling, Zeeman fields, and disorder in mesoscopic quantum systems, offering new avenues for theoretical exploration and experimental verification.

Science Games

General Science Visual Quiz
This week's quiz involves answering questions based on visual cues.

Themed Crossword
This theme for this issue is **Evolution**. Send us your crosswords if you want to be featured!

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

General Science Quiz

Q1. In this picture taken at Ehrenfest's home, Einstein and Bohr can be seen debating about one of the most mysterious aspects of quantum mechanics. Can you guess the topic of their debate, which later became part of the well-known Bohr–Einstein debates.

(a) Whether quantum mechanics can be unified with gravity
(b) Whether the Copenhagen interpretation of quantum mechanics was a valid description of nature
(c) Whether quantum systems can be chaotic
(d) Whether a classical system can transition into a quantum system

Q2. The above picture is of the announcement of a fundamental experimental discovery in physics, which was predicted theoretically by the two scientists in the picture, almost half a decade before. They were awarded with the Nobel prize a year after the experiment. What is the discovery being reported here?

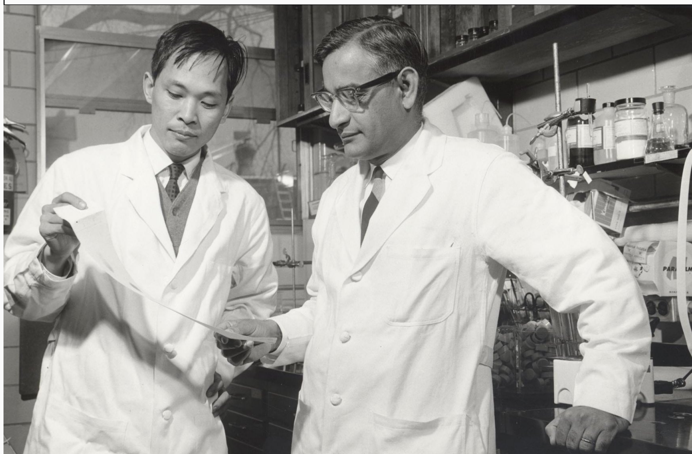
(a) Discovery of gravitational waves
(b) Successful run of a quantum computer
(c) Discovery of water on moon's surface
(d) Discovery of the Higgs boson

Q3. This image shows the succesful completion of a very important mission for India's development and defense strategy. The three persons are the then chief of the organisations who headed the mission: Dr. K Santhanam (technical advisor of DRDO), Dr. Rajagopala Chidambaram (head of DAE) and Dr. A P J Abdul Kalam (head of DRDO). Do you know what the mission was?

(a) India's second nuclear bomb test
(b) India's first satellite test
(c) India's first missile test
(d) India's first nuclear submarine test

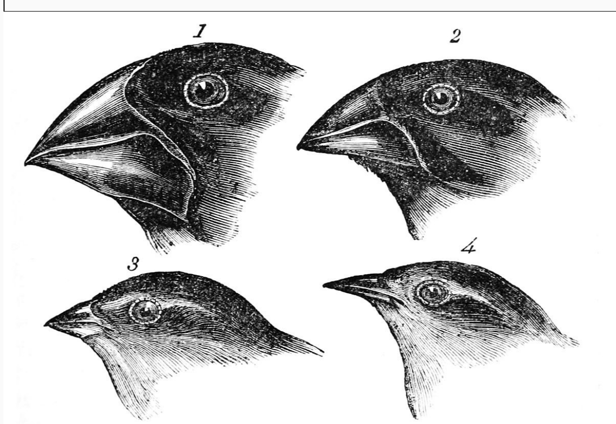
Q4. This is the picture of a very prestigeous conference that occurred in 2024. It is one of the oldest conferences and was started by scientists to discuss important and timely topics of natural science. The 1927 edition of this conference involved the coming together of several top physicists of that time, including Einstein, Lorentz, De Broglie and Poincare. Incidentally, the only woman physicist there was Marie Curie. Name the conference.

(a) International Conference on Theoretical Physics
(b) The Solvay Conference
(c) International Conference on Quantum Physics
(d) Planck Roundtable Conference



Q5. The man on the right in the above image is an Indian American scientiat who worked on molecular genetics .His main contribution was to demonstrate the role of nucleotide in protein synthesis, for which he got the nobel prize. He was the first scientist to chemically synthesize oligonucleotides. After years of work, he became the first to complete the total synthesis of a functional gene outside a living organism in 1972. Who is he ?

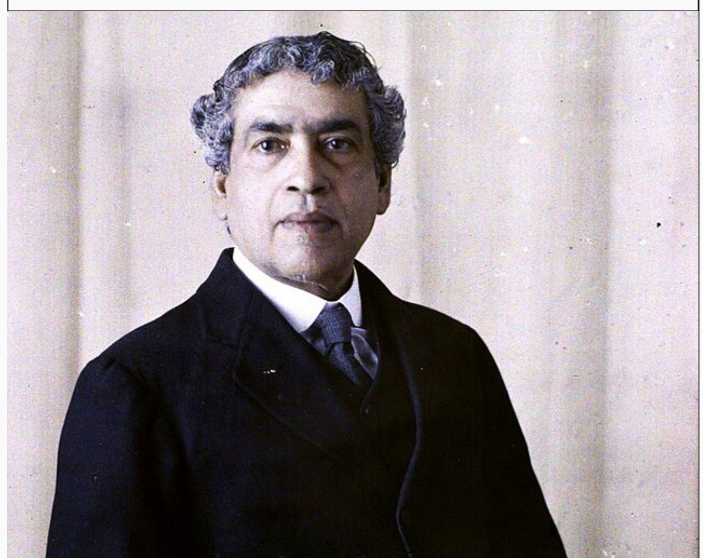
(a) MS Swaminathan
(b) Venkat Ramakrishnan
(c) Manjul Bhargava
(d) Hargobind Khorana



Q6. The picture on the left is of the announcement of a fundamental experimental discovery in physics, and the two scientists in the picture were the ones to first predict the discovery, almost half a decade before, and they were awarded with the Nobel prize a year after the experiment. What is the discovery being reported here?

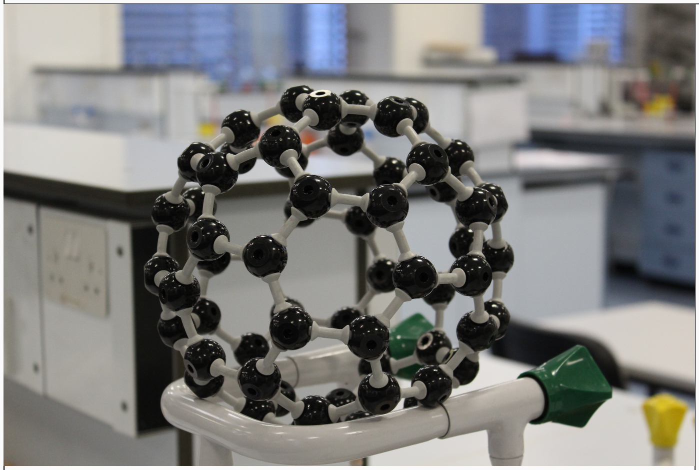
Q7. It is observed that the male birds of the type represented in the picture for Q6 have two types of song sounds A and B .Observation leads to the fact that birds with song A have short beaks and this helps them tear apart the cactus base and eat the pulp and any insect larvae and pupae, while birds with song B have longer beaks and they are able to punch holes in the cactus fruit and eat the fleshy aril pulp, which surrounds the seeds. What do you think is the possible advantage of this difference in features?

(a) Reduces competition for nesting sites during breeding season, ensuring higher reproductive success for all groups.
(b) Ensures that birds with song A can avoid predators more effectively by staying near the cactus base, while birds with song B can feed higher up and escape aerial predators.
(c) Helps maintain genetic diversity among the population by encouraging different song types during mating displays.
(d) Maximises their feeding opportunities during the non-breeding season when food is scarce



Q8. The man shown in the above picture was at University of Calcutta, where he flared out the end of a waveguide, demonstrating the horn antenna. He pioneered the investigation of radio microwave optics, made significant contributions to botany, and was a major force behind the expansion of experimental science on the Indian subcontinent. He was also the first one to announce the presence of ” nervous system ” of plants .Identify the man and also name the instrument which he used to measure the plant’s growth

(a) Jagadish Chandra Bose, crescograph
(b) Satyendranath Bose, radiometer
(c) Debendramohan Bose, botanogram
(d) Gyanchandra Bose, coherer



Q9. In 1985, Harold Kroto from the University of Sussex, along with James R. Heath, Sean O'Brien, Robert Curl, and Richard Smalley from Rice University, discoered structures resembling the picture. These were found in the sooty residue formed by vaporizing carbon in a helium atmosphere. The mass spectrum of the residue revealed distinct peaks corresponding to molecules with precise masses equivalent to 60, 70, or more carbon atoms—specifically, C_{60} and C_{70}. Identify the molecule

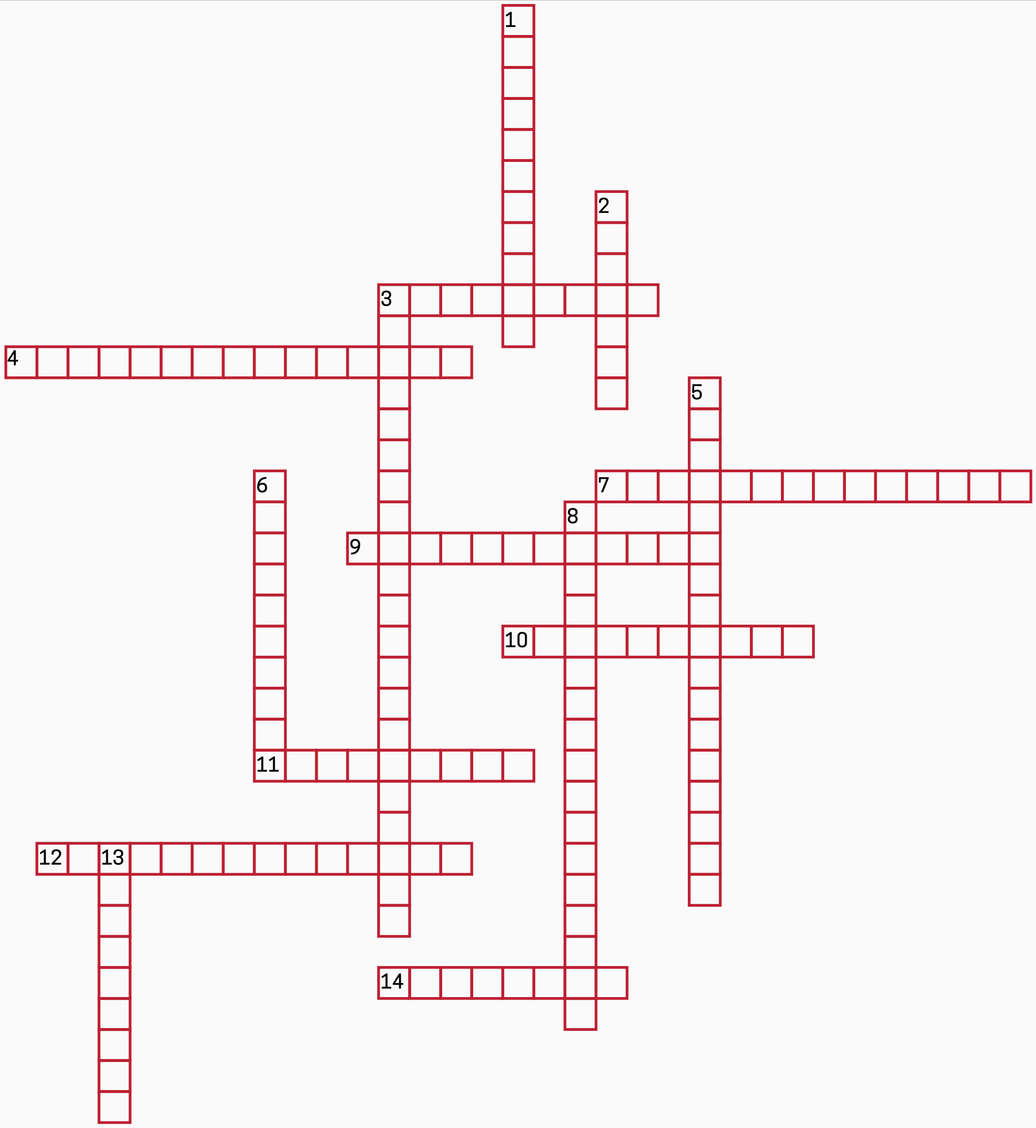
(a) Graphite
(b) Diamond
(c) Fullerene
(d) Carbon nanotube

Q10. Poincare conjecture is a theorem in geometric topology that states that every closed three dimensional manifold is topologically equivalent to sphere. This was an unsolved problem till 2002, until it was solved by the man in the picture. He went on to decline the Fields medal, saying "I'm not interested in money or fame, I don't want to be on display like an animal in a zoo. I'm not a hero of mathematics. I'm not even that successful; that is why I don't want to have everybody looking at me". Can you name this mathematician ?

(a) Don Zagier
(b) Grigori Perelman
(c) Dennis Sullivan
(d) Andrew Wiles

Themed Crossword

This issue's crossword is based on **evolutionary biology**.



Across

3 Evolutionary history and relationships among species (9)
4 This refers to the proportion of a specific allele (variant of a gene) within a population's gene pool (15)
7 Estimation of evolutionary timescales based on mutation rates (14)
9 Random changes in allele frequencies in a population (12)
10 The effect that refers to a sharp reduction in population size causing genetic diversity loss (10)
11 Long-term interaction between different species, often mutually beneficial (9)
12 This refers to evolutionary changes within a population or species over a relatively short period of time (14)
14 Movement of genes between populations through migration (8)

Down

1 Reciprocal evolutionary changes between interacting species (11)
2 The effect which refers to genetic variation resulting from a small group establishing a new population (7)
3 The idea that evolution occurs in rapid bursts rather than gradually (21)
5 Environmental factors that influence reproductive success (17)
6 Anatomical similarities due to shared ancestry (10)
8 The rapid evolution of multiple species from a common ancestor (17)
13 A diagram depicting evolutionary relationships (9)

Solution can be found at the end of the issue.

Linked List

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

Find all the words!

Today's seed: **ENZYME**

2. A thermodynamic quantity representing the degree of disorder in a system (7)

E

3. The amount of product formed in a chemical reaction (5)

4. The bending of waves around obstacles leading to patterns of bright and dark bands. (11)

5. A nearly massless subatomic particle with no electric charge (8)

6. The diffusion of water across a selectively permeable membrane (7)

7. Quantum mechanical attribute, must be integer for bosons (4)

8. A subatomic particle with no electric charge, found in the nucleus of an atom (7)

9. A point in a standing wave where the amplitude is zero (4)

10. A negatively charged subatomic particle (8)

11. Fundamental unit of chromatin, consisting of a segment of DNA wound around a core of histone proteins (10)

E

Answers can be found at the end of the issue.

Do Contribute!

Contributions are welcome from students and faculty members across all academic institutions, on a rolling basis. The portals for submitting all kinds of content can be found on our website. More specific details regarding content submission can also be found there, so please take a close look at the linked page if you are interested in contributing. For any queries, reach out to us at **scicomm@iiserkol.ac.in.**

Science Articles: We publish write-ups on interesting ideas in science, as long as the content is accessible to a broader audience and not just to the experts. Submit your articles here.

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Quizzes and Games: We also feature science games such as crosswords, quizzes and word-link games. If you have content for these games or have new interesting games in mind, please pass them on to us via our email.

Interview Recommendations: If you want us to interview specific scientific personalities or if you have an interview that you want to publish, please send us an email.

Finally, but very importantly, we would love to hear any feedback that you might have about this endeavour, so please send us your comments at scicomm@iiserkol.ac.in.

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Crossword Solution

Across
3 PHYLOGENY
4 ALLELEFREQUENCY
7 MOLECULARCLOCK
9 GENETICDRIFT
10 BOTTLENECK
11 SYMBIOSIS
12 MICROEVOLUTION
14 GENEFLOW

Down
1 COEVOLUTION
2 FOUNDER
3 PUNCTUATEDEQUILIBRIUM
5 SELECTIONPRESSURE
6 HOMOLOGOUS
8 ADAPTIVERADIATION
13 CLADOGRAM

Quiz Answers

1. Option 1
2. Option 4
3. Option 1
4. Option 2
5. Option 4
6. Option 3
7. Option 4
8. Option 1
9. Option 3
10. Option 2

Linked List Solution

2. ENTROPY
3. YIELD
4. DIFFRACTION
5. NEUTRINO
6. OSMOSIS
7. SPIN
8. NEUTRON
9. NODE
10. ELECTRON
11. NEUCLEOSOME

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