Ahmedabad University

Illustrated Science

Winter 2024

Illustrated Science

Editor

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Edition

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Digital Curve
Centre for Learning Futures
Ahmedabad University

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From *the* Instructors

Dear Readers,

Welcome to the second edition of our magazine Illustrated Science. It chronicles the semester long efforts of the students from the COM211 Science Communication using Digital Media course at Ahmedabad University.

In an era where scientific advancements significantly impact our lives, the role of effective science communication is more crucial. This edition covers articles in Atmospheric Chemistry, Engineering, Material Science, Cellular Biology, Animal Physiology, Cancer Biology, Applied Genetics, Public Health, Ecology, Plasma Science and Astrophysics.

Join us in celebrating the dedication of these emerging science communicators and illustrators from across different disciplines as they contribute to the ongoing dialogues in Science.

Bhumi Shah & Tana Trivedi

About *the* Course

Science Communication using Digital Media is a unique, interdisciplinary course offered at Ahmedabad University. The course trains students to bridge the gap between complex scientific concepts, and popular understanding of science through explanatory science illustrations created using digital tools and software. As a part of the course, students engage in the following activities during the semester:

01 | Collaborating with a Science Mentor to simplify and introduce cutting-edge research for the general audience to newer ideas, discoveries and scientific progress. Students work closely with faculty researchers, to understand their research and translate it into engaging popular science and illustrated articles.

02 | Writing a Feature and a News Story by observing, describing and explaining. Students learn how storytelling and other literary techniques can help communicate science news. They also understand the difference between science writing and science fiction.

03 | Storytelling Strategies for Graphics by grasping the fundamentals of science graphics, organisation and emphasis, visual Style, colour and typography. Students understand the role that visualizations of data and concepts of science play in enhancing public understanding, and increasing engagement with science.

04 | Sketching Digital Illustrations by learning tools like Sketchbook and Inkscape to develop illustrations.

05 | Crafting Illustrated Articles, data visualizations and info-graphics. Students learn to communicate complex ideas and relationships through a visual language of diagrams, charts, maps and imagery with annotated explanations.

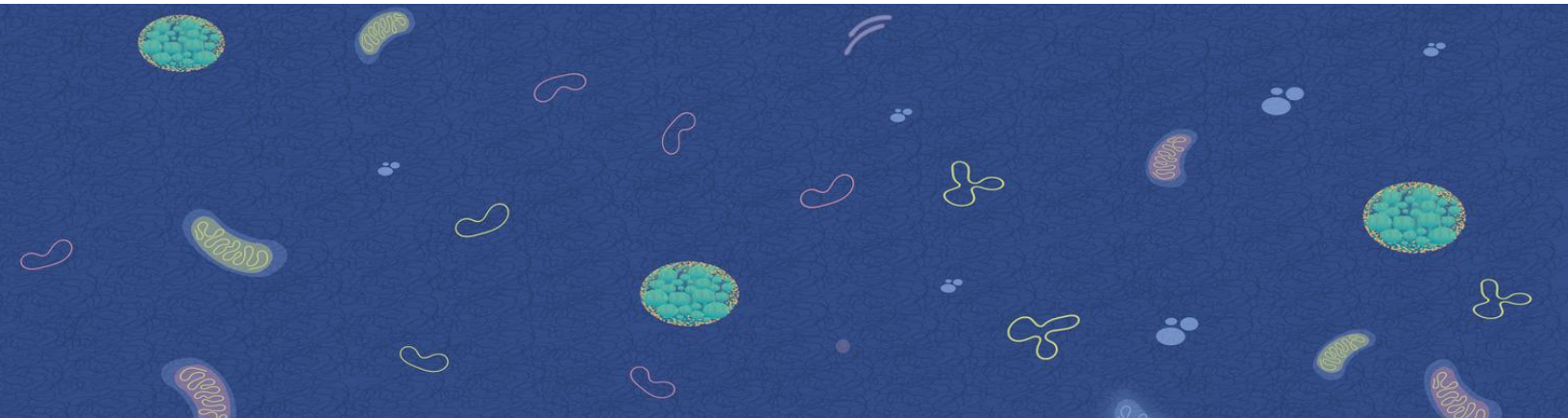
Through a combination of creative assignments, readings, listening to podcasts, and field trips, this course exposes students to multiple approaches and perspectives on understanding and communicating science for lay audiences.

Course *Instructors*

Tana Trivedi is a faculty at the Amrut Mody School of Management at Ahmedabad University. She completed her PhD from Christ University and conducted her Postdoctoral research at the University of Edinburgh. With over seventeen years of teaching experience in business history, literature, literary theory, and postcolonial diaspora studies, her research interest lies in examining the notions of nation and identity formation. At Ahmedabad University, she offers science fiction and science writing courses, both of which she enjoys reading and discussing.

Bhumi Shah is a Fellow at Digital Curve, Centre for Learning Futures at Ahmedabad University. She holds a Master in Computer Applications, specialising in Mobile Computing, and a Master of Management Studies in Heritage Management. Her work is interdisciplinary and ranges across computer science, learning design, immersive media and research communication. She teaches courses in Interactive Media and Creative Coding at Ahmedabad University. She develops projects with researchers to understand, interpret, and communicate ideas, concepts or processes through interactive media and explanatory illustrations.

Inside



Unveiling Cosmic Wonders

Spectral Energy Distributions of Young Stellar Objects

Writer and Illustrator **Krishali Shah** | *Science Mentor* **Samyaday Choudhury**

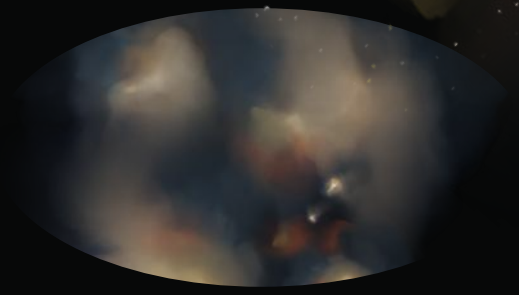
The universe was born 14 billion years ago in the Big Bang, and galaxies and stars were eventually born. Stars fostered the formation of heavier chemical elements from hydrogen, including life-sustaining elements like carbon and oxygen, and formed planetary systems. Physicist Brian Cox articulated beautifully, "We are the cosmos made conscious, and life is how the universe understands itself." This deep connection between the evolution of the cosmos and life's emergence underscores the importance of studying star and planet formation.

Questions about star and planet formation have puzzled scientists for decades. Scientists now think planets likely started as grains of dust smaller than the diameter of a human hair. They emerged from the giant, donut-shaped disk of gas and dust, called protoplanetary disk, that circled young stars. Our sun was once such a young star from which the planets we know today formed. Therefore, understanding the origin of these stars can answer fundamental questions: How was the sun born? How did the planets around the sun form? How did the solar system evolve?

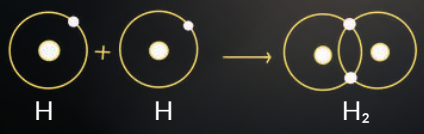
Some of these fundamental questions can be answered by studying the stars in their early stages of life, which harbour protoplanetary discs. In their early lives, these stars are called Young Stellar Objects (YSOs). The early stages of a new star's life are critical for the star and its future planets. Star formation was once thought to be a simple amalgamation of different elements under the influence of gravity. But that is not true. In fact, it involves a series of complex processes.

Formation of Young Stellar Objects

1



Formation of a Molecular Cloud
Hydrogen atoms (H) combine to form large gas clouds of molecular hydrogen (H_2) in the interstellar medium. Interstellar medium refers to the space between the stars.



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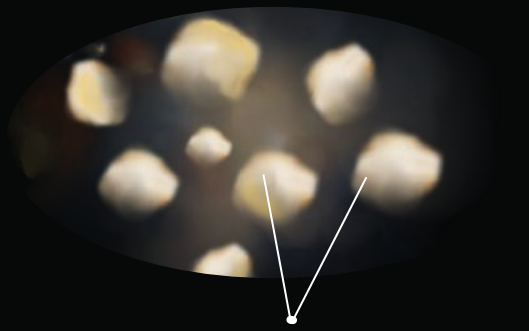
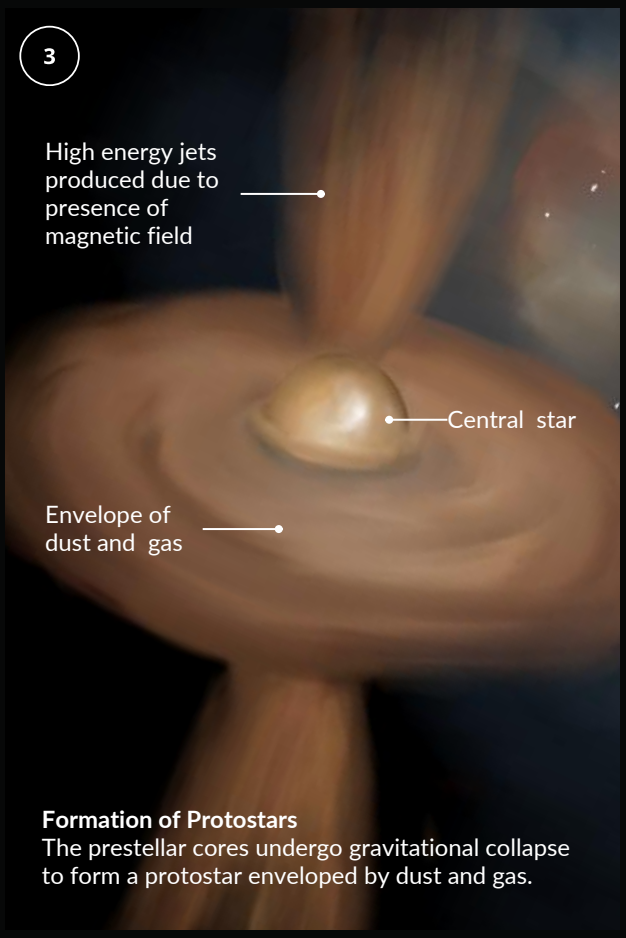


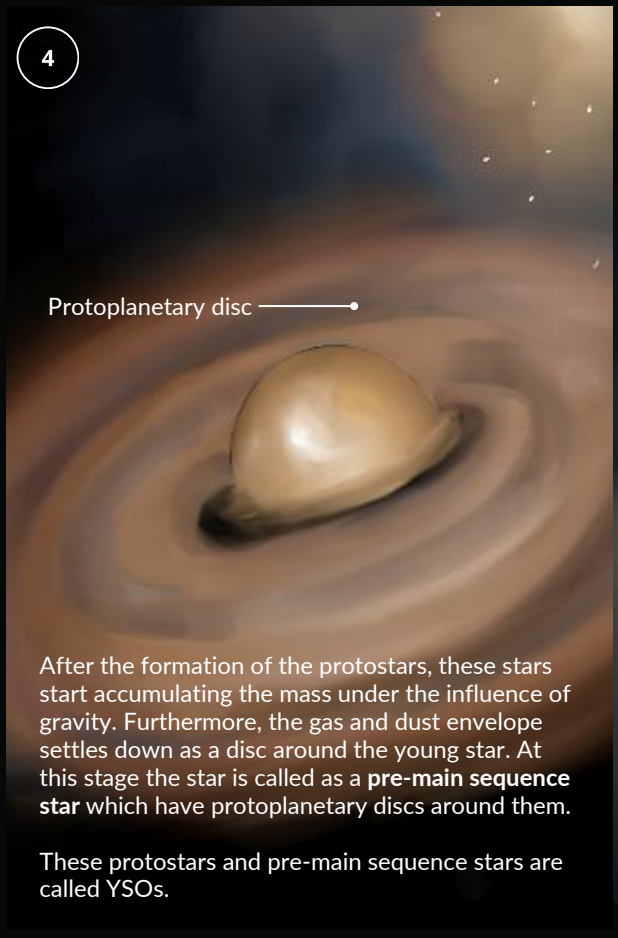
Formation of Prestellar Cores
The molecular cloud then undergoes fragmentation and forms smaller clumps called the prestellar cores. These prestellar cores only form if they satisfy the "Jeans Cloud Collapse Criterion ". Prestellar cores are the basic units of star formation, as they each produce an individual stellar system.

3



Formation of Protostars
The prestellar cores undergo gravitational collapse to form a protostar enveloped by dust and gas.

4



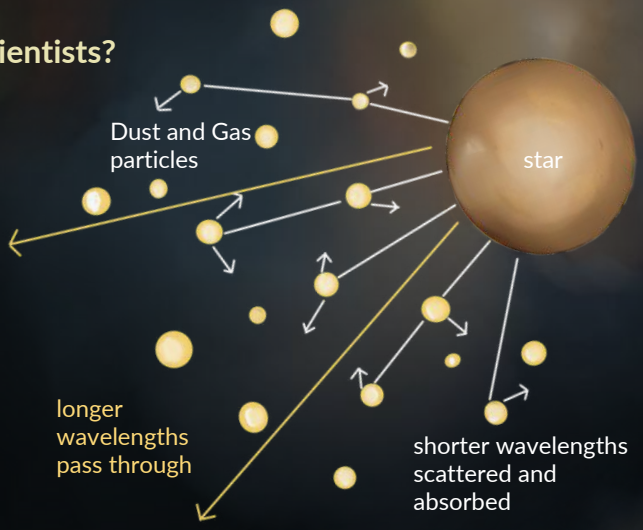
After the formation of the protostars, these stars start accumulating the mass under the influence of gravity. Furthermore, the gas and dust envelope settles down as a disc around the young star. At this stage the star is called as a **pre-main sequence star** which have protoplanetary discs around them.

These protostars and pre-main sequence stars are called YSOs.

Why is it Challenging to Detect YSOs for Scientists?

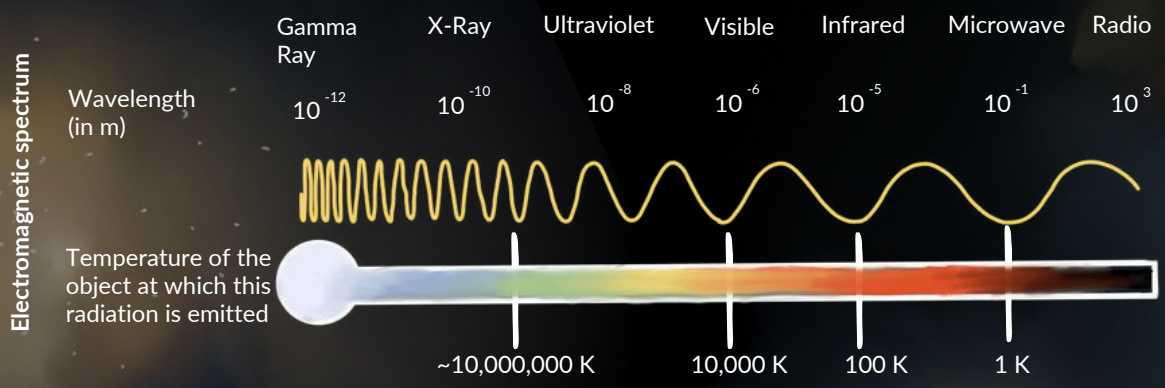
1 **Scattering of light**

YSOs are often surrounded by dense clouds of dust and gas. This obscures the light emitted by the young star, making it difficult to detect because the particles absorb and scatters shorter wavelengths, such as visible light and ultraviolet (UV) radiation. So, only the longer wavelengths of light reach us.



2 **Effect of Temperature**

YSOs are in the early stages of their formation and are typically cooler compared to older, more evolved stars. As a result, they emit a significant amount of their radiation in longer wavelengths, particularly in the infrared part of the **electromagnetic spectrum**.



How are YSOs Detected?

Infrared telescopes such as NASA's James Webb Space Telescope (JWST) and Spitzer Space Telescope are extremely useful in detecting these YSOs and studying their formation and evolution.

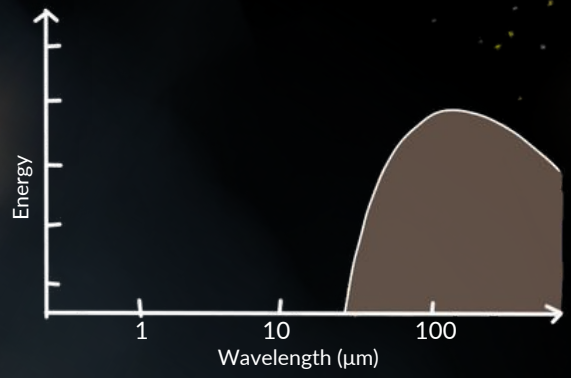
Recently, JWST revealed the image of the Rho Ophiuchi cloud complex. It is the closest star-forming region to Earth. One can see the jet bursts impacting the surrounding interstellar gas and lighting up molecular hydrogen. Some stars even show hints of a circumstellar disk, which gives rise to future planetary systems.

How do Scientists Analyse Telescope Data?

Scientists plot Spectral Energy Distributions (SEDs) to identify YSOs using the data obtained from different telescopes. SEDs are graphical representations of the amount of energy emitted by an object at different wavelengths across the electromagnetic spectrum. Plotting SEDs helps identify potential YSOs.

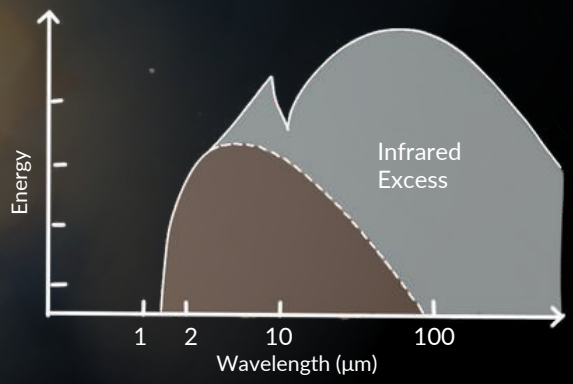
In the case of young stellar objects, they are further divided into four categories based on their stage in life. Their SEDs look something like this:

CLASS 0



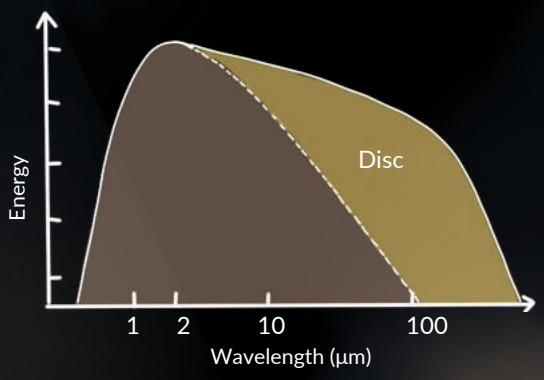
- Youngest protostars
- Difficult to observe in visible light
- Temperature : ~10 K which implies the radiation in longer wavelengths
- Age : < 30,000 years

CLASS I



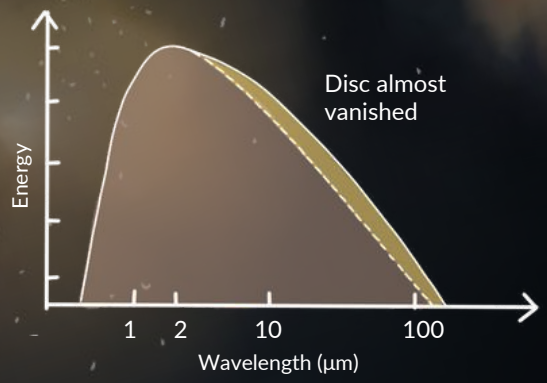
- Most of the energy comes from the dusty cocoon around the central star. This corresponds to the area shaded in Grey colour.
- The "dip" at about 10 microns tells us that silicates are present in the dust around the star.
- Temperature: ~70 - 650 K
- Age : ~ 200,000 years

CLASS II (Classical T Tauri star)



- In pre-main-sequence stars, most of the energy comes from the central star. This corresponds to the area shaded in Brown colour.
- Bright infrared emission due to their warm circumstellar/ Protoplanetary discs. This corresponds to the area shaded in yellow.
- Potential progenitors of Sun-like stars.
- Temperature: ~650-2880 K
- Age: ~ 1 Million years

CLASS III (Weak-Lined T Tauri)

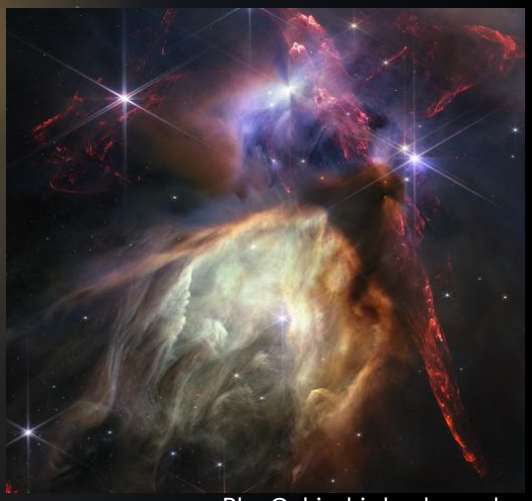


- The star still has a little dust left around it but not too much meaning the disc is almost gone. Hence, less infrared emission.
- Temperature : >2880 K
- Age : ~ 10 Million years

A peak into the real world!

The image below shows a real star's Spectral Energy Distributions (SED) generated using Bayesian Extinction and Stellar Analysis Tool (BEAST). This Python package fits the ultraviolet to near-infrared light SEDs of stars. It also helps extract stellar parameters such as temperature, surface gravity, extinction etc.

Star Forming Regions Where YSOs have Been Found!



Rho Ophiuchi cloud complex
Image Credit: NASA, ESA, CSA, STScI, K. Pontoppidan (STScI), A. Pagan (STScI)

NGC3324 in the Carina Nebula
Image Credit: NASA, ESA, CSA, STScI

While there has been significant progress in understanding YSOs, they still hold many mysteries that need to be unravelled. Research studies such as these not only help us learn about our past but also take us one step further into exploring and understanding the infinite universe we live in.

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Krishali Shah is a student of Bachelor of Science (Honours) Physics Major at Ahmedabad University. She is passionate about Astronomy and Astrophysics. Currently, she is doing an Undergraduate Research Project with Professor Samyaday Choudhury on the topic of "Understanding BEAST and applying it to stars in the Magellanic Bridge." She aspires to pursue a PhD in Astronomy and Astrophysics.

Samyaday Choudhury is an Assistant Professor at the School of Arts and Sciences at Ahmedabad University. He earned his PhD degree from Indian Institute of Science, Bengaluru, in 2016. he was a 'Lee Wonchul Postdoctoral Fellow' at Yonsei University Observatory, South Korea, and a Postdoctoral Research Fellow at Macquarie University, Australia. His research interests are star formation, stellar evolution, galaxy evolution, space astronomy and big data analysis in astronomy.

A Turning Point in Cancer Therapy

Epigenetics Joins the Battlefront in Combatting Cancer

Writer and Illustrator **Pranav Prabhu** | *Science Mentor* **Ankit Naik**

With the inception of radiotherapy and chemotherapy, humanity believed that a successful cancer treatment method had been found and that cancer would cease to be a life-threatening condition. However, metastasis has proven to be a proverbial Achilles heel for us. Metastasis, a condition in cancer where cells spread throughout the body and invade other organs, has been the cause of more than 90 per cent of cancer-related deaths. It has single-handedly ruined the treatment options for cancer, reducing them to merely a game of odds where patients try to gamble away their health in hopes of killing the tumour.

What if cancer treatment wasn't a risky gamble but a sure-fire strategy for survival? What if we had the power to stop metastasis in its tracks? Imagine a world where the odds are stacked in our favour, where hope triumphs over uncertainty.

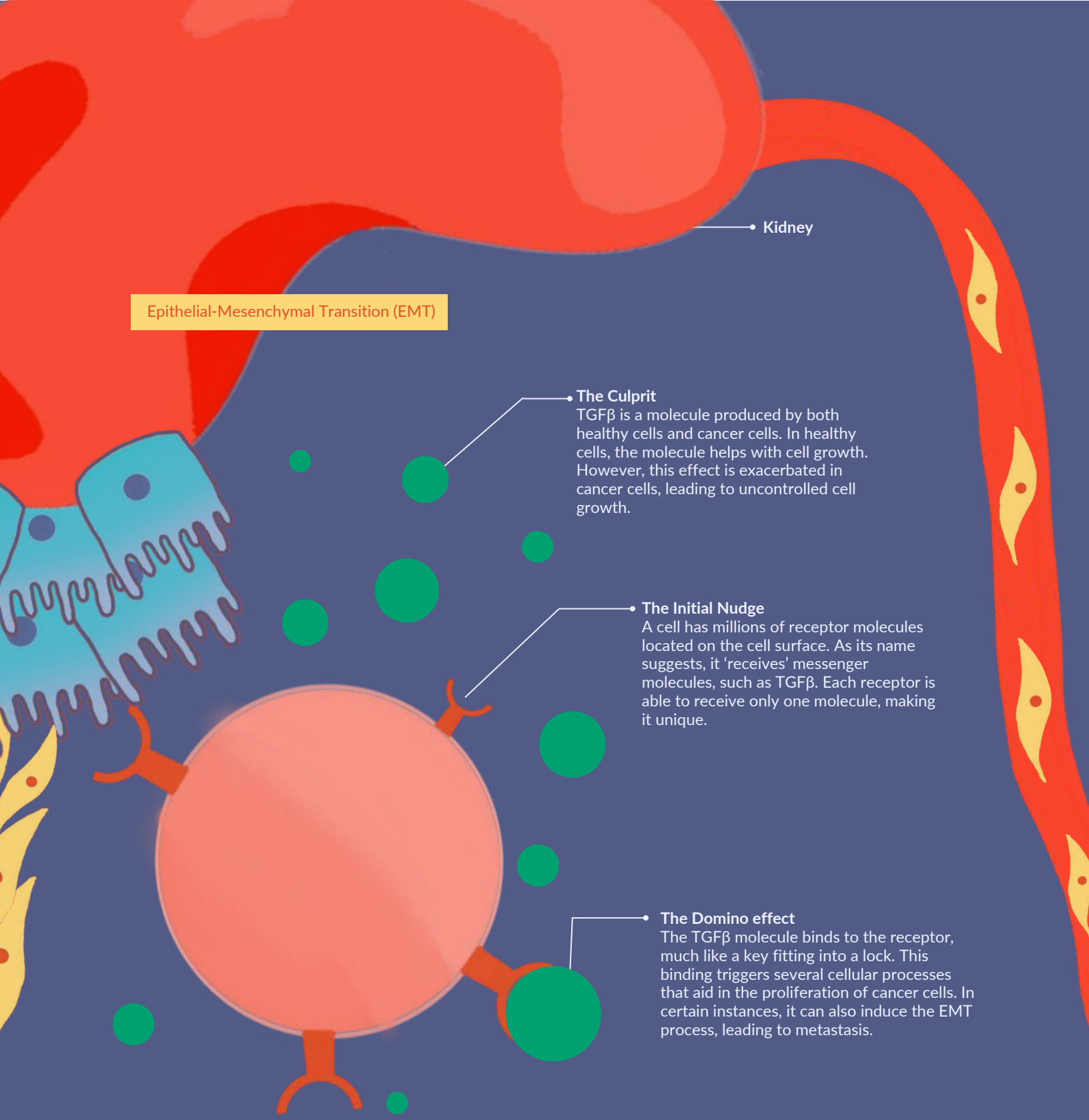
Cancer's Growth Tactics

Cells usually stuck to organ walls must change to travel in the bloodstream and invade other organs. This biological process is called Epithelial-Mesenchymal Transition (EMT). This is a prerequisite for metastasis, the spread of cancer cells.

Cancer Epithelial Cells
Cancer epithelial cells are bound to each other due to a group of molecules called the extracellular matrix. They cannot move away from each other and depend on an organ for survival.

Cancer Mesenchymal Cells
Cancer mesenchymal cells have enhanced mobility and invasive characteristics. They can survive the blood pressure and acclimate to new environments.

However, this process is not inherent to every cell and not all cancer cells undergo this transformation. Literature suggests that a molecule called TGFβ is responsible for triggering this transformation.



At first, scientists attempted to stop the binding of this molecule to the receptor. If the lock doesn't have a key, it is useless! Scientists tried to do this by using other molecules that are of similar shape. These molecules would sit on the receptors instead of TGFβ, stopping cancer cells from metastasising. Unfortunately, these medications cannot be cleared for clinical trials, meaning they cannot be used on humans. So what do we do now? Do we lay our hands down and wave the white flag? Scientists are still optimistic that there might be another way around it.

A New Approach After Failure

In response to the earlier failure, scientists have approached the problem differently. Ankit Naik, a Doctoral Scholar at the Cancer Biology Lab at Ahmedabad University, is working on halting the EMT process. To do so, he first had to understand how the Epithelial-Mesenchymal Transition (EMT) process is triggered.

1 **Human Cell: The Database**
The human cell has a database of information called DNA to dictate what action is required and when. All cells have the same database that remains unchanged.

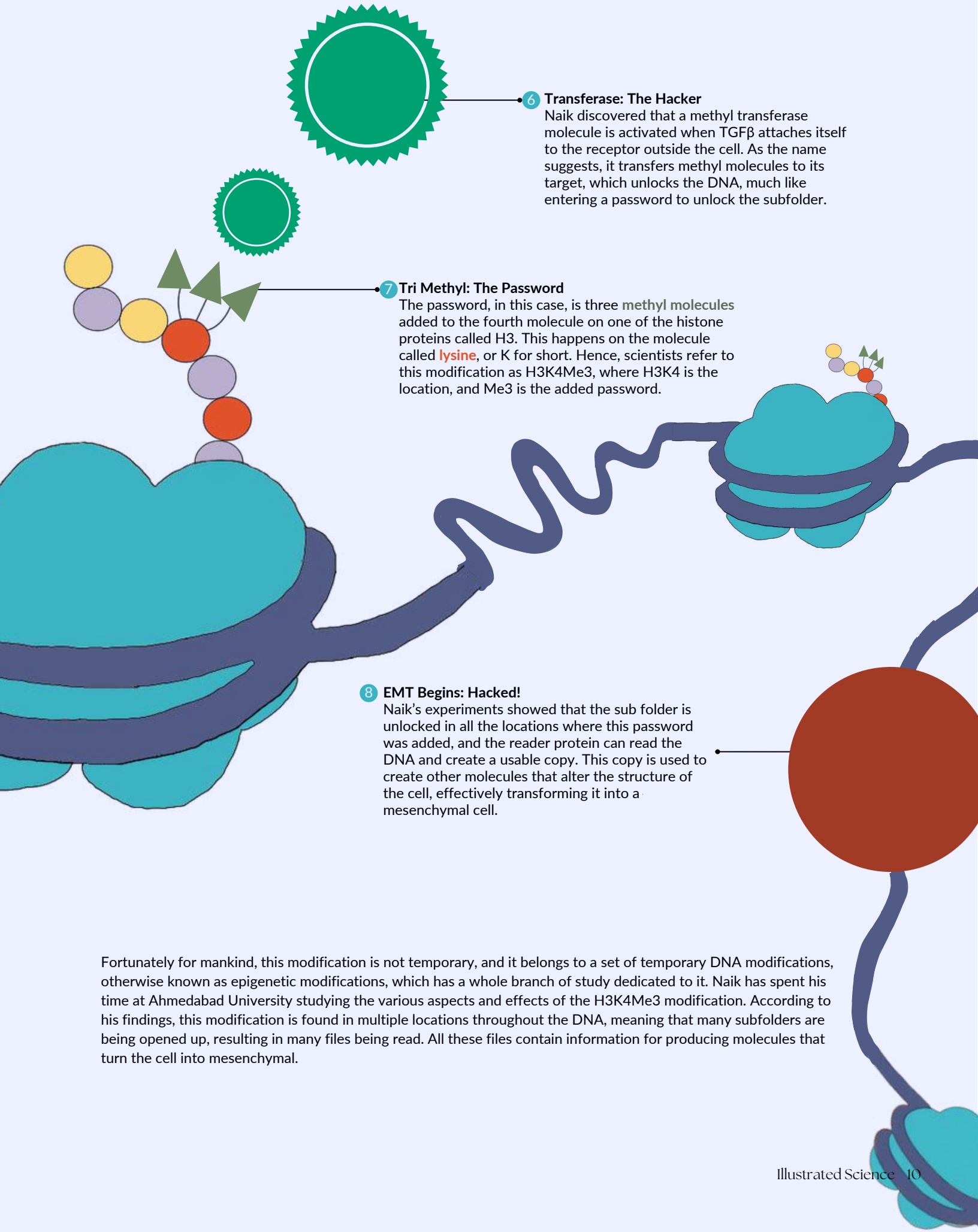
2 **Chromosomes: The Folders**
The entire database is divided into 46 folders called chromosomes. Each chromosome contains the part of DNA that carries the information for producing a molecule, known as a gene. This is much like how files are stored within a folder.

Gene

3 **Histone Proteins: The Subfolders**
A cell needs help to go through millions of such files and find the right one to read. Thus, cells use a group of proteins called histone proteins to divide the chromosome further into subfolders.

4 **Polymerase: The Copy Machine**
These are reader proteins. They are responsible for reading the file and making a copy that can be used by other parts of the cell without altering the central database.

5 **Restricted Access**
Genes that cause the EMT process to activate are usually not accessible to reader proteins, just like password protected files. Since a copy of the genes is not created, the cells do not turn mesenchymal.



6 **Transferase: The Hacker**
Naik discovered that a methyl transferase molecule is activated when TGFβ attaches itself to the receptor outside the cell. As the name suggests, it transfers methyl molecules to its target, which unlocks the DNA, much like entering a password to unlock the subfolder.

7 **Tri Methyl: The Password**
The password, in this case, is three **methyl molecules** added to the fourth molecule on one of the histone proteins called H3. This happens on the molecule called **lysine**, or K for short. Hence, scientists refer to this modification as H3K4Me3, where H3K4 is the location, and Me3 is the added password.

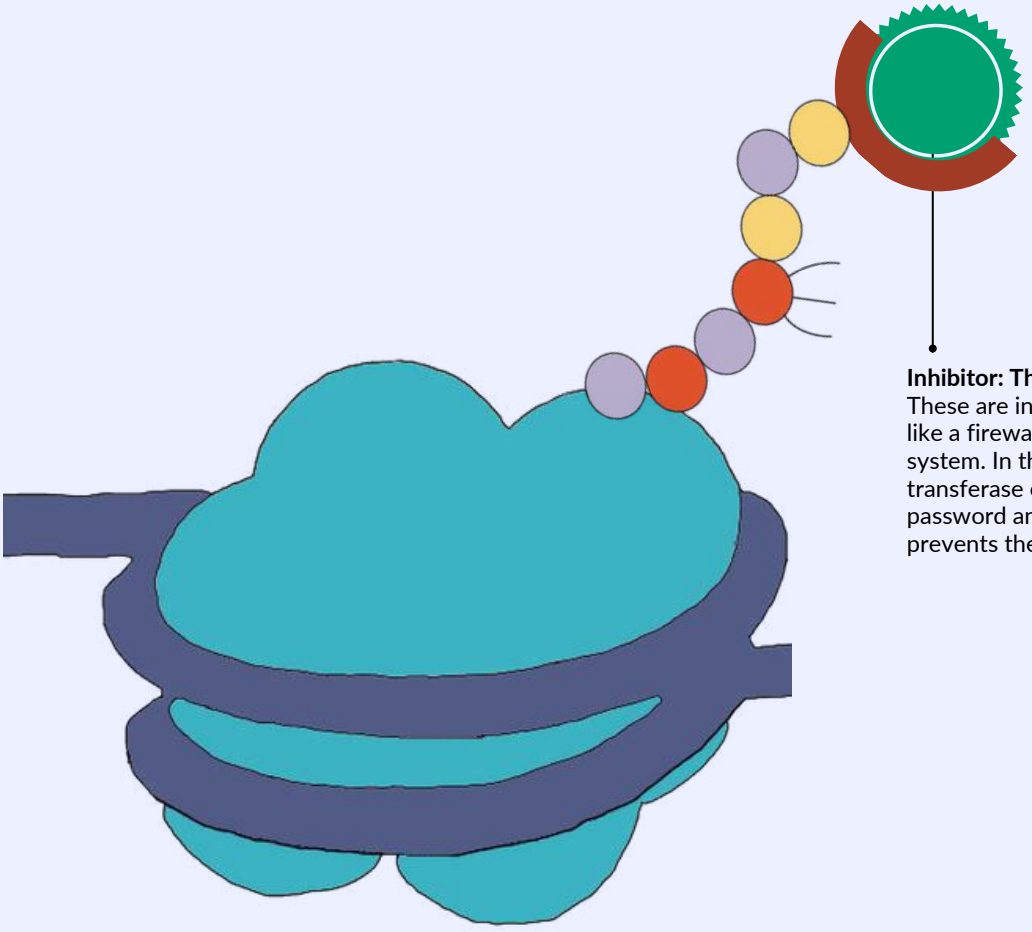
8 **EMT Begins: Hacked!**
Naik's experiments showed that the sub folder is unlocked in all the locations where this password was added, and the reader protein can read the DNA and create a usable copy. This copy is used to create other molecules that alter the structure of the cell, effectively transforming it into a mesenchymal cell.

Fortunately for mankind, this modification is not temporary, and it belongs to a set of temporary DNA modifications, otherwise known as epigenetic modifications, which has a whole branch of study dedicated to it. Naik has spent his time at Ahmedabad University studying the various aspects and effects of the H3K4Me3 modification. According to his findings, this modification is found in multiple locations throughout the DNA, meaning that many subfolders are being opened up, resulting in many files being read. All these files contain information for producing molecules that turn the cell into mesenchymal.

The Counter Attack: Naik's Relentless Attempts

According to Naik's preliminary research, he has established a significant connection between H3K4Me3 and the EMT process. By mapping out this modification's locations, he has demonstrated that it acts as an active marker, indicating which genes are activated. Naik has initiated efforts to prevent enzymes from adding methyl molecules to the histone proteins. If these active markers can be halted, those genes will not be accessible to reader proteins, thereby preventing the cell from undergoing mesenchymal transformation.

When asked about his line of research, he emphasised that researching the effect of such marks is a highly tedious procedure, with many researchers joining hands to reach a consensus. He explained that multiple researchers must obtain consistent results to ensure reliability. While he has submitted his preliminary results, other scientists must replicate his experiments before they can be trusted. Only when these replicated results match Naik's findings can the scientific community trust his paper. In the meantime, Naik has continued with his research and is focused on identifying a suitable molecule capable of inhibiting methyl transferase enzymes - these molecules are referred to as inhibitors.



Inhibitor: The Firewall
These are inhibitor molecules. They function like a firewall, keeping hackers out of the system. In the cell, they stop the methyl transferase enzyme from adding the password and unlocking the DNA, which prevents the cell from turning mesenchymal.

Naik said, "My research does not aim to discover a magical, cure-all pill for cancer. I hope my research helps develop a supplemental therapy option that can greatly increase a patient's odds of survival." His therapy option will reduce the chances of metastasis, which is the primary cause of death in cancer cases. By eliminating the fatal possibility of metastasis, treating cancer would become more manageable, thus enabling doctors to provide better care.

Success Stories

Tazemetostat is an FDA approved medication that works on similar principles. It has already been used on many patients and has shown promising results in the corporate world. It treats a slow-growing type of cancer, and it has demonstrated long-lasting results on several occasions.

Another medication called GSK-J4 is an inhibitor for an enzyme that is responsible for the removal of methyl molecules from histone proteins. It has shown promise in reducing cancer cells' invasion and migration capabilities and increased repair of damaged DNA.

Finally, a plant chemical called Hesperetin has shown promise in stopping gastric cancer cells from developing and spreading. This chemical is found in citrus fruits and is responsible for its flavour. It also helps in killing cancer cells.

A Ray of Hope

This new approach to providing cancer patients with some more hope, ensuring that they have a better chance of survival, has been garnering more attention in scientific communities and in the general public. If Naik is successful in his research, his medication will have massive potential in the market. We would have not only gained the upper hand in the battle against cancer, but we would also have a greater understanding of the complexities of cancer. Never has humanity faced a disease this firm and this complex, akin to the Hydra. Decoding the mechanisms of cancer has always been and will always be a herculean task. But we must remember, Heracles did not triumph against the Hydra alone... he had help. Help from a young lad, Iolaus.

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Pranav Prabhu is a student of Integrated Master of Science at Ahmedabad University. He has been interested in all domains of science. He views science as not only a subject but a way of life. His illustration aims to inform people about an up-and-coming treatment method for cancer that has shown promise. Not only does he want people to realise its potential, he also wants them to understand its primary mechanism. He believes science is easy to understand only if it is explained correctly.

Ankit Naik is a Doctoral Scholar and a DST-INSPIRE Fellow in the Cancer Biology Lab at the School of Arts and Sciences at Ahmedabad University. His research interests lie in Cancer epigenetics, especially in the role of various histone modifications in dictating the gene expression in cancer cells. With modern technology, he is working towards understanding the connection between TGFβ Signaling and different epigenetic modifications in cancer. He aims to decode the changes in the underlying Histone methylation landscape in cancer cells, especially during the Epithelial-to-Mesenchymal Transition process.

What is in the Air We Breathe?

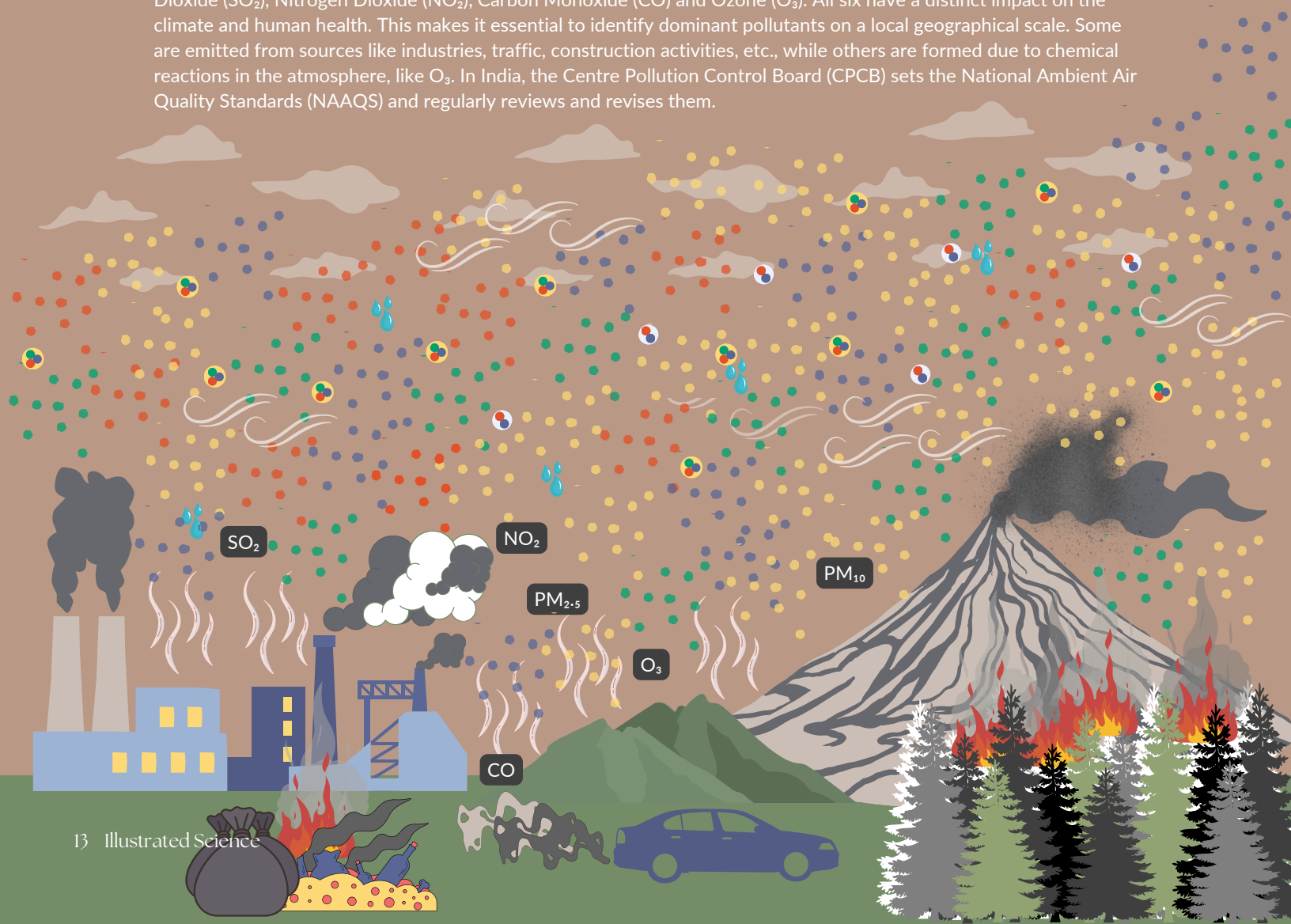
Chaotic and Complex Nature of Air Pollution in Ahmedabad

Writer and Illustrator **Pratix Ruparel** | *Science Mentor* **Aditya Vaishya**

Imagine standing in a bustling city centre. As you breathe in the air, you might not realize that every breath contains a complex mix of pollutants. But what if you get to know that the air you breathe could be drastically different just a few kilometres away? Do summers boast cleaner skies, or does winter's chill bring a clear breath? From bustling metro cities like Ahmedabad to serene hill stations like Mussoorie, every corner of our planet holds a distinct blend of pollutants shaped by various factors. How does pollution vary from place to place, and what does it mean for our health and environment? The chaotic and complex nature of air pollution makes identifying its sources challenging, especially since a region is influenced by its meteorological parameters.

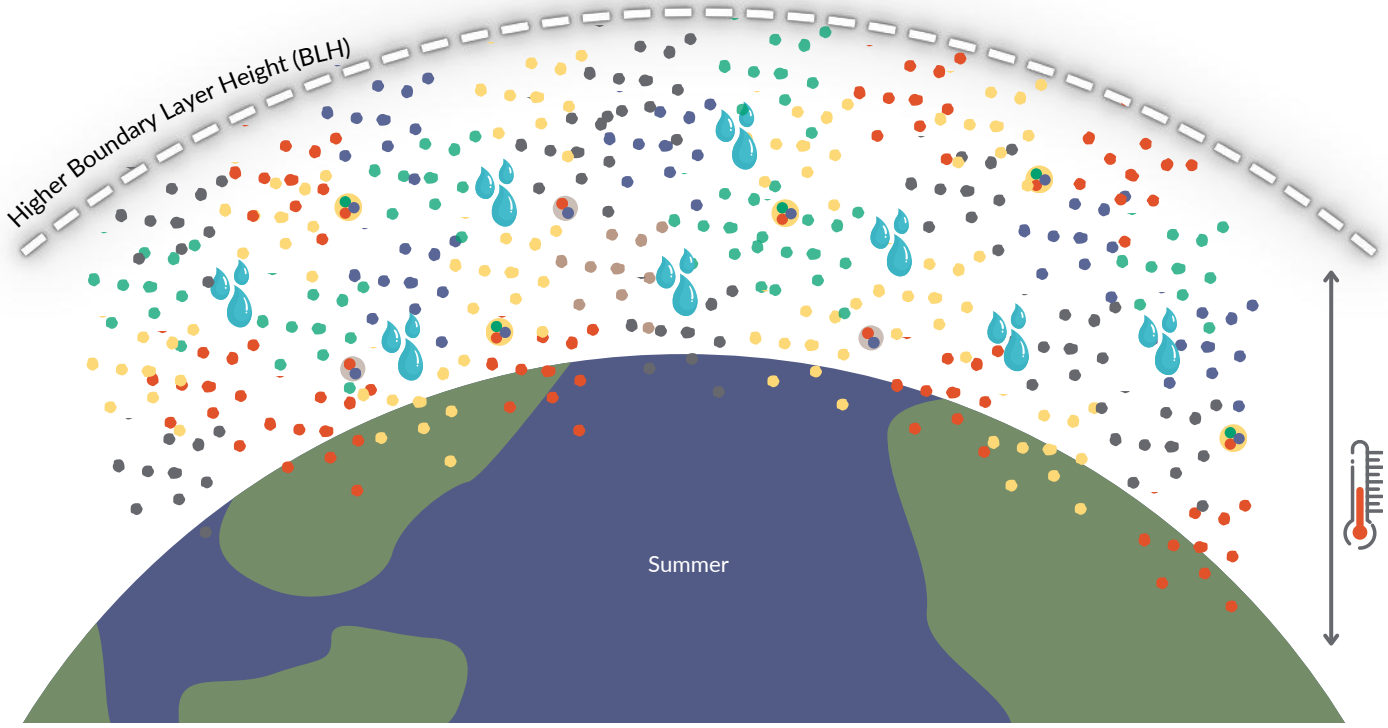
What Qualifies as an Air Pollutant?

A set of six air pollutants, known as criteria air pollutants, are monitored and regulated by governmental agencies due to their harmful effects on human health and the environment. These are Particulate Matter (PM_{10} and $PM_{2.5}$), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO) and Ozone (O_3). All six have a distinct impact on the climate and human health. This makes it essential to identify dominant pollutants on a local geographical scale. Some are emitted from sources like industries, traffic, construction activities, etc., while others are formed due to chemical reactions in the atmosphere, like O_3. In India, the Centre Pollution Control Board (CPCB) sets the National Ambient Air Quality Standards (NAAQS) and regularly reviews and revises them.

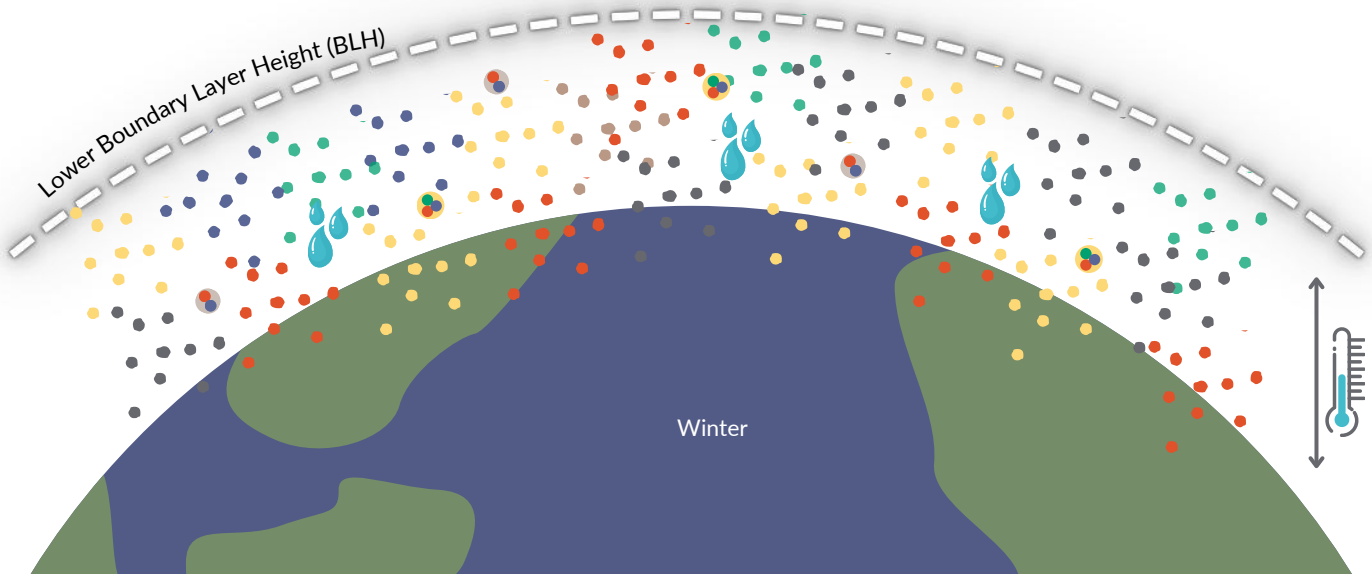


Earth's Boundary Layer Dynamics

The height from the Earth's surface to the point where the effect of surface-emitted radiation is present is known as the Boundary Layer Height. The properties of the air above this layer are more influenced by large-scale atmospheric processes rather than local surface effects. The height of the boundary layer usually governs the concentration of pollutants. The pollutant concentration is higher when the boundary layer height is lower and vice-versa. This height can fluctuate from as little as ten meters during a cold winter night to several kilometres above a desert region during a hot sunny day.



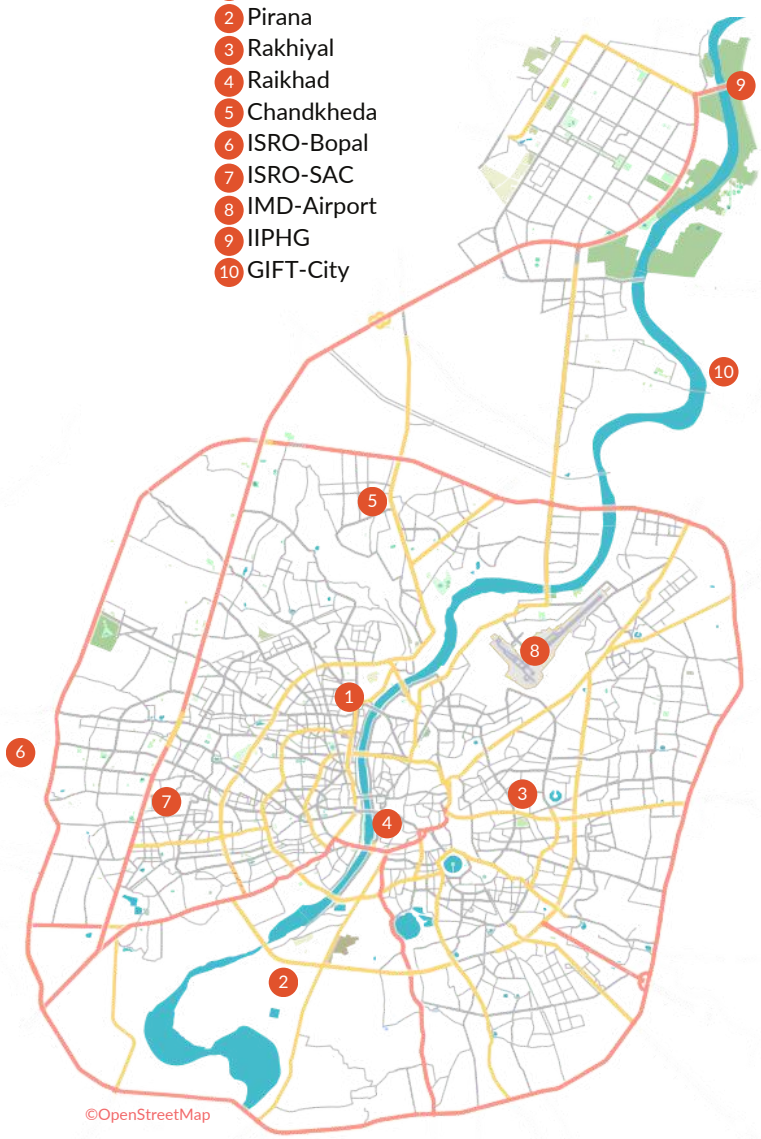
High Temperature • More Humidity • More Dispersion • More Air Circulation • Lower Pollutant Concentration



Low Temperature • Less Humidity • Less Dispersion • Less Air Circulation • High Concentration of Pollutants

Measuring Air Pollution in Ahmedabad

Researchers from national institutions in India studied criteria pollutants across three years and in various geographical locations within Ahmedabad, India. Ahmedabad is an exciting study site because it is a highly populated metro city with a semi-arid hot climate in Gujarat. Gufran Beig, who administered this study, served as the Program Director of the System of Air Quality and Weather Forecasting and Research (SAFAR) by the Ministry of Earth Sciences, Government of India. The SAFAR network was established in Ahmedabad in 2017 and spans ten locations. The study collected meteorological data from SAFAR datasets and hourly concentrations of various pollutants using various instruments from 2017-2019.



SAFAR Automatic Weather Station (AWS)
Automatic Weather Stations collect real-time data on meteorology parameters such as temperature, humidity, wind speed, and wind direction from different locations. This data can be used for various purposes, such as studying microclimates, investigating weather patterns, or validating weather models.

Instruments Measuring Pollutant Concentration
Researchers used various instruments to measure pollutants: a Beta Attenuation Monitor for particulate matter, an online analyzer based on ultraviolet fluorescence for SO_2, the chemiluminescence detection method for NO_2, Non-Dispersive Infra-Red detectors for CO, and a UV photometric analyzer for O_3.

Boundary Layer Height
BLH data was recorded from the Copernicus Climate Change Service (C3S).

How was this Massive Data Analysed to Map Pollution Patterns?

A study across time and geographical locations helps understand the dynamics of dispersion, transportation and dilution due to meteorological processes and how they affect the concentration of criteria pollutants. The researchers used statistical tools to analyse the data and understand how weather conditions relate to changes in air pollution levels in Ahmedabad. Some insights from the study are given below:

1. **Temporal and Spatial Average Analysis**
Average values of pollution and meteorological parameters over three years, 2017-2019, to understand how they behaved over time. How have pollution levels varied across locations?

2. **Seasonal Variability Analysis**
The researchers divided the year into four seasons - Pre-Monsoon, Monsoon, Post-Monsoon, and Winter - to see the variation in dispersion of pollutant concentrations and their heterogeneity across different locations.

3. **Weather and Pollution Dispersion Patterns**
The researchers examined how pollution levels were related to various meteorological factors such as temperature, relative humidity, wind speed, boundary layer height (BLH) etc. How air pollutants are effectively dispersed or accumulated in the atmosphere.

Highest Concentration vs. Location
PM_{10} Raikhad
NO_2 Rakhiyal
$PM_{2.5}$ Pirana
CO S.P. Stadium
SO_2 Pirana
O_3 GIFT City

2018
High Concentration
2019: Four Cyclonic Activities in the Arabian Sea
Rain
Low Concentration

Seasonal Variability of Pollutant Concentration
PM_{10} $PM_{2.5}$ Post-monsoon followed by Monsoon
NO_2 O_3 SO_2 Post-monsoon followed by Pre-monsoon
CO Winter followed by Post-monsoon

Seasonal PM Variation
PM_{10} Monsoon
PM_{10} $PM_{2.5}$ Winter

Concentration Variation
Summer to Monsoon
Monsoon to Winter

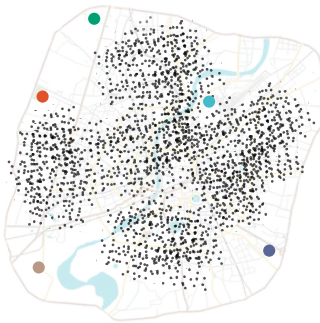
Pre-monsoon strong winds from Thar Desert
PM_{10} $PM_{2.5}$

ISRO-SAC
Highest Wind Speed $PM_{2.5}$
Faster Dispersion PM_{10}

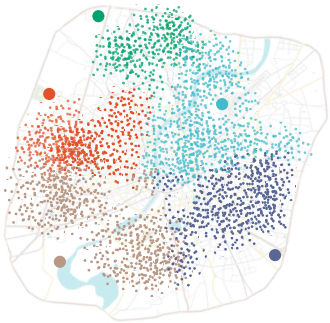
Post-monsoon Maritime breezes
Highest variation
Higher concentration
Increased Pollutant mixing processes

Clustering Identical Stations

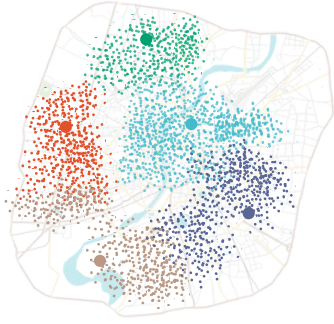
K-means clustering, a popular technique used in data science, was applied to the data of the ten stations from Dec 2017 to Feb 2020. The task was to identify the distinct clusters based on a variation of the six air pollutants across ten stations. Let us understand this technique was used to create these clusters based on the data.



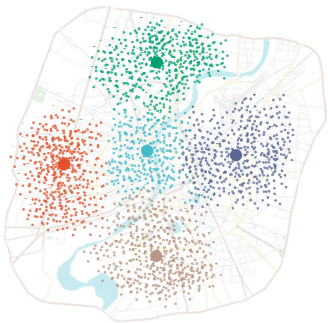
Step 1
All data points are plotted on a plane and five cluster centroids are placed on random positions.



Step 2
Each data point is assigned to the nearest centroid to form an initial cluster.



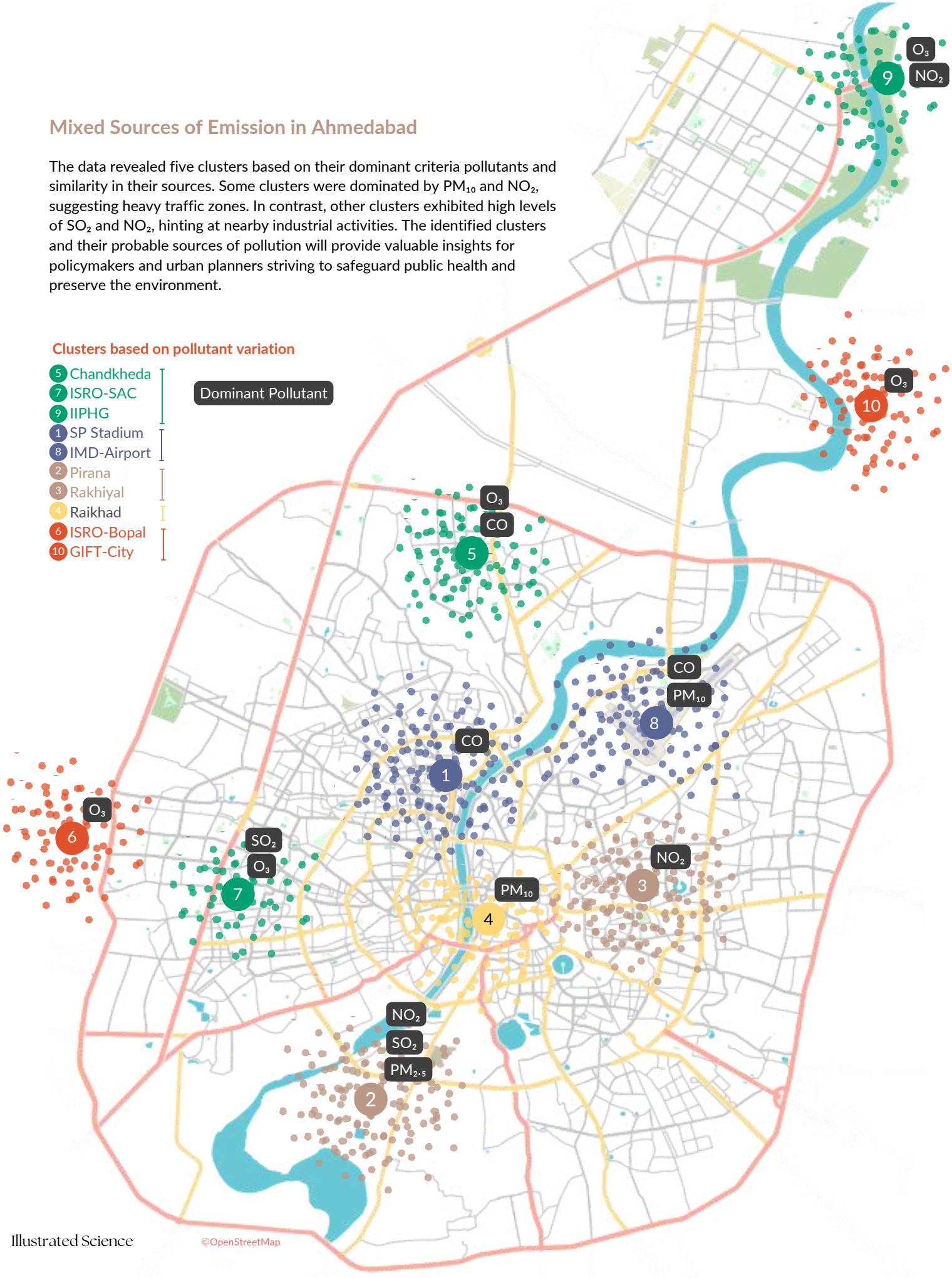
Step 3
Centroid positions are re-calculated based on average distance and repositioned. Each data point is then reassigned to the nearest centroid.



Step 4
Steps 2 and 3 are repeated until the centroids no longer change significantly, thus forming the final clusters.

Mixed Sources of Emission in Ahmedabad

The data revealed five clusters based on their dominant criteria pollutants and similarity in their sources. Some clusters were dominated by PM_{10} and NO_2, suggesting heavy traffic zones. In contrast, other clusters exhibited high levels of SO_2 and NO_2, hinting at nearby industrial activities. The identified clusters and their probable sources of pollution will provide valuable insights for policymakers and urban planners striving to safeguard public health and preserve the environment.



1 SP Stadium
8 IMD-Airport

Emissions from vehicles especially diesel powered vehicles. Paper and Textile industries. Open land dust.

Residential zone

2 Pirana
3 Rakhiyal

Emissions from vehicles especially diesel powered vehicles. Textile and metal Industries. Traffic. Dumpyard.

Industrial zone

6 ISRO-Bopal
10 GIFT-City

Mixed sources. Agricultural activities. Construction activities. Emissions from heavy-duty vehicles. Tailpipe. Biomass burning and incomplete combustion.

Mixed Sources zone

5 Chandkheda
7 ISRO-SAC
9 IIPHG

Vehicles. Biomass burning. Thermal power plants. ISRO-Sac and IIPHG have high wind speed. This fastens dispersion of PM resulting in lower concentration.

Cleaner evironment zone

4 Raikhad

Heavy-duty diesel-fueled vehicles. Local area emissions, re-suspension of road dust. Construction activities. Biomass burning and incomplete combustion. Ozone formation in presence of other pollutants and sunlight.

High Traffic density zone

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Pratix Ruparel is a student of Bachelor of Business Administration (Honours) at Ahmedabad University. This project was undertaken to demonstrate the significance of air pollution in our surroundings by scientifically showcasing the pollutant concentration in each area. He aims to simplify science and scientific research for general audience to increase the reach of popular, day-to-day science.

Aditya Vaishya is an Assistant Professor at the School of Arts and Sciences at Ahmedabad University. He is an Atmospheric Physicist and heads the 'Air and Climate Research Laboratory' at Ahmedabad University. His research interests include aerosol-cloud-radiation interaction, the development of lightweight sensors for atmospheric studies, and air quality modelling. He teaches courses in core areas of physics, air quality, atmospheric physics, and climate. He obtained his PhD from the Centre for Climate and Air Pollution Studies and the School of Physics, National University of Ireland Galway.

A Silent Threat in Every Breath

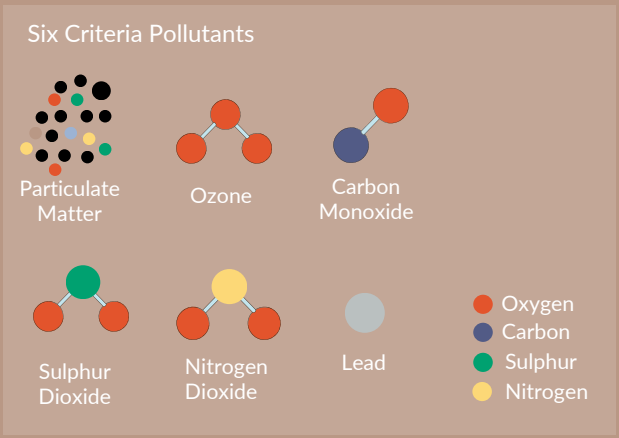
Particulate Pollution and its Impact on Human Health

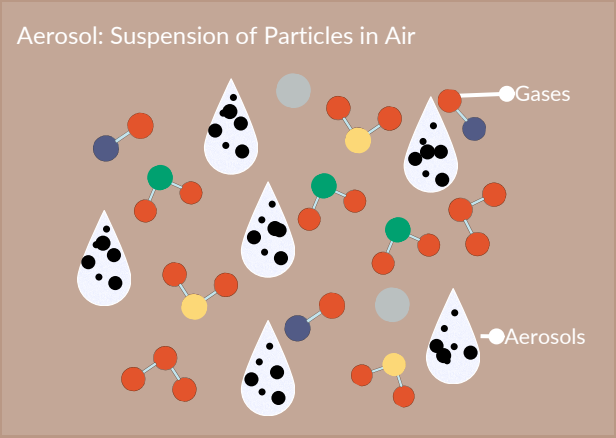
Writer and Illustrator **Malav Dhruv** | *Science Mentor* **Aditya Vaishya**

A silent menace drifts amid the air we breathe. Particulate pollution is invisible to the naked eye yet significantly impactful to the environment and health of millions worldwide. These particles, known as particulate matter, are a complex mixture of tiny particles, liquid droplets, and gases. They are emitted from various sources such as vehicles, industrial processes, and natural sources like dust storms and wildfires.

Aerosol Particles vs. Gases

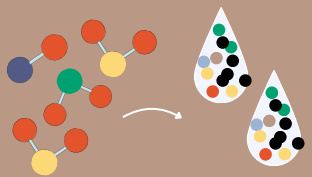
In the aerosol state, matter exists as fine solid or liquid particles suspended in a gaseous medium. The size of particles can vary between nanometers to micrometers (μm). In the gaseous state, matter exists as individual molecules or atoms that are free to move and diffuse throughout a container, filling its volume uniformly.





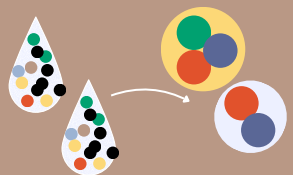
Formation of Particulate Matter

Particulate matter (PM) is formed by primary or secondary processes in the atmosphere. Primary processes include nucleation, coagulation, condensation, and mechanical disintegration. Secondary processes include gas-to-particle conversion, etc. There are several types of particulate matter (PM). Particulate contaminants include smog, soot, tobacco smoke, oil smoke, fly ash, and cement dust. Biological Contaminants include microorganisms like bacteria, viruses, fungi, and bacterial spores and allergens. Dust includes suspended atmospheric dust, settling dust, and heavy dust.



Nucleation
Gas molecules come together and form nanometer size aerosols

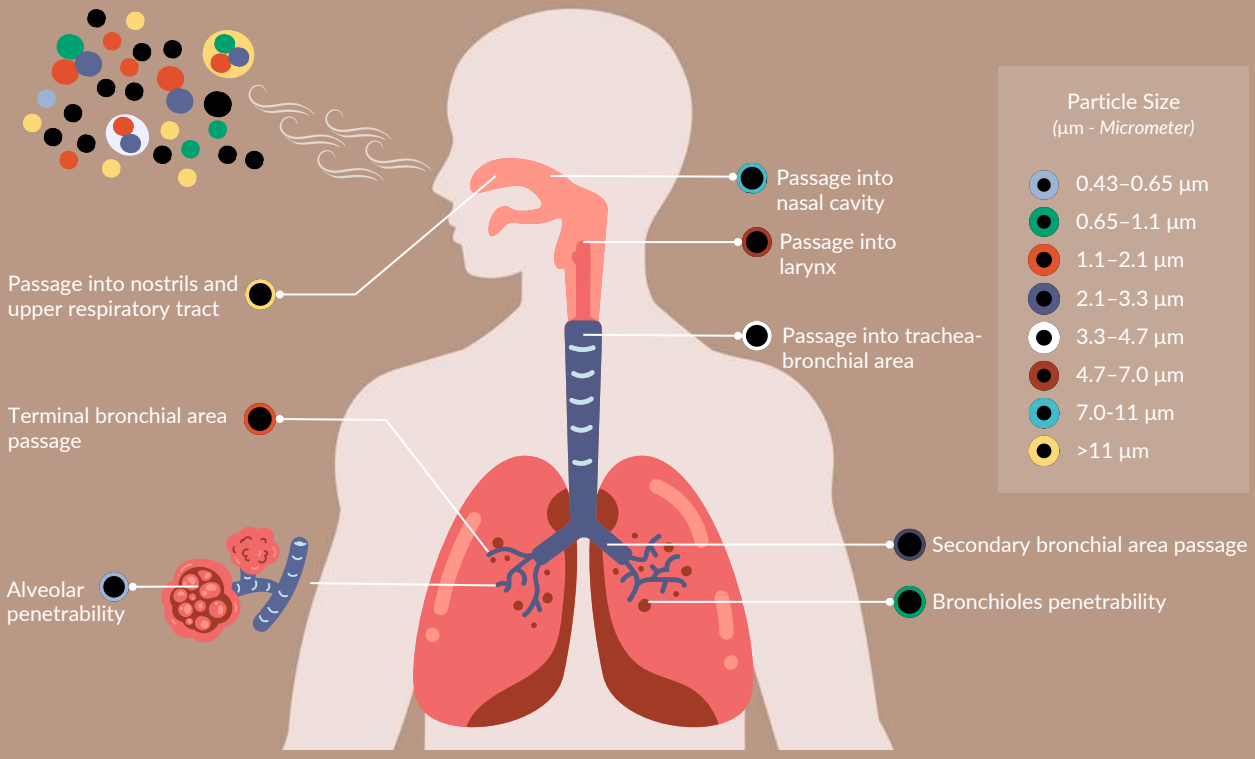
Condensation
Gas condenses into tiny droplets and settles on surface of particles



Coagulation
Nanometer size particles group together to form larger particles

Health Impacts of Inhaling Particulate Matter

Once inhaled, particles can penetrate deep into the lungs and even enter the bloodstream, causing a range of health problems. For comparison, the diameter of a human hair is 50-70 µm while particles are <10 µm in diameter (PM_{10}) and fine particles are <2.5 µm ($PM_{2.5}$).



The short-term effects can range from mild irritation in the eyes, nose, skin, and throat to more serious illnesses like asthma, pneumonia, bronchitis, lung, and heart problems. They can also include wheezing, coughing, and tightness in the chest. A brief exposure to air pollution can also cause nausea, dizziness, and severe headaches. Chronic long term effects from carcinogenic particulate matter include cancer, which can be fatal and persist for years at a time, it can also cause harm to the neurological, reproductive, and respiratory systems.

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Malav Dhruv is a student of Bachelor of Technology (Mechanical Engineering) at Ahmedabad University. He is interested in aerospace technology in Design Thinking and Problem Solving. He is eco-conscious and a strong supporter of a green and clean environment. He has a strong goal for developing and promoting greener and cleaner technologies.

Aditya Vaishya is an Assistant Professor at the School of Arts and Sciences at Ahmedabad University. He is an Atmospheric Physicist and heads the 'Air and Climate Research Laboratory' at Ahmedabad University. His research interests include aerosol-cloud-radiation interaction, the development of lightweight sensors for atmospheric studies, and air quality modelling. He teaches courses in core areas of physics, air quality, atmospheric physics, and climate. He obtained his PhD from the Centre for Climate and Air Pollution Studies and the School of Physics, National University of Ireland Galway.

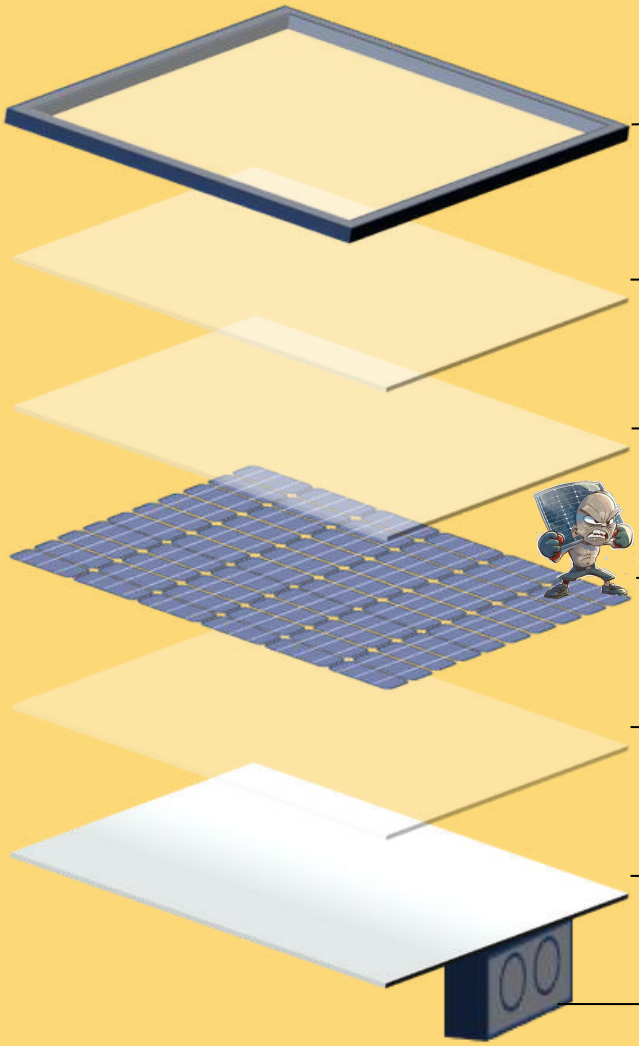
This Material Can Revolutionise How We Use Solar Energy

Writer and Illustrator **Krish Kotecha** | *Science Mentor* **Mayuribala Mangrulkar**

Solar panels are often considered one of the most promising alternatives to non-renewable sources to counter global warming. However, they are still competing to match the energy efficiency provided by non-renewable resources. Solar panels offer an efficiency of 15-20%, compared to a 60% and 40% efficiency of gas and coal (La Solar group, 2022). Researchers are attempting to increase the efficiency rate by exploring the core material of solar panels, a semiconductor that helps generate electricity.

Silicon Solar Cells

Traditionally, solar cell panels are made with silicon, a semiconductor material. The solar cells are placed at the center of the panel, whilst the rest of the elements of the solar panel aim to maximise the overall performance of the solar cells.



Aluminum frame
Provides protection and structural support to the solar cells

Tempered Glass
Transparency allows sunlight to efficiently reach the solar cells while protecting them

Encapsulant
Protects front side of cells from moisture, dust and other environmental factors. Prevents electricity from leaking out

Silicon Solar Cells
The most important part of solar panel as it absorbs and converts sunlight into electricity

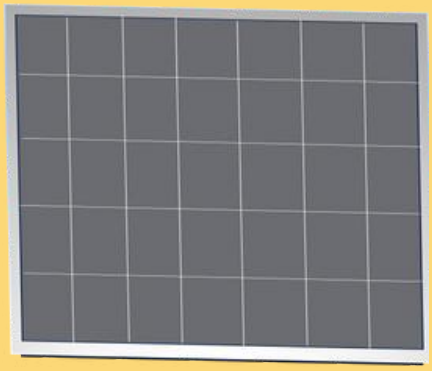
Encapsulant
Protects back side of cells from moisture, dust and other environmental factors. Prevents electricity from leaking out

Back Sheet
Acts as an electric insulator and protects the inner components of the panel

Junction Box
Connects the solar panel to grid lines while ensuring that they work effectively.

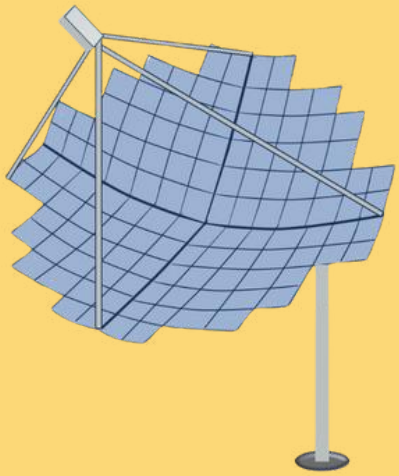
Alternative Materials for Solar Cells

Many alternative materials have been investigated to replace conventional silicon-made solar cells. Each of these materials has its own advantages as well as shortcomings.



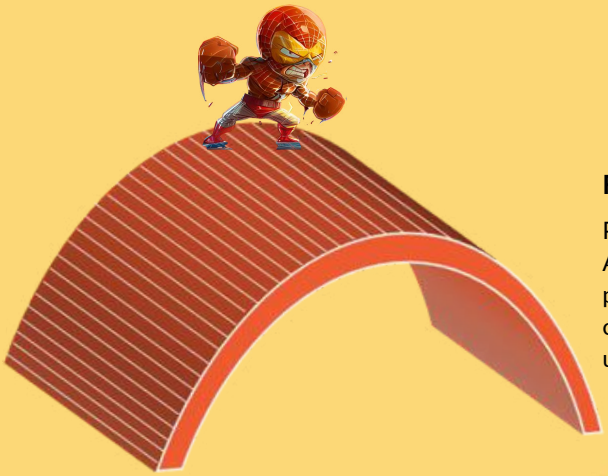
Cadmium Telluride Solar Cells

These solar panels are made from thin layers of Cadmium Telluride, a compound that is also a semiconductor. These solar panels are lightweight and provide higher efficiency than silicon solar panels.



Solar Concentrator

Solar concentrator systems are commonly made of semiconductors such as gallium arsenide. These solar panels can generate electrical and thermal energy and possess high energy storage capabilities.



Flexible Perovskite Solar Cells

Perovskite materials are materials with a unique ABX_3 crystal structure formula. A and B are usually positively charged metal ions, and X is a negatively charged ion. This structure gives the material its unique ability to convert sunlight into electricity.

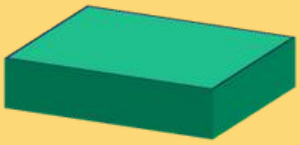
Perovskite Solar Cells		Silicon Solar Cells
Reached 26.1% efficiency, with potential for further improvement	**Efficiency**	Reached the maximum efficiency rate of ~23%
Low cost and easier to produce due to solution process ability	**Production Cost**	Costly: High material processing and complex manufacturing
Highly flexible, can adhere to walls or specific devices	**Flexibility**	Not flexible and often requires large spaces for assembling
Deteriorates very quickly when exposed to dust and extreme heat	**Durability**	Extremely durable with ability to last for as long as 25 years

How are Perovskite Solar Cells Fabricated?

The solution process ability and lower cost of production, which is almost half of traditional silicon solar cells, make the perovskite material attractive for manufacturing. Preparing perovskite solar cell solutions is easy as perovskite materials dissolve in suitable solvents, forming a liquid solution. There are five primary methods for this solution-based fabrication process, all requiring a perovskite solution and substrate.

Perovskite Solution

Perovskite material is dissolved in suitable solvents to turn it into a liquid solution

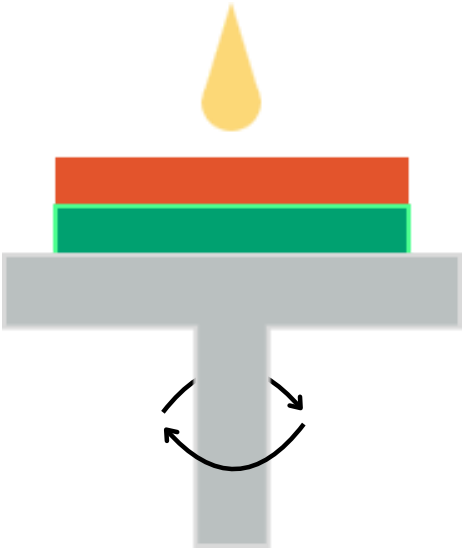


Substrate

Surface where perovskite solution is deposited and combined with other cell components

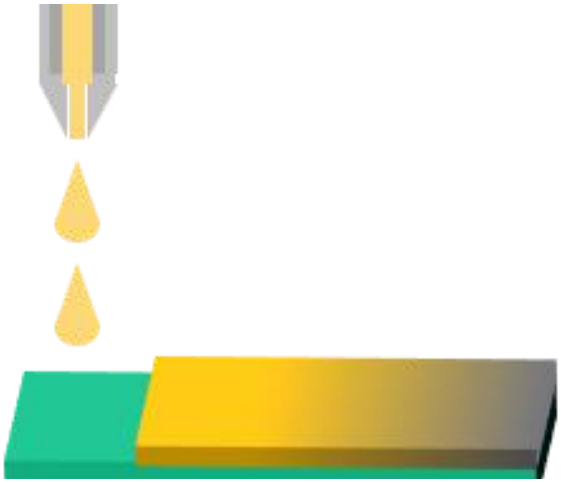
Method 1 Spin Coating

A small amount of perovskite solution is deposited onto a spinning substrate. This spreads it evenly across the surface. One significant advantage of this technique is its precise control over layer thickness, which is helpful in research and development.



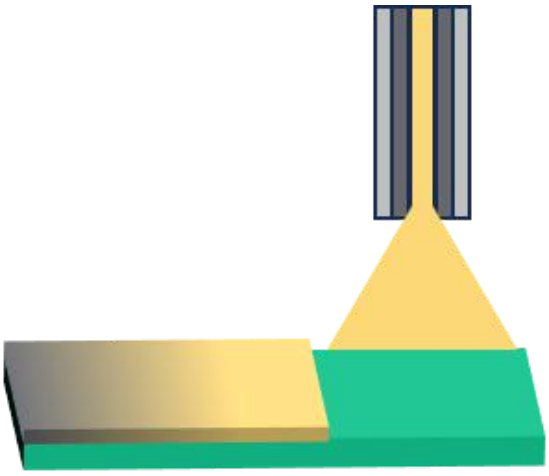
Method 2 Inkjet Printing

An inkjet printer deposits small amounts of perovskite solution onto the substrate to form the perovskite layer. This approach is helpful for large-size panels.



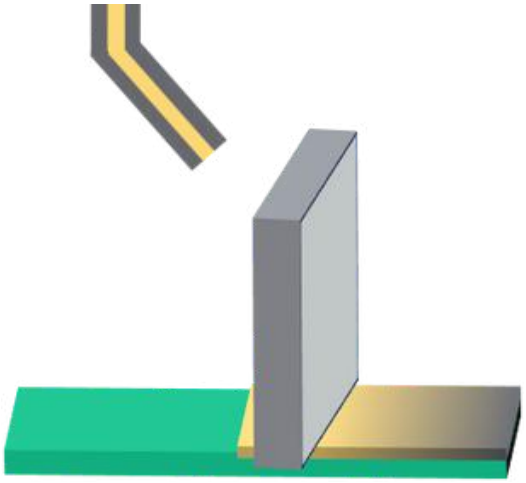
Method 3 Spray Coating

A mist of perovskite solution will be sprayed on the substrate. It is primarily applicable when the perovskite solution must be deposited on a substrate with a larger surface area.



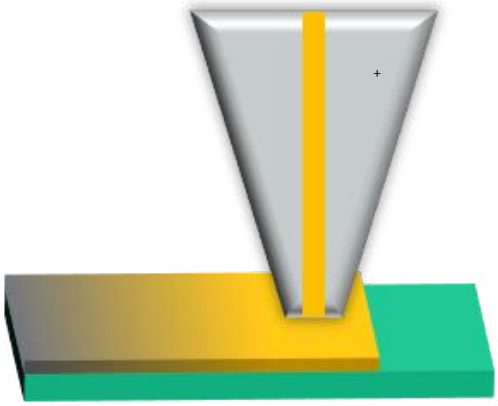
Method 4 **Blade Coating**

A blade or a knife is used to spread the perovskite solution across the substrate



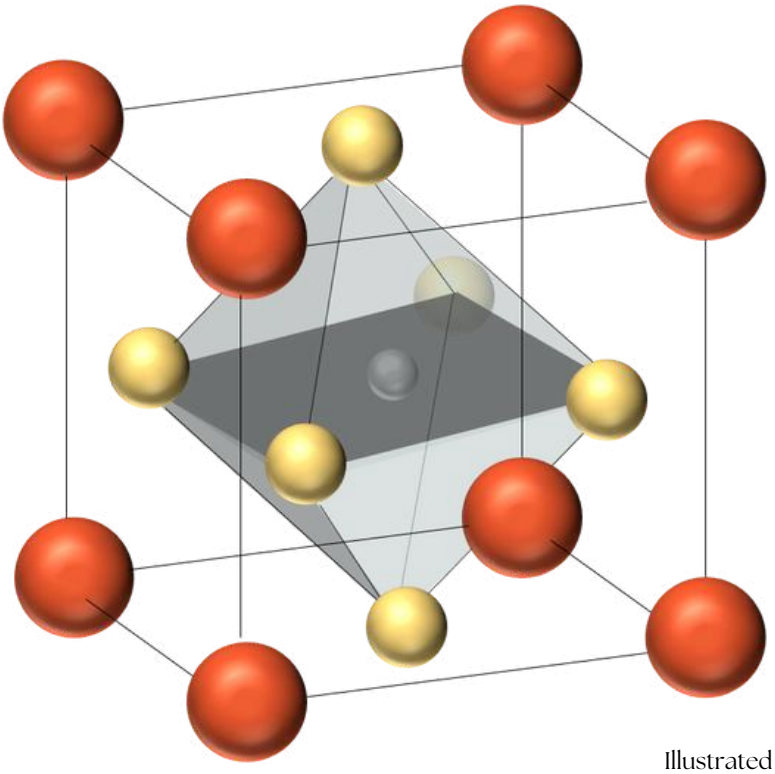
Method 5 **Slot-die Coating**

A thin stream of perovskite solution is passed onto the substrate through a narrow slot



Material Edge of Perovskite Solar Cells

The complete fabrication process of perovskite solar cells involves many layers of deposition on the substrate, which completes the formation of the entire solar cell device. These involve the Electron Transport Layer (ETL), Hole Transport Layer (HTL) and Transparent Conductive Oxide (TCO). When the sunlight hits the perovskite layer, it creates electrons and holes. The electron transport layer helps to transport these electrons to the electrode, while holes are transported to the electrode by the hole transport layer. Thus, charges are extracted from the external circuit. The Transparent Conductive Oxide (TCO) allows the sunlight to pass through the perovskite layer. Therefore, light is converted into electricity. The flexible perovskite solar cells have a huge edge over traditional solar cells when it comes to factors such as maximizing usage of space, high portability, and adaptability to different surfaces. But what gives these perovskite based solar panel such material proprieties?



Inner Structure

The perovskite photoactive layer is made up of a chemical structure represented by ABX_3

- 'A' corresponds to a larger monovalent cation and can be as Cs_+ or Methylammonium.
- 'B' corresponds to a divalent cation and can be as Pb^{2+} or Sn^{2+}
- 'X' corresponds to anion and can be as I^-, Cl^-, Br^-

Material Science Researchers Changing the Landscape of Solar Energy

Despite the various advantages of perovskite based photovoltaic technology, perovskite solar cells face stability challenges due to their sensitivity to environmental parameters. This hinders their commercial application in the absence of long-term stability. Therefore, the research community is working to overcome stability problems by using various routes, such as adding different materials in the perovskite matrix, passivating perovskite layers or encapsulating perovskite solar cells.

Mayuribala Mangrulkar, a Material Science Professor at Ahmedabad University, focuses on improving the stability of perovskite thin film and solar cells in her research. In one of her experiments, she demonstrated that mixing perovskite with Hydrazinium Iodide can help to improve the stability of the absorption layer and perovskite solar cells. Mangrulkar's other study showed that compounds such as Lactose and Mercaptosuccinic acid addition to perovskite matrix could also significantly improve perovskite solar cells' stability. Her research is crucial in improving the stability of perovskite based solar cells and makes their mass commercialization possible in the near future.

At this rate, we are headed towards a future where perovskite solar cells will change the landscape of solar energy. They can be attached to the walls of a house or even on particular devices. Their high flexibility, cost-effectiveness, and a bunch of scalable production processes have drawn the interest of the scientific community and that of the solar power industry. With more and more investments being brought on to develop this technology, it could evolve rapidly and change how solar energy is perceived and implemented. The exponential rise of perovskite solar cells is a formidable step to counter global warming, and it is a certainty that we are in for a very exciting future.

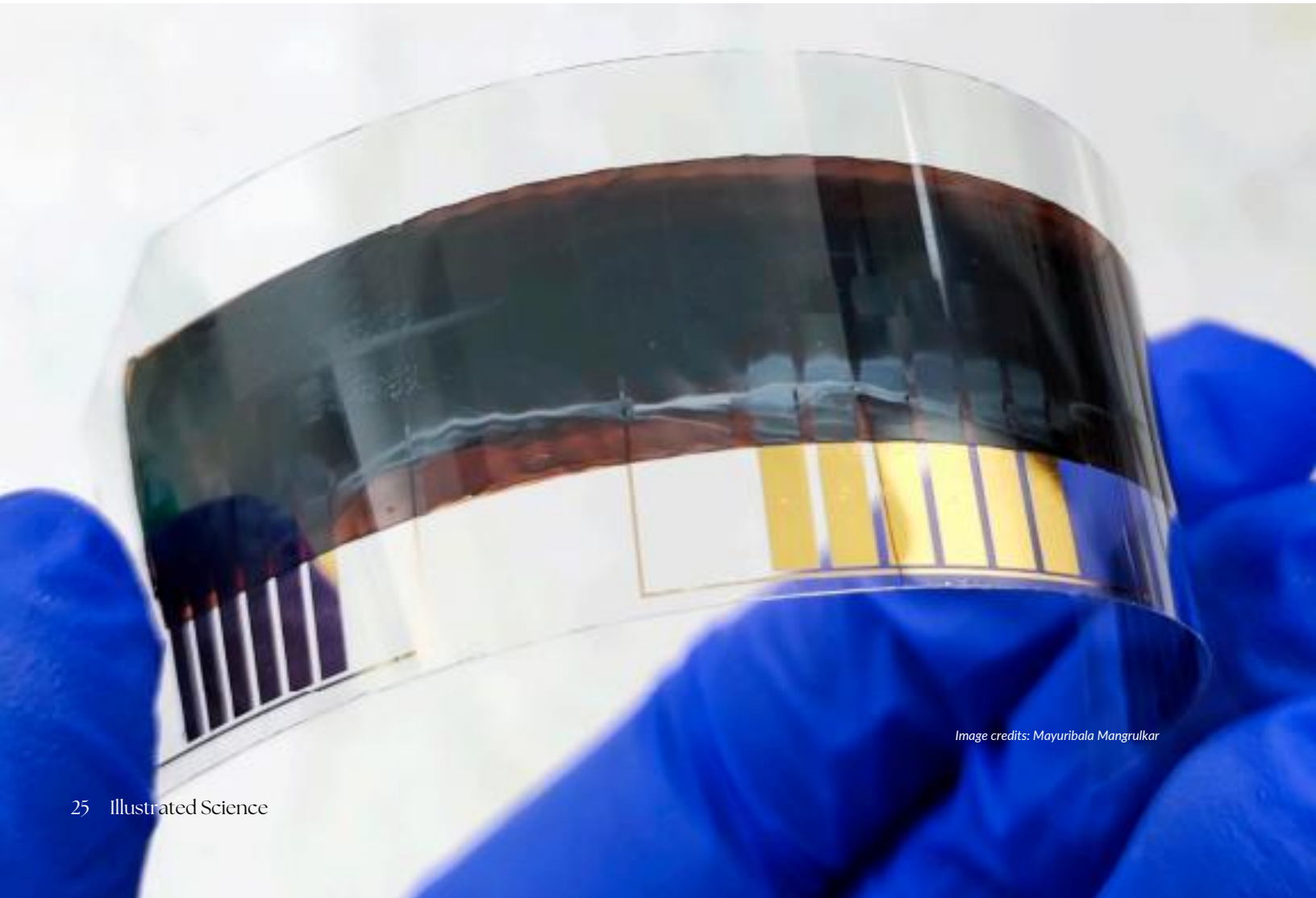


Image credits: Mayuribala Mangrulkar

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Krish Kotecha is a student of Bachelor of Business Administration (Honours) at Ahmedabad University. He is pursuing his major in marketing and is keen to take on an interdisciplinary approach that will help to broaden his knowledge of other fields.

Mayuribala Mangrulkar is an Assistant Professor at the School of Engineering and Applied Science at Ahmedabad University. She received a Bachelor of Engineering in Electronics and Telecommunication from Rajiv Gandhi Proudhyogiki Vishwavidhyalaya, Bhopal, India. She holds a Master of Science in Nanoelectronics from The University of Manchester in the United Kingdom. She later pursued her doctoral degree in Materials Science and Engineering at Skolkovo Institute of Science and Technology in Moscow, Russia, where she researched enhancing the stability of perovskite solar cells. She was a Postdoctoral Fellow at Nazarbayev University in Nur-Sultan, Kazakhstan, where her research focused on upscaling and printing large-area perovskite photovoltaics before joining Ahmedabad University.

Tune In! Nisir's Musical Genes

Do people with musical genes perceive pitch better?

Writer and Illustrator **Nutan Kain** | *Science Mentor* **Rama Ratnam**

Listening to budding singers on Sa Re Ga Ma Pa, a TV reality show, is a severe nostalgia for many of us. Nisir could magically recognize pitch variations, effortlessly discerning even the most minor fluctuations in tone and melody. Nisir never got any musical training. But shockingly, it just took her a few seconds to understand what went wrong. Then, is she a wizard?! Or is it because of her musical disposition?

It could be her genes! Nisir's exceptional ability to perceive pitch may be attributed to her genetic predisposition for music. Genes may be microscopic, but they pack a massive punch in shaping our behaviour. Nisir seems to understand variations in pitch despite no musical training. How is this biological element so powerful? Why is she different from us? How can she hear differently from us? Understanding such permeability of a musical ability into a person's genes has been a topic of curiosity for scientists, so let's probe Nisir and her abilities!

Wiza sings "Wadderrrrmelonn ssugarrr HI-EURGH"

"How did I sing?" asks Wiza to Nisir.

Nisir wondered whether to be honest or keep her friendship intact. Thankfully, as Nisir was about to answer Wiza, the bell rang. They both rushed to their class. The 16-year-old Nisir loves her friends. However, she hates them to torture both their throats and her ears. Nisir was born into a family of musicians, surrounded by the vibrant music world since childhood. However, she was yet to start her formal music training. As the day passed by, Wiza had forgotten her question, and Nisir's anxiety dwindled. Nisir went to her home, slept, and woke up to the sounds of familiar words emerging from her TV. "Sa Re Ga Ma Pa" she said as she got up.

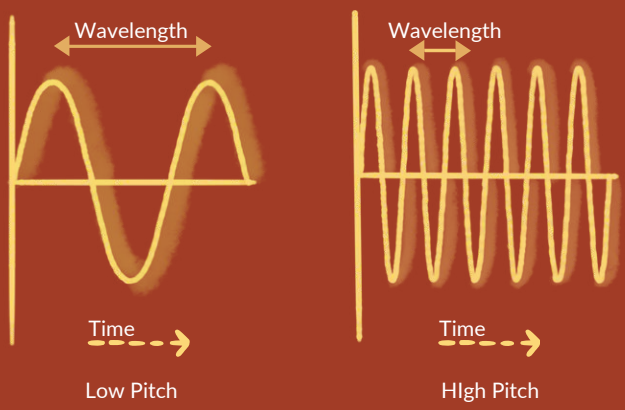
Understanding Musicality

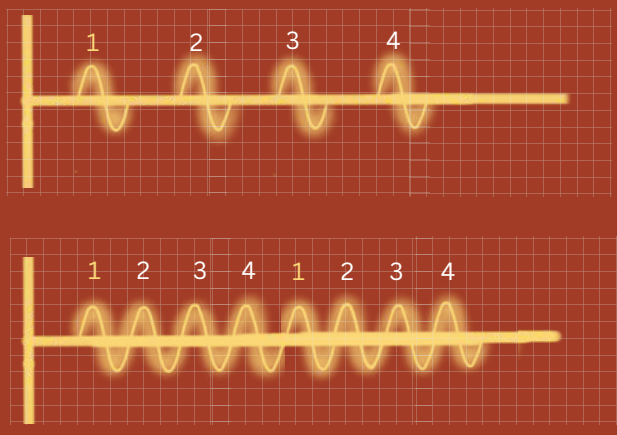
In Nisir's case, abilities focus on musicality, specifically pitch. Musicality is the ability to interpret, create, or reproduce music and is recognized as a communication process involving pitch, rhythm, and timbre (Szyfter & Witt, 2020). Let's discuss the three components of musicality.

Pitch

Pitch refers to how high or low a particular note is. Let's use mountains as an example. Like some mountains can be tall or short, musical notes can be high or low. Note acts as the building blocks of melodies, containing sound.

High-pitched notes can have peaks soaring into the sky and tend to have shorter wavelengths, like the distance between the mountain peaks. The low-pitched notes are gently rolling hills, with more distance between the mountain peaks or longer wavelengths.





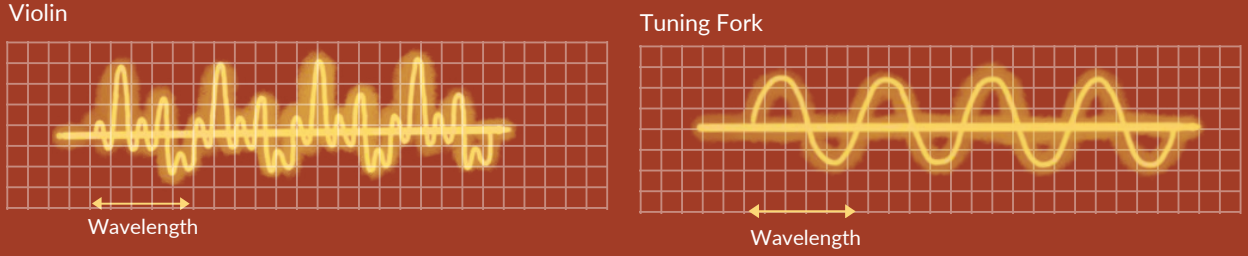
Rhythm

Rhythm refers to a recurring pattern in music. A beat is played at equal intervals, creating a particular pattern.

For example, imagine the regular tick-tock of a clock's hands. Music has recurring beats as they tend to move in a regular pattern. We tap our feet in time with the beat, following the rhythmic pattern in the music. Just as the clock tick-tock helps track time, rhythm helps stay within the framework of a song.

Timbre

Timbre refers to what makes musical instruments sound different. Despite the same frequency of the tuning fork and the violin, they both sound different.

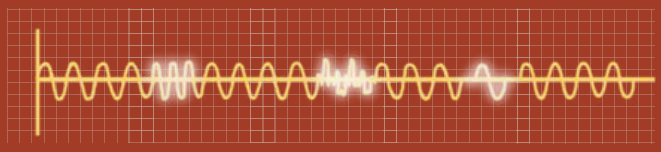


The Karma Music Test

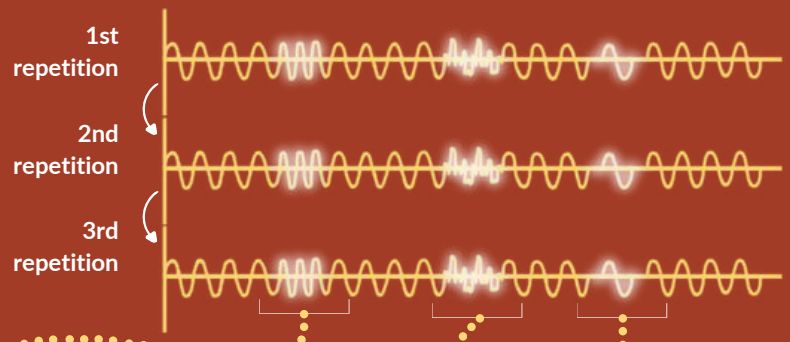
Everyone likes to listen to music, but how does one appreciate it? Several tests focus on musical aptitude- an ability to estimate rhythm, pitch, timbre, tone duration, and music structure. One of the tests used by Szyfter and Witt in their study is the Karma Music Test (KMC). It involves small abstract sound patterns repeated to form hierarchical structures.

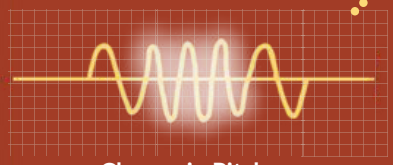
1. The individual wears a headphone.

2. An abstract sound pattern is continuously repeated to make it sound more complex.

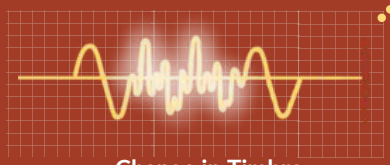


An abstract sound pattern

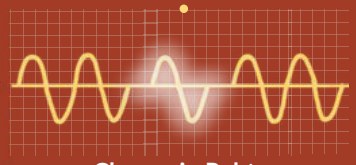




Change in Pitch



Change in Timbre



Change in Ryhtym

3. These patterns involve specific alterations such as pitch, timbre, or rhythm change; the individual has to figure these out and report the changes. Moreover, as these patterns are repeated, the individual must realize these larger recurring patterns when the repetition begins again.

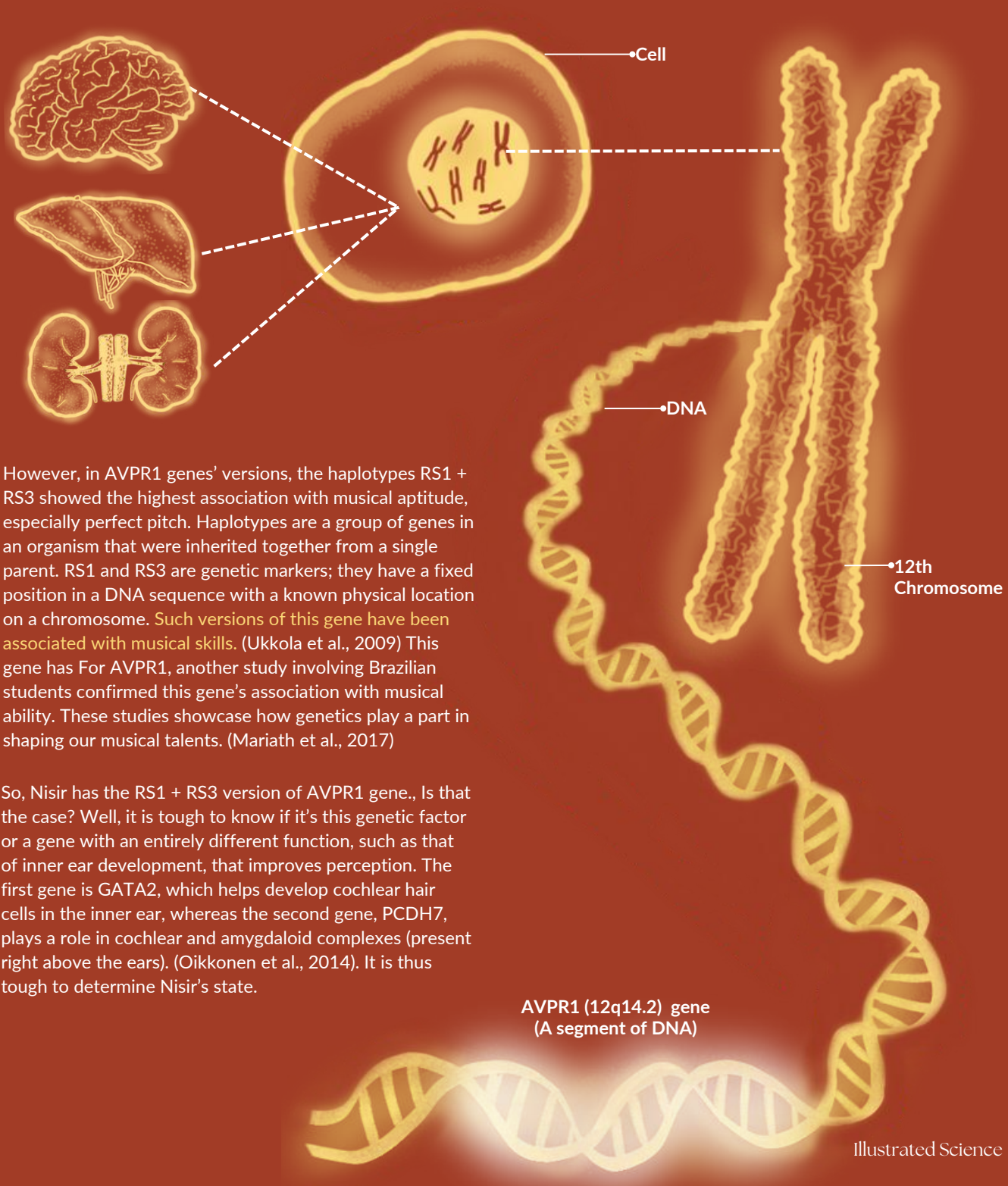
4. Scoring focuses on the accuracy of recognizing patterns and alterations. The higher the person scores, the better their musical aptitude.

Another research study conducted a version of this test on 136 monozygotic twin pairs and 148 dizygotic. Monozygotic condition refers to when the mother's egg, after being fertilized by the father's sperm, divides itself into two eggs, causing the twins to have the same genetic information. On the other hand, in di-zygotic, two eggs are fertilized by two sperm, so the children are genetically different. Regarding the method, the version was a Distorted Tunes Test (DTT) in which the individual had to figure out whether simple popular melodies have notes with incorrect pitch. The study found that monozygotic twins who share 100% of the same genes were more similar in their ability to recognize incorrect notes than dizygotic, who share half the same genes. This showed that genetics strongly influences pitch perception, with 71% to 80% of differences due to the genes. Moreover, they found that shared environments don't have a larger impact, substantiating that upbringing plays a minimal role in shaping our musical abilities. Cardinally, the differences in pitch perception can be attributed to genetic factors more than the shared environment. (Drayna et al., 2001).

Charisma of Genetics

The twin study substantiates the genes' presence in pitch perception. Nisir's case is similar. She could have those genes, but each person is composed of nearly 20,000-25,000 genes. How do you know which genes are contributing to her ability?

To explain the gene involved, researchers conducted a study focusing on musical aptitude and creativity using the Karma Music test. The study found several genes and AVPR1(12q14.2) linked to musical aptitude. AVPR1 (12q14.2) is the arginine vasopressin receptor 1A, present on the 12th chromosome in the brain, liver, or kidneys.



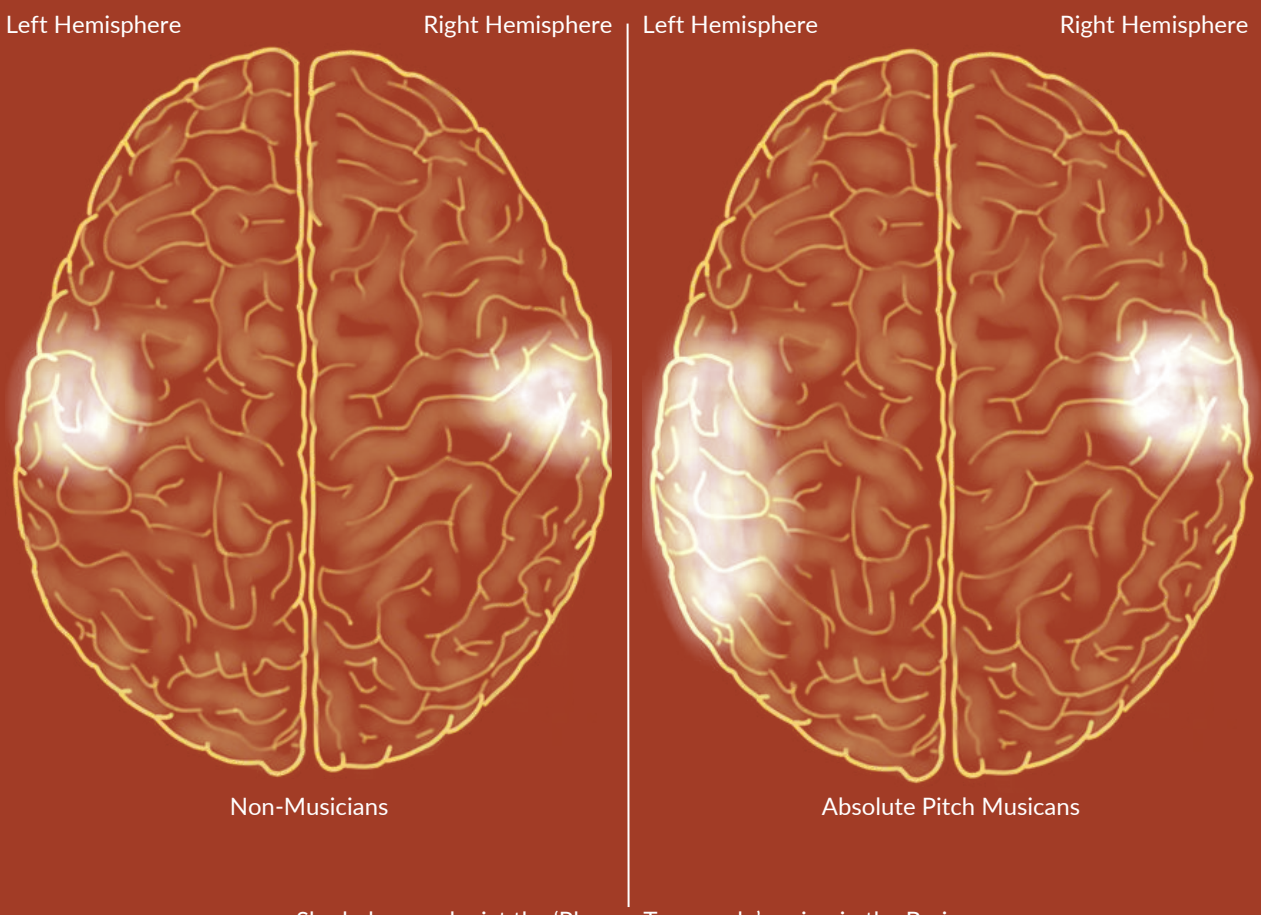
However, in AVPR1 genes' versions, the haplotypes RS1 + RS3 showed the highest association with musical aptitude, especially perfect pitch. Haplotypes are a group of genes in an organism that were inherited together from a single parent. RS1 and RS3 are genetic markers; they have a fixed position in a DNA sequence with a known physical location on a chromosome. Such versions of this gene have been associated with musical skills. (Ukkola et al., 2009) This gene has For AVPR1, another study involving Brazilian students confirmed this gene's association with musical ability. These studies showcase how genetics play a part in shaping our musical talents. (Mariath et al., 2017)

So, Nisir has the RS1 + RS3 version of AVPR1 gene., Is that the case? Well, it is tough to know if it's this genetic factor or a gene with an entirely different function, such as that of inner ear development, that improves perception. The first gene is GATA2, which helps develop cochlear hair cells in the inner ear, whereas the second gene, PCDH7, plays a role in cochlear and amygdaloid complexes (present right above the ears). (Oikkonen et al., 2014). It is thus tough to determine Nisir's state.

You're Absolutely a Pitch!

Undeniably, Nisir's abilities are causing some cumbersome problems. How can she perceive pitch so accurately? Can she produce one as well? That, too, without a reference or any help! This sort of ability is known as Absolute Pitch. Those with Absolute pitch can identify or produce a pitch without reference. How can we substantiate if Nisir has this? A morphometric study of the human brain can be useful.

Morphometric, in biological terms, means comparing the sizes or shapes of living organisms and their body parts/organs. We do this in numbers, therefore quantifying the comparison. (Ochs & O'Brodovich, 2019). Such a comparison was made between people who are not musicians and AP musicians- musicians who can identify and produce a pitch without reference. A multimedia source from *The Science Museum* explained that MRI magnetic resonance imaging uses radio waves and magnetic fields to create images of several body parts. The crux of this procedure is the water in our bodies. We are mostly water (H_2O), and hydrogen atoms are the main focus of an MRI. These atoms contain protons. They act like tiny magnets and spin randomly. As a person enters the MRI machine, the powerful magnet causes our bodies' protons to align with that magnet's magnetic field, and therefore, our protons stop spinning randomly. Then, the radio waves are sent in, which disrupts this alignment with protons temporarily misaligning. As these waves stop coming, the protons release energy to re-align with the magnetic field. This energy is interpreted by the computer and converted into detailed images of the body.



Shaded areas depict the 'Planum Temporale' region in the Brain

The same study was done with the Absolute Pitch musicians, and it was found that they had a leftward asymmetry of a part in the temporal lobe called planum temporale, involved in language and information processing. This region is present right behind our ears.

Nisir's Dread

Should Nisir get her MRI scan done then? Well, that depends on her. She is creating quite the suspense! Is it the genes in her inner ear leading to better development and perception, or is it the brain with a different structure than most of us? Regardless of the cause, it shows us how musical abilities, such as pitch, can be gained just through our genes, or it can be a gift from nature to our brains' structure. It is funny how art created 35,000 years ago can permeate a person's genes. Our genes are undeniably the epitome of "Chota Packet, Bada Dhamaka."

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Nutan Kain is a student of Bachelor of Arts (Honours) at Ahmedabad University. This project was an upgrade for her from listening to music on Spotify to trying to understand the genetic mechanisms behind the music through research papers. Having a fervor for biology and music allowed her to amalgamate them and work on such a topic. The incessant quality of the Nature vs. Nurture debate allowed her to discover music's association with genetics.

Rama Ratnam is a Professor at the School of Arts and Sciences at Ahmedabad University. He is a neuroscientist with a broad interest in brain and behaviour, particularly in neurobiological mechanisms of sensory processing that give rise to perception. His research interests include Neuroscience, Brain And Behavior, Sensory Processing, and Neural Engineering. He obtained his doctoral degree from the University of Illinois at Urbana-Champaign. His engineering roots from IIT Delhi have deeply influenced his research in biology to combine biology and engineering to explore how natural selection mirrors optimal design.

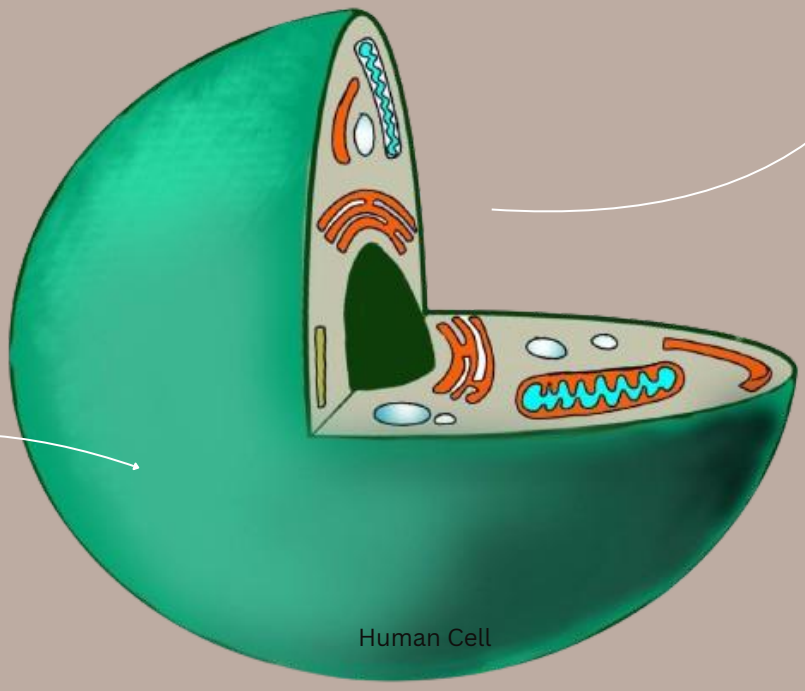
A Day in the Life of Human Cell

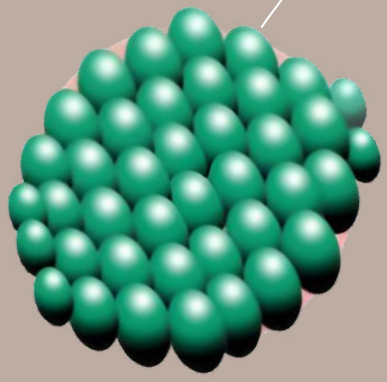
Cellular Cargo Transportation towards Lysosomes

Writer and Illustrator **Subramanya G.Gouda** | *Science Mentor* **Ashim Rai**

Cargo trucks navigate through a complex network of roads, creating a web of connectivity that binds a country together. Picture the bustling highways of the country, where cargo on wheels are travel to reach their intended destinations with precision and efficiency for an easy flow of goods. In the intricate world of cellular biology, a parallel is the vast network of cellular highways within the trillions of human cells that are bustling with constant movement for the delivery of cellular cargo like proteins and nutrients. Construction is happening constantly, facilitating cell growth and repair and destruction of waste inside the cells to maintain immunity.

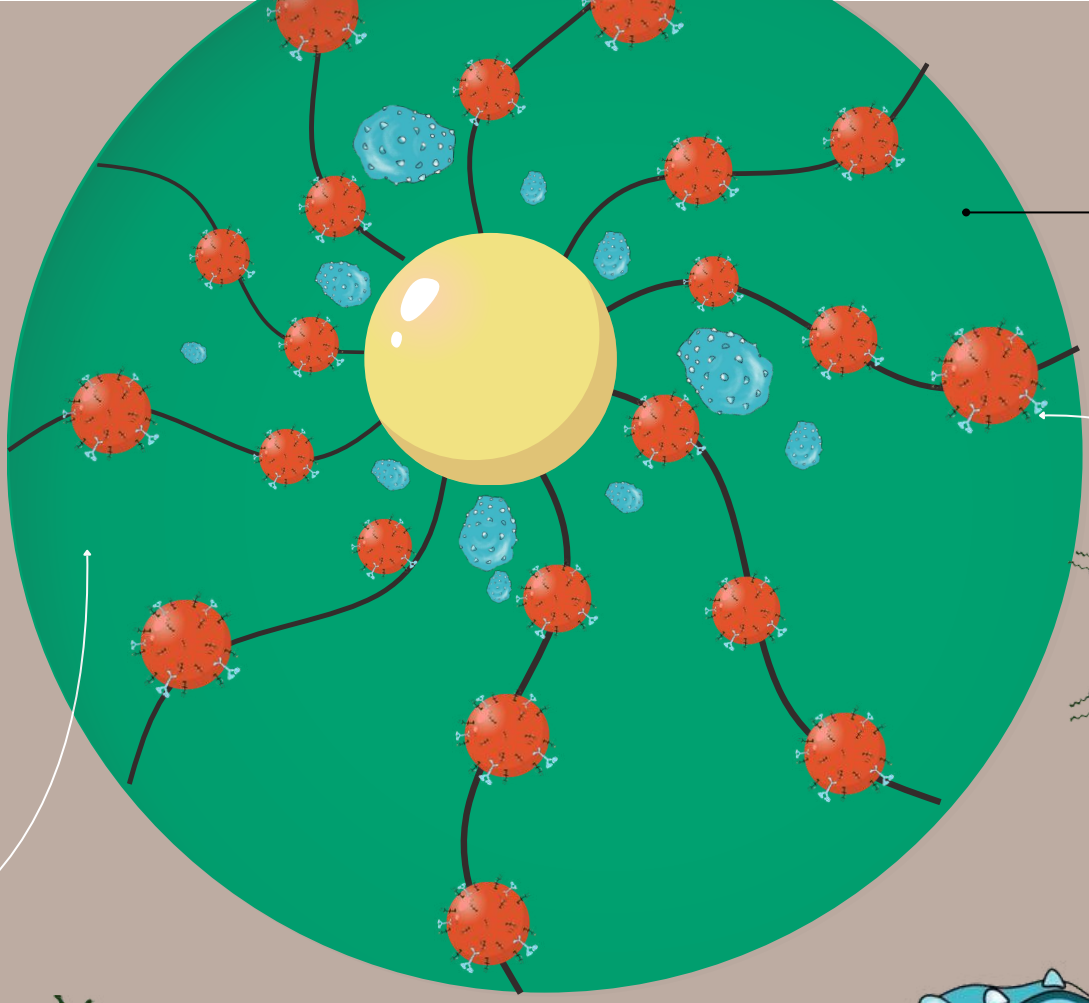
Similar to how cargo trucks ensure the flow of goods across the country's roads, cellular transportations are powered by motor proteins inside each cell. Motor proteins within cells, like cargo trucks, are tasked with ferrying essential cargo like molecules, ions, proteins and nutrients across the cellular landscape. The flow of goods across a country's roads and highways mirrors the intricate mechanism of human cells called cellular transportation.



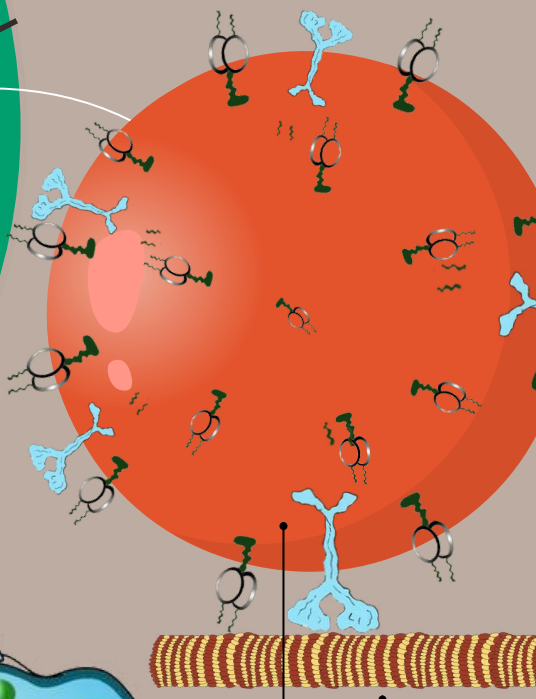


Motor Proteins: Driving force of Cellular Transportation

Just as the intricate network of roads guides trucks to their destinations, the cellular highways within cells serve as pathways for motor proteins. These cellular highways ensure that motor proteins travel efficiently, directing them towards their intended destinations within the cell. Motor Proteins are found within the cytoplasm, a jelly-like fluid surrounding the cell organelles. Motor Proteins are the main engine for various cellular functions. They also perform crucial cellular functions like cell division and maintaining cell structure.

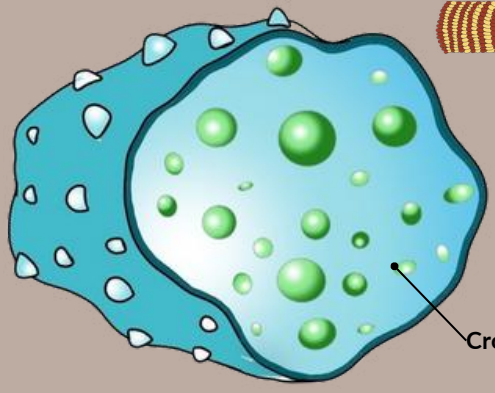


Cross-Section of Human Cell



Phagosome

Microtubule



Cross-Section of Lysosome

Dyneins: The Wheels

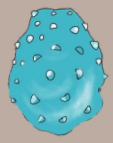
Dyneins are motor proteins that move along microtubules in cells to convert the chemical energy stored in cells to mechanical energy. Dyneins help transport the cargo from the cell membrane to lysosomes.

Kinesins: The Wheels

Kinesins are molecular motors made of two heavy and light chains connecting the phagosome to the microtubule to facilitate cargo movement.

Microtubules: The Cellular Highways

Microtubules are tiny hollow tubes that mainly act as a highway for transporting foreign particles by phagosomes. They are made up of two tubulins called Alpha tubulin and Beta tubulin. They typically spread throughout the cell, giving it structure.



Lysosomes: The Waste Disposal Chambers

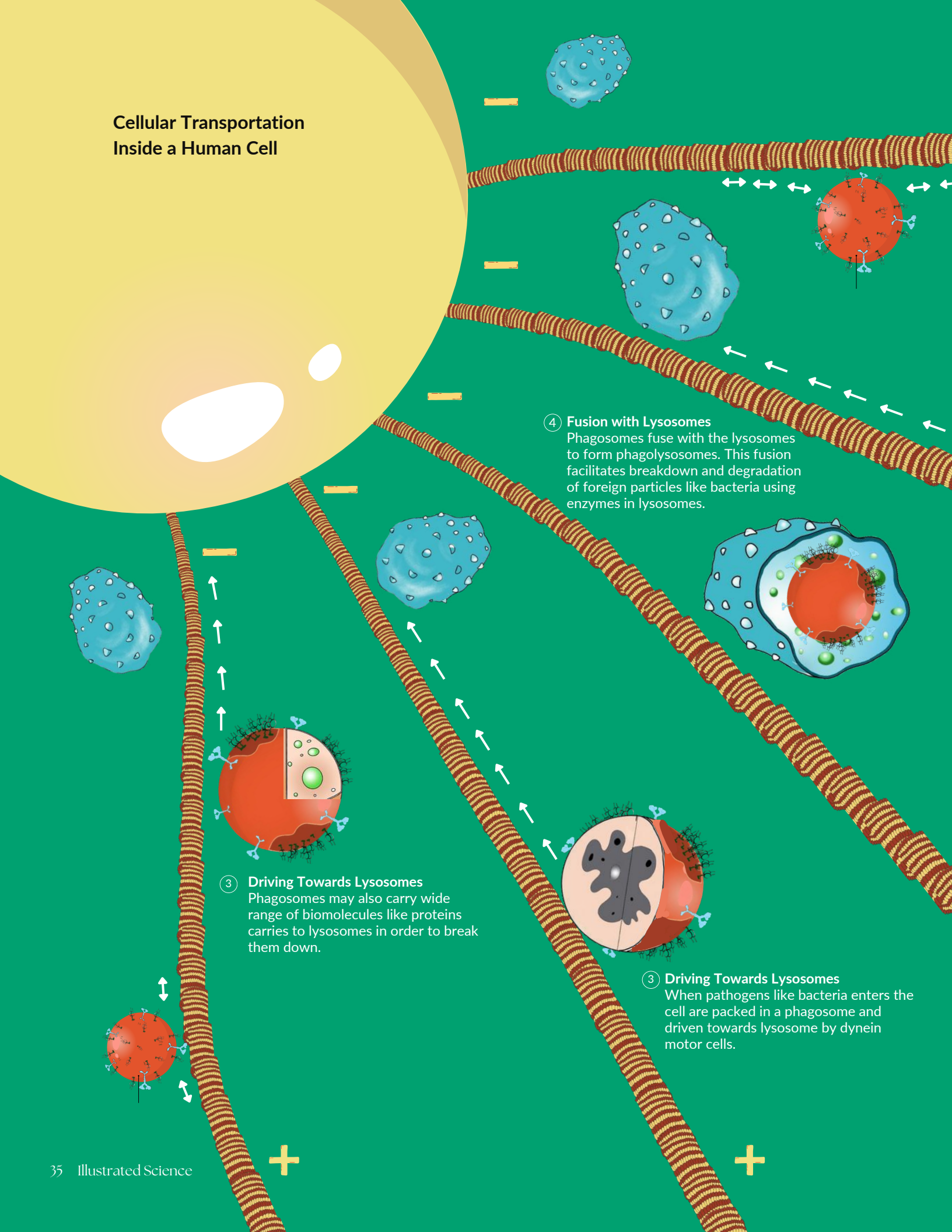
Lysosomes are like waste disposal chambers for bacteria and other pathogens within a cell. They are tiny digestive sacs containing digestive enzymes that can break down various biomolecules, including proteins, carbohydrates, lipids and nucleic acids, and any foreign particles.

Phagosome: The Cargo Trucks

Phagosomes are like cargo trucks loaded with food particles and nutrients for the cells, and sometimes, they work as garbage trucks containing bacteria, dead cells, and dust. The motor proteins are present near the phagosome to ferry them within the cell to interact with other cellular components.

When WBC encounters a foreign particle such as dust, bacteria or food, it triggers the cell membrane to extend and surround the particle, which later forms the Phagosomes. This process of phagosome is essential for the immune system to fight pathogens. This mechanism is fundamental to the immune system's defence against pathogens and other harmful substances.

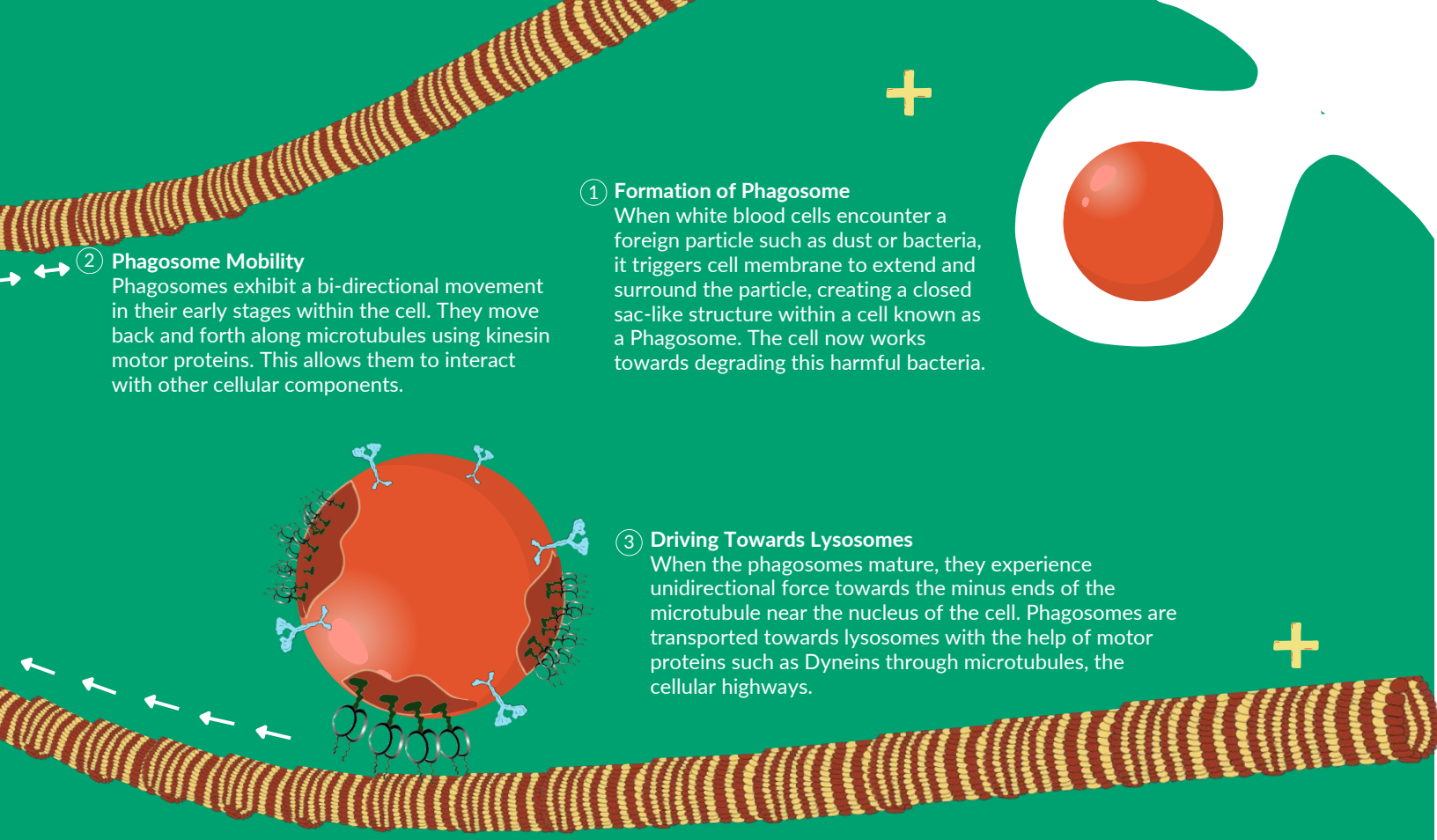
Cellular Transportation Inside a Human Cell



④ **Fusion with Lysosomes**
Phagosomes fuse with the lysosomes to form phagolysosomes. This fusion facilitates breakdown and degradation of foreign particles like bacteria using enzymes in lysosomes.

③ **Driving Towards Lysosomes**
Phagosomes may also carry wide range of biomolecules like proteins carries to lysosomes in order to break them down.

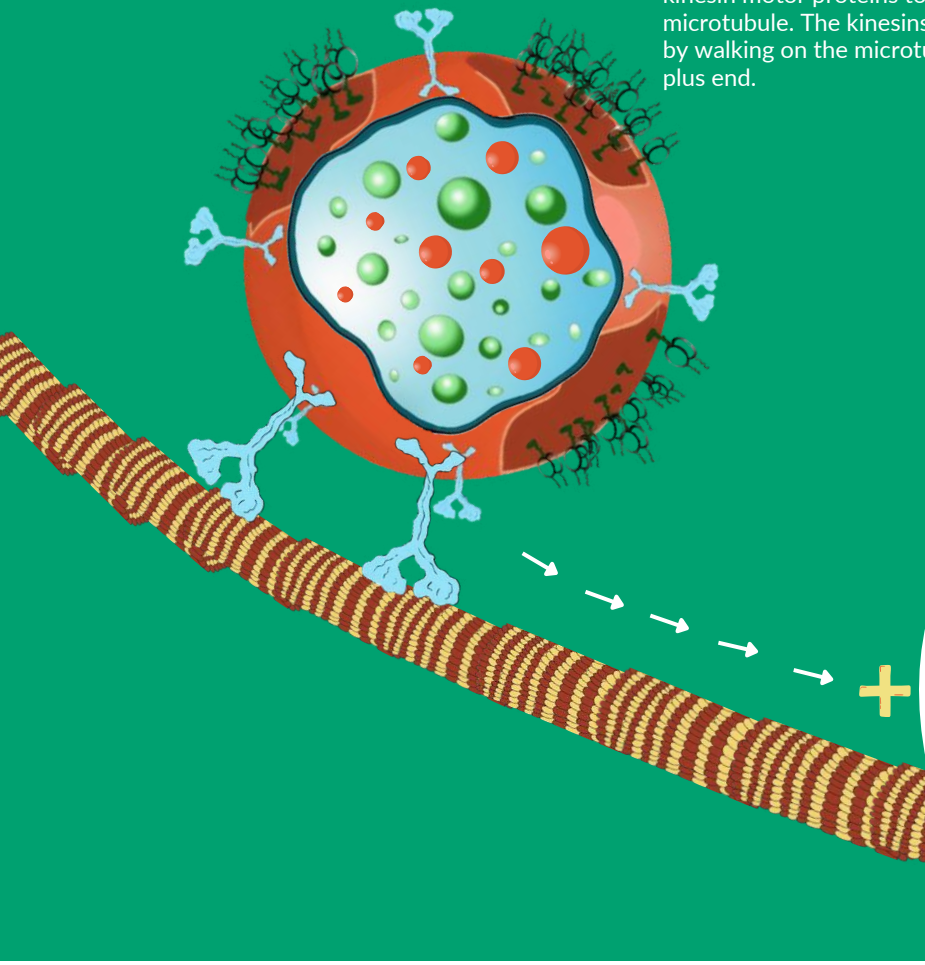
③ **Driving Towards Lysosomes**
When pathogens like bacteria enters the cell are packed in a phagosome and driven towards lysosome by dynein motor cells.



① **Formation of Phagosome**
When white blood cells encounter a foreign particle such as dust or bacteria, it triggers cell membrane to extend and surround the particle, creating a closed sac-like structure within a cell known as a Phagosome. The cell now works towards degrading this harmful bacteria.

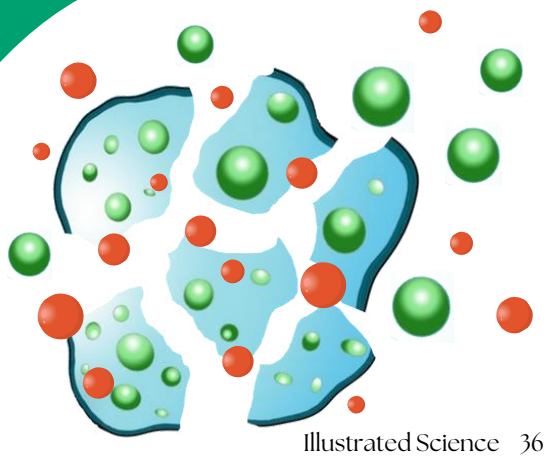
② **Phagosome Mobility**
Phagosomes exhibit a bi-directional movement in their early stages within the cell. They move back and forth along microtubules using kinesin motor proteins. This allows them to interact with other cellular components.

③ **Driving Towards Lysosomes**
When the phagosomes mature, they experience unidirectional force towards the minus ends of the microtubule near the nucleus of the cell. Phagosomes are transported towards lysosomes with the help of motor proteins such as Dyneins through microtubules, the cellular highways.



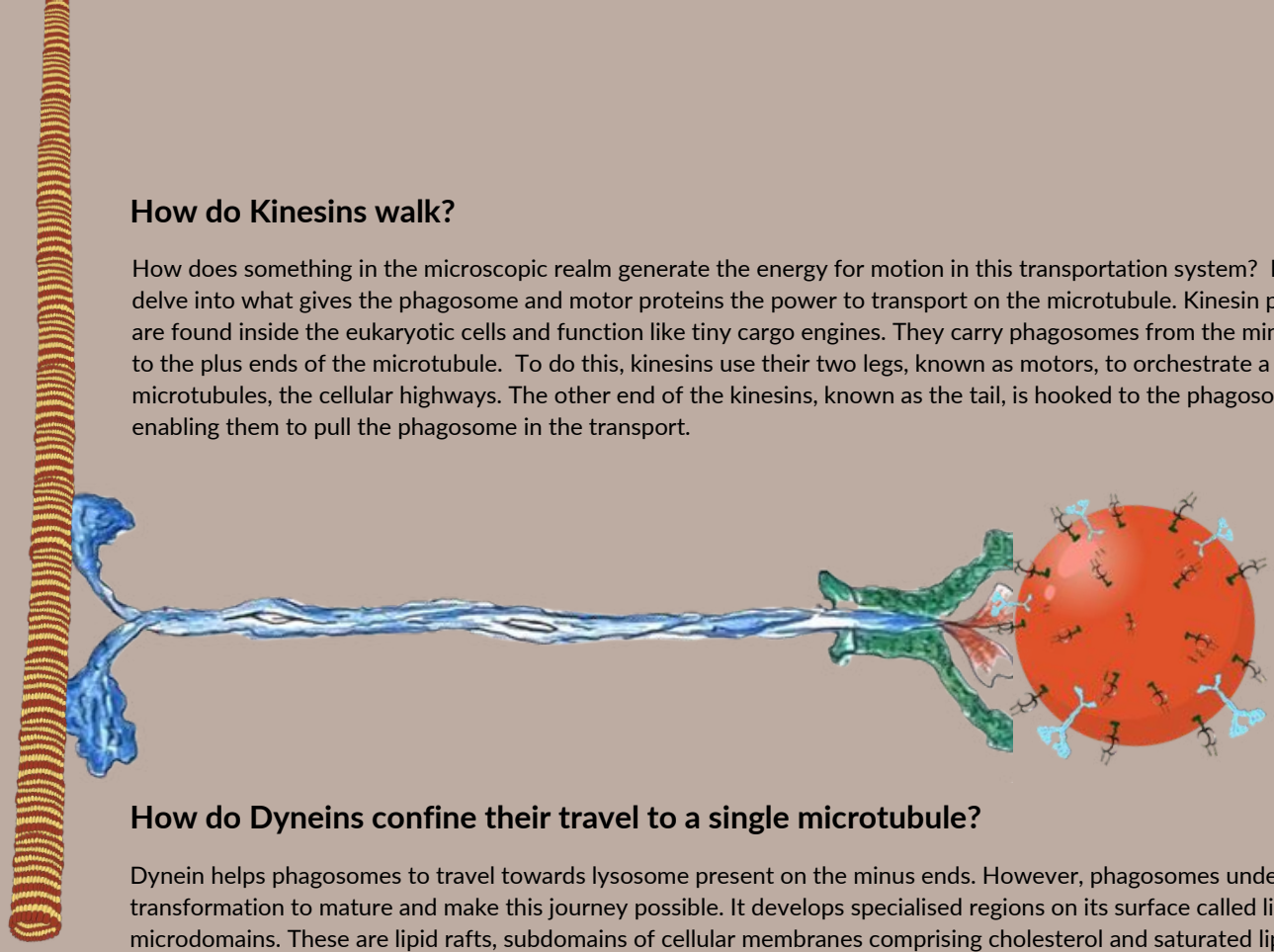
⑤ **Ready for Degradation**
Once the breakdown of engulfed material is complete, phagosomes are transported by kinesin motor proteins towards the plus end of microtubule. The kinesins propel phagosome by walking on the microtubule from minus to plus end.

⑥ **Discarding Waste from a Cell**
Any indigestible waste material remains within the phagolysosome and is eventually discarded from the cell through the cell membrane.



How do Kinesins walk?

How does something in the microscopic realm generate the energy for motion in this transportation system? Let us delve into what gives the phagosome and motor proteins the power to transport on the microtubule. Kinesin proteins are found inside the eukaryotic cells and function like tiny cargo engines. They carry phagosomes from the minus ends to the plus ends of the microtubule. To do this, kinesins use their two legs, known as motors, to orchestrate a walk on microtubules, the cellular highways. The other end of the kinesins, known as the tail, is hooked to the phagosome, enabling them to pull the phagosome in the transport.

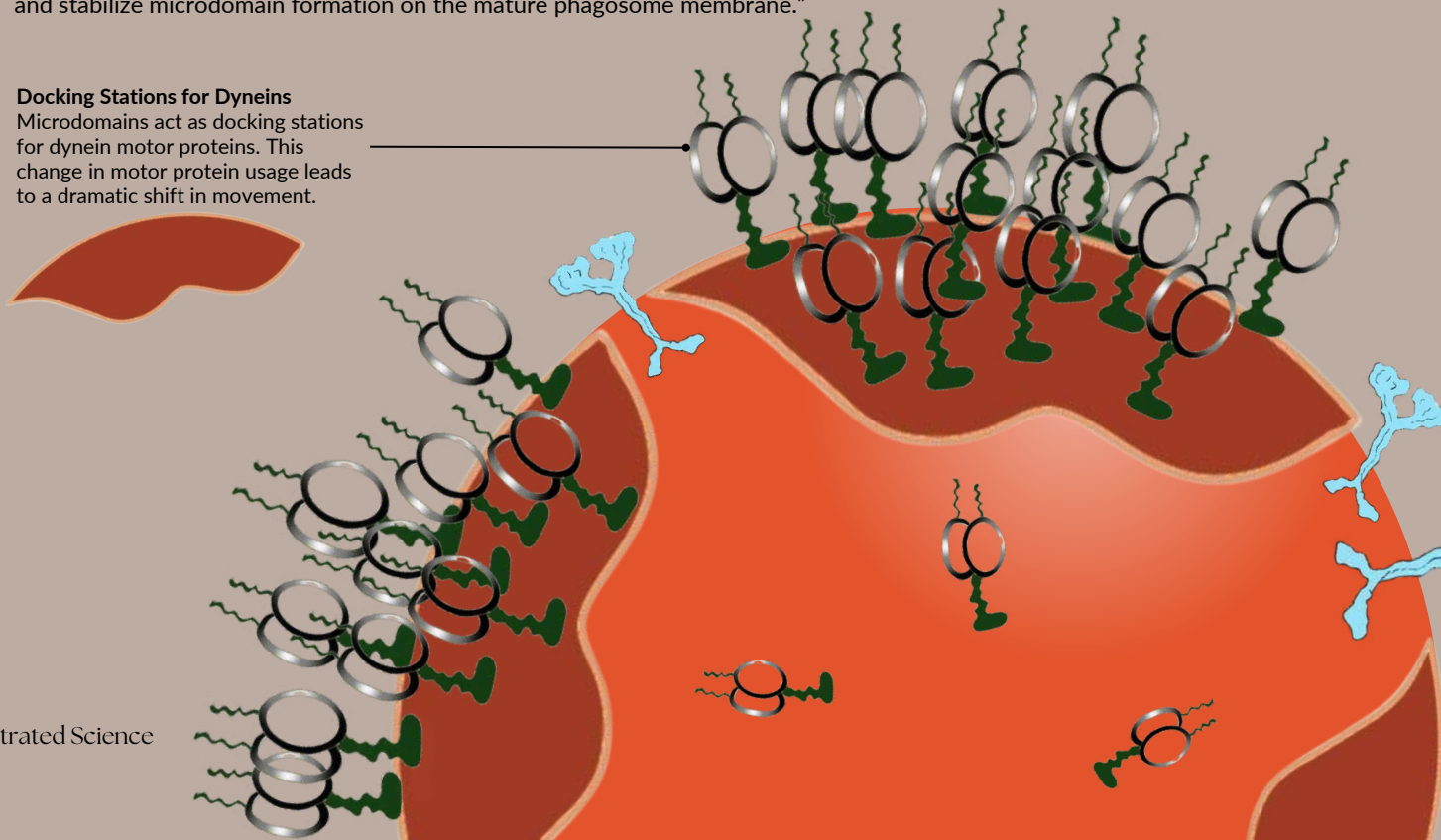


How do Dyneins confine their travel to a single microtubule?

Dynein helps phagosomes to travel towards lysosome present on the minus ends. However, phagosomes undergo a transformation to mature and make this journey possible. It develops specialised regions on its surface called lipid microdomains. These are lipid rafts, subdomains of cellular membranes comprising cholesterol and saturated lipids. While researchers have figured out the mechanism of the microdomain formation, very little is known about how the membrane regulates the energy from motors to reach its intended destination.

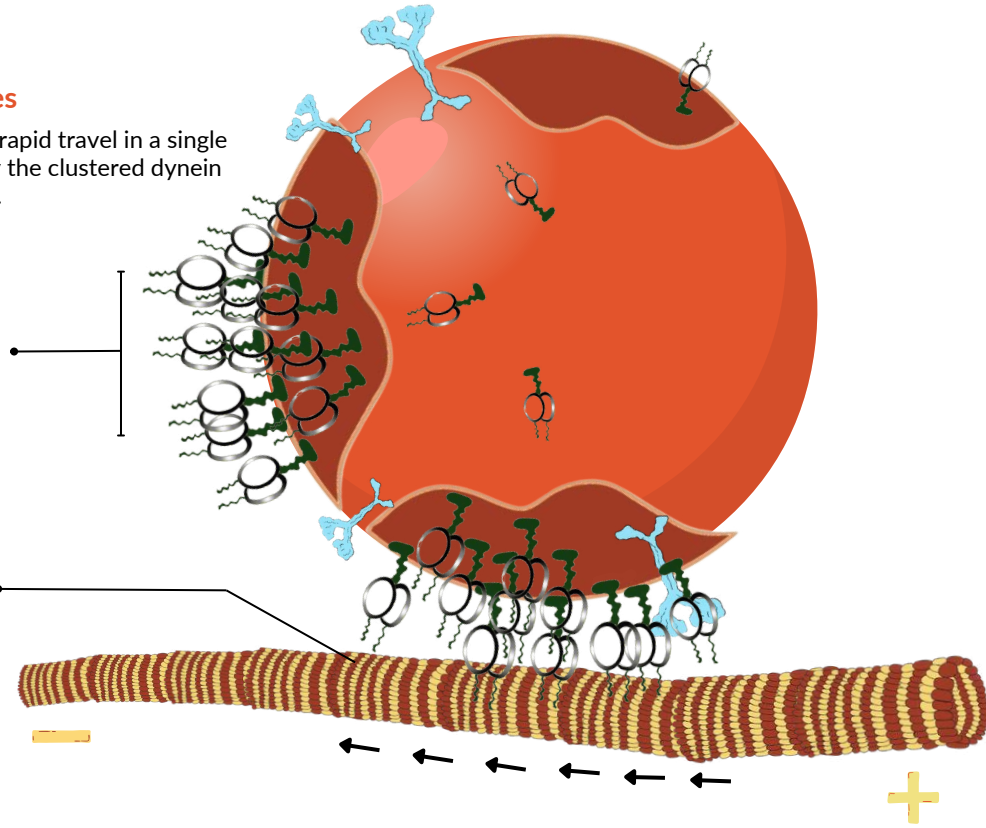
Ashim Rai, a professor at Ahmedabad University, and other researchers conducted experiments to observe the functional consequences of lipid microdomain formation on intracellular transport. They wanted to understand how such motor teams gather at specific cellular locations before they move unidirectionally along a single microtubule. How do they firmly attach to one single microtubule and not engage with multiple random microtubules? Rai observed an increase in cholesterol, which prompted him to make a hypothesis for dynein clustering: “As phagosomes mature, they fuse with the cholesterol-rich elements in the cell to acquire cholesterol and membrane-associated that promote and stabilize microdomain formation on the mature phagosome membrane.”

Docking Stations for Dyneins
Microdomains act as docking stations for dynein motor proteins. This change in motor protein usage leads to a dramatic shift in movement.



Rapid travel by Mature Phagosomes

Rai found that mature phagosomes exhibit rapid travel in a single direction towards the minus end, guided by the clustered dynein motors on microdomains, pulling it steadily.



What happens on the day when this network of cargo trucks is disrupted? Much like the country's commerce and economy would grind to a halt, our overall health would be bungled up. We all have motor proteins, but what happens if this little molecular motor isn't working like it should? Maybe it's moving too slowly or not picking up cargo. Perhaps it's stuck on the road or not getting on the road at all. This can cause life-threatening symptoms.

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Subramanya G. Gouda is a student of Bachelor of Business Administration (Honours) at Ahmedabad University pursuing an Accounting Major. He had a curiosity about how the human body functions since childhood. He was intrigued by how even small changes in tiny cells could significantly impact the human body. This interest led him to research topics related to understanding the functioning of the immune system and how the body combats pathogens such as bacteria.

Ashim Rai is an Assistant Professor at the School of Arts and Sciences at Ahmedabad University. His research interests include Cytoskeleton, Single-molecule Biophysics, FRET Biosensors, and DNA Origami. He holds a PhD from the Tata Institute of Fundamental Research, where he used in vitro reconstitution and force spectroscopy methods to study phagosome transport mechanisms. His research revealed a unique dynein motor clustering mechanism and highlighted the disruption of dynein clustering as a mode of pathogen survival.

Croak and Roll

The Science of Green Tree Frog Mating

Writer and Illustrator **Yuvan Sutaria** | *Science Mentor* **Rama Ratnam**

On a rainy night by the pond, Kermit the frog croaked loudly, hoping to find a mate. Amidst the raindrops, he searched eagerly for companionship, but the frog romance industry is often quite competitive. There could be hundreds of males out there making calls and advertising themselves on a good night. A pond usually has far more males than females. Most females only mate once a summer because it requires a lot of energy. Females are ready to mate when they form a clutch, which can range from hundreds to thousands of eggs and naturally, that would require a lot of energy.

The typical calls we hear are called advertisement calls, which means it is a male frog advertising as a potential partner in hopes of finding a mate. A male frog's primary aim to find a female is to breed. They typically make mating calls in or near water ponds, dams, streams and wetlands. The reason for this is that the eggs are often laid near/in water, where the tadpoles develop. Frogs have managed to combine the advantages of both worlds: they have lowered their vulnerability to predators through land adaptation, yet they can still move when environmental conditions change because they can still survive in water.

Virtually all males lack an intromittent organ, or penis and thus must inseminate the eggs externally. The male frog fertilizes the egg outside as the female lays them. The male grips his mate tightly in a hold called amplexus. Many frogs have a soft swelling called a nuptial pad on a digit located on the inside of the forelimb, which is used during amplexus to cling to the female.

In addition to their unique reproductive anatomy, frogs exhibit sexual dichromatism, a common phenomenon in the animal kingdom where males and females display different colours. A type of sexual dimorphism known as sexual dichromatism occurs when the colours of males and females differ. While this is found in many creatures, birds, fish, and butterflies are the most common. In frogs, sexual dichromatism is also common. It can be ontogenetic (permanent colour change in males or females) or dynamic (temporary colour change in males).

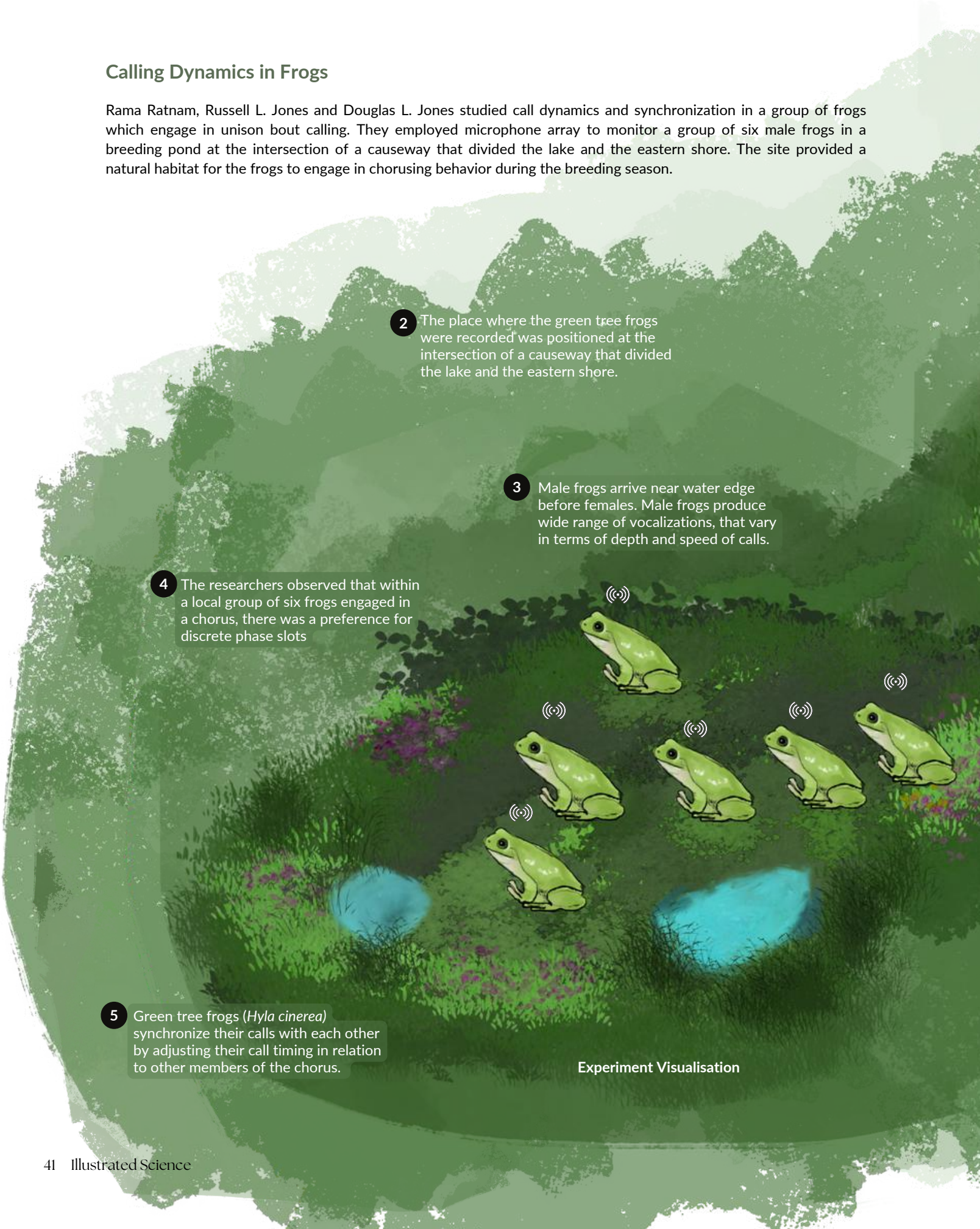
The yellow frog (male) is smaller then the brown frog (female). This is an example of fecundity that is when females are bigger than males.

Sexual Size Dimorphism is a difference in the body length/mass of sexually mature organisms. There is a general trend in amphibians that females are bigger than males. One of the reasons for this dimorphism is to accommodate the mating process called amplexus. It is hypothesized that females are bigger because they harbour eggs, producing large clutches.

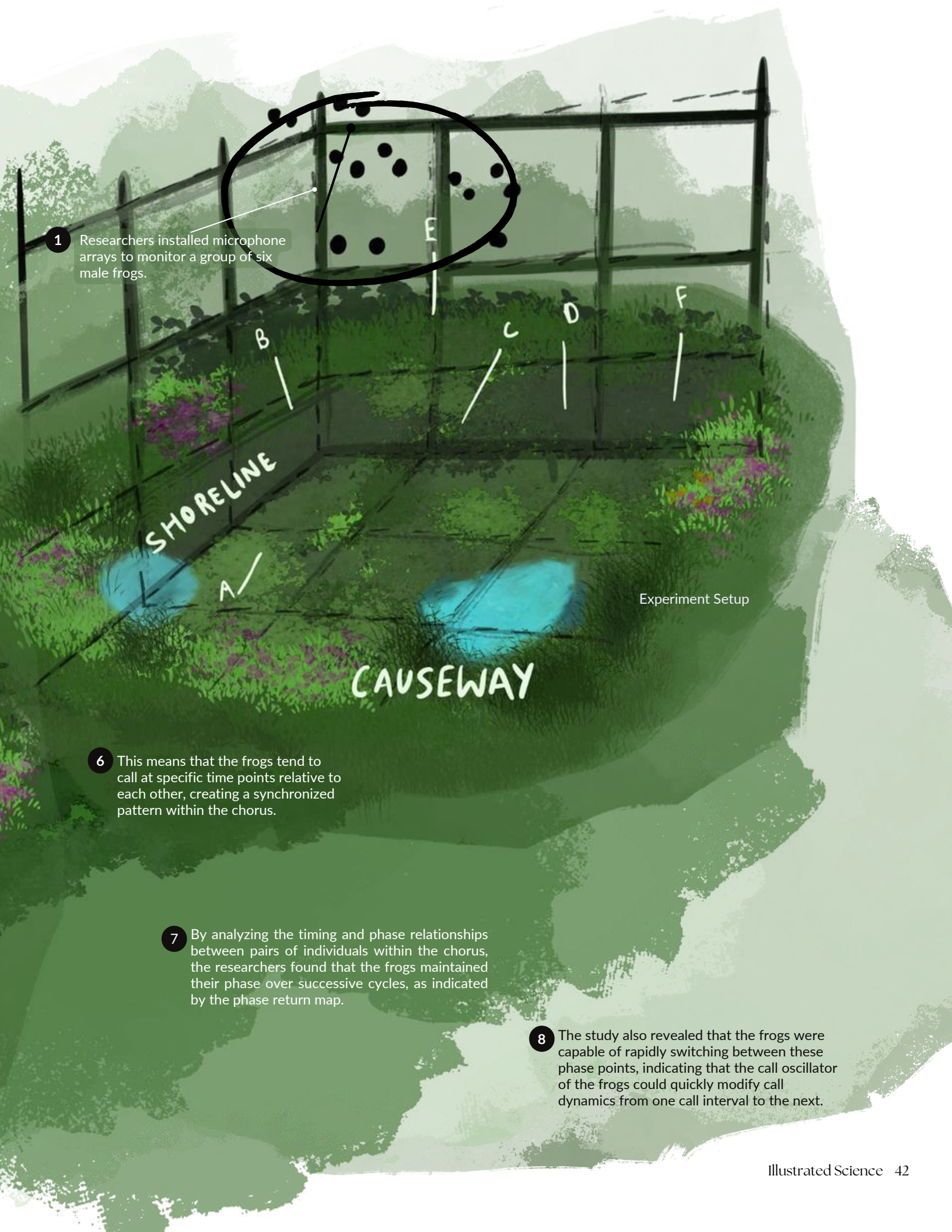
Female frogs use a multifaceted approach to mate selection, influenced by factors related to the potential partner's overall fitness. Mating calls, a fundamental aspect of frog communication, are critical in this process. Females are frequently drawn to calls that indicate the caller's health and genetic fitness, with traits such as a robust and clear call or specific call characteristics that are especially appealing. Additionally, size and physical condition are essential, as larger size is associated with increased reproductive success. Male frog courtship behaviour, including visual displays and bodily movements, influences female mate choice and provides information about the male's ability to provide parental care or defend a suitable breeding site.

Calling Dynamics in Frogs

Rama Ratnam, Russell L. Jones and Douglas L. Jones studied call dynamics and synchronization in a group of frogs which engage in unison bout calling. They employed microphone array to monitor a group of six male frogs in a breeding pond at the intersection of a causeway that divided the lake and the eastern shore. The site provided a natural habitat for the frogs to engage in chorusing behavior during the breeding season.

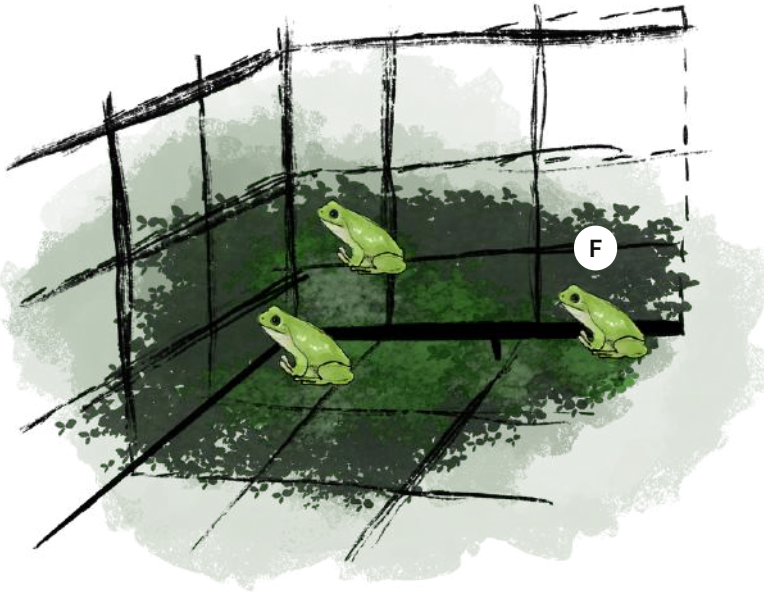


Experiment Visualisation

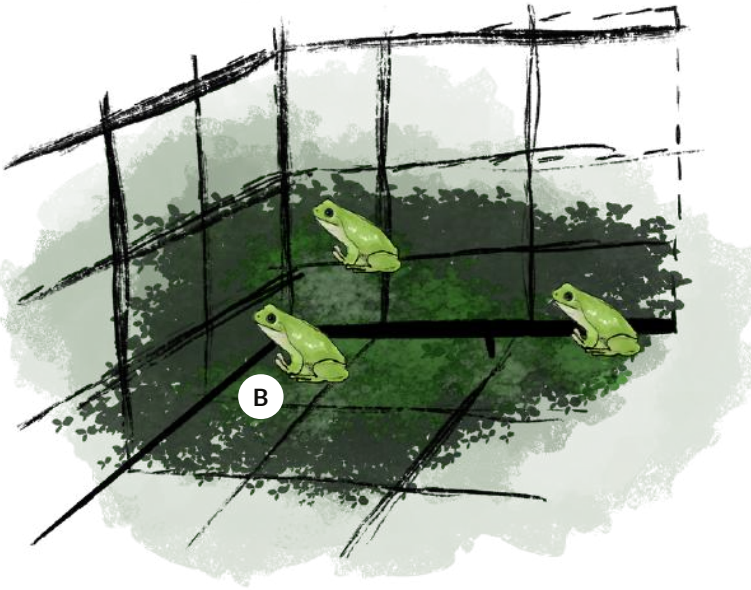


Experiment Setup

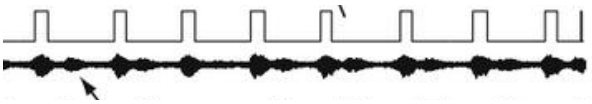
Synchronisation in Frog Calling



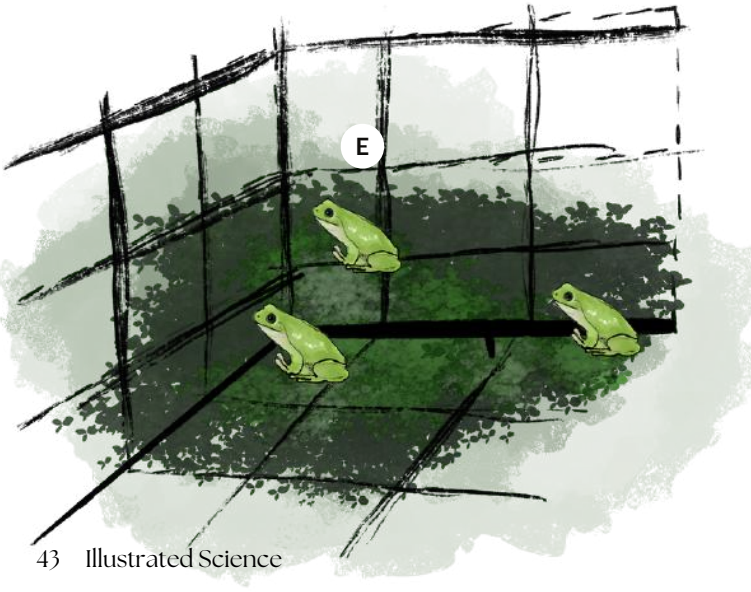
The researchers found that the frogs maintained their phase over successive cycles, as indicated by the phase return map. Points along the diagonal of the map indicated that the phase was maintained between successive call periods, while points along the edges indicated call collisions (synchrony) or phase skipping

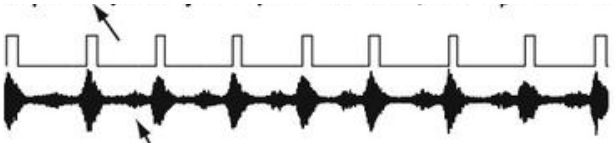


Furthermore, the researchers observed that the frogs tolerated call collisions and maintained their phase over successive cycles, indicating a sophisticated level of communication within the chorus. This synchronization likely helps the frogs minimize acoustic interference and enhance their communication effectiveness during the breeding season.



The study revealed that within a local group of six frogs, a captivating pattern emerged. These frogs synchronized their calls by timing them at specific intervals relative to each other. They showed a preference for calling at precise moments, creating a harmonious symphony of sounds within the chorus.





What's even more intriguing is that these frogs demonstrated a remarkable ability to adjust their call timing rapidly. They could seamlessly switch between different phase points, showcasing a high level of flexibility in their vocal communication.

In conclusion, the calls of frogs aren't just beautiful sounds—they're essential for finding mates and indicate the health of their habitats. Frogs use their calls like a language, helping them connect and reproduce. By protecting their homes, we're not only preserving their songs but also maintaining the balance of nature. So let's ensure these amphibian crooners have a bright future! After all, when it comes to conservation, every "leap" forward matters!

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Yuvan Sutaria is a student of Bachelor of Business Administration (Honours) at Ahmedabad University. He loves puns, animals and design. His love for animals birthed his interest in filmmaking as well. He has always been fascinated by amphibians and reptiles and this topic allowed him to do the things he loves to do- thinking about animals and designing. His interests in animals, photography and designing helped him with this topic.

Rama Ratnam is a Professor at the School of Arts and Sciences at Ahmedabad University. He is a neuroscientist with a broad interest in brain and behaviour, particularly in neurobiological mechanisms of sensory processing that give rise to perception. His research interests include Neuroscience, Brain And Behavior, Sensory Processing, and Neural Engineering. He obtained his doctoral degree from the University of Illinois at Urbana-Champaign. His engineering roots from IIT Delhi have deeply influenced his research in biology to combine biology and engineering to explore how natural selection mirrors optimal design.

A Symphony of Movement

What Does It Take for a Bird to Migrate?

Writer and Illustrator **Krishi Bhojani** | *Science Mentor* **Jitesh Jhawar**

Migration, the periodic journeys of organisms in response to seasonal environmental changes, is widespread across various species. This phenomenon serves as a compelling demonstration of the complex interplay between life and its environment. From the grand migrations of humpback whales to the delicate journeys of monarch butterflies, this behaviour enables species to take advantage of the shifting patterns of resource availability throughout the year. However, within migration, birds hold a particularly fascinating position.

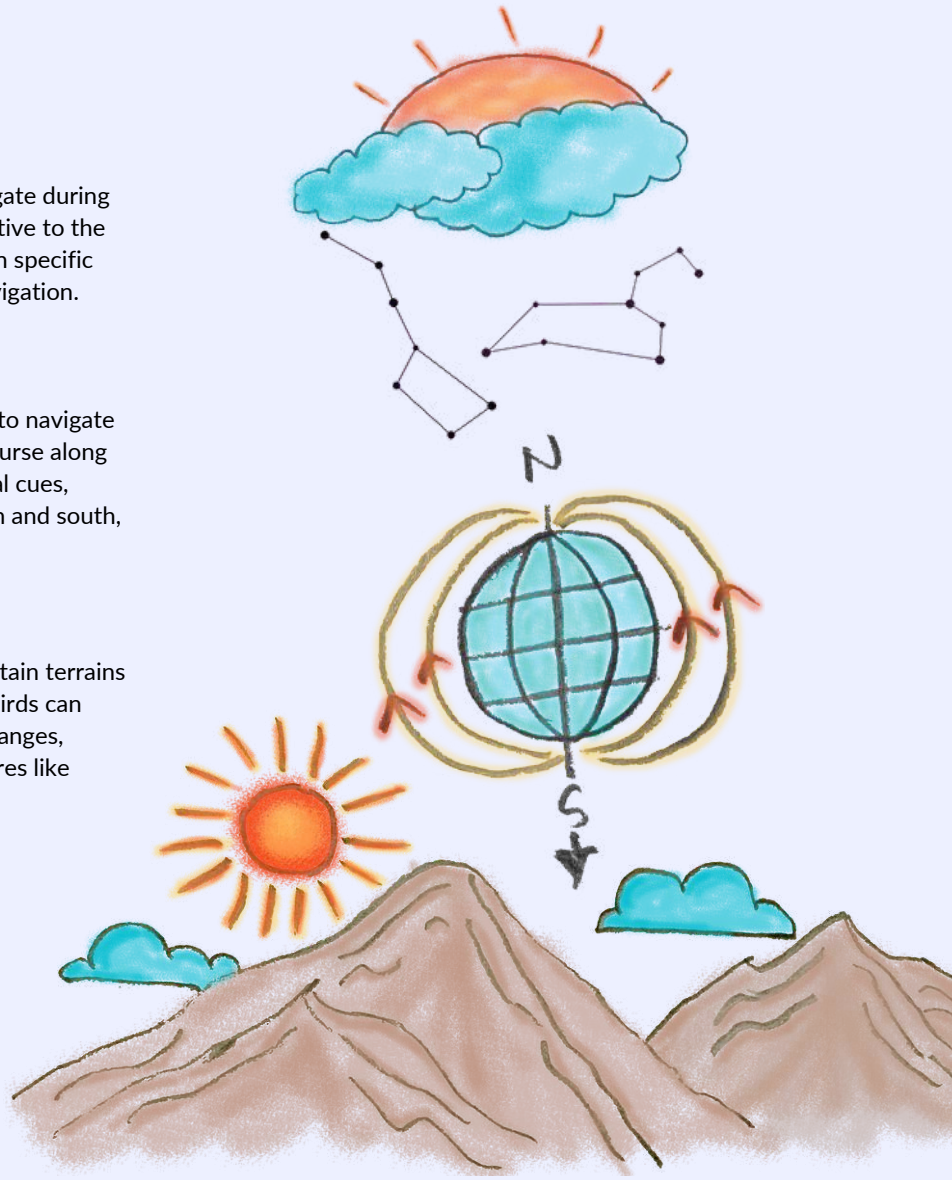
Bird migration goes beyond simple relocation. Birds construct a well-coordinated seasonal strategy to travel incredible distances, often spanning across continents, in contrast to sedentary bird species. The motivations behind these travels are just as diverse as the birds themselves. Certain species move in visually pleasing formations, including the Canada Goose. On the other hand, solitary birds, such as the Bar Tailed Godwit, travel alone and use the Earth's magnetic field and celestial bodies as guides.

Navigational Cues

Sun and Star Compass
Migratory birds use the sun's position to navigate during the day, maintaining a consistent heading relative to the sun. At night, nocturnal migratory birds rely on specific star patterns as celestial cues for accurate navigation.

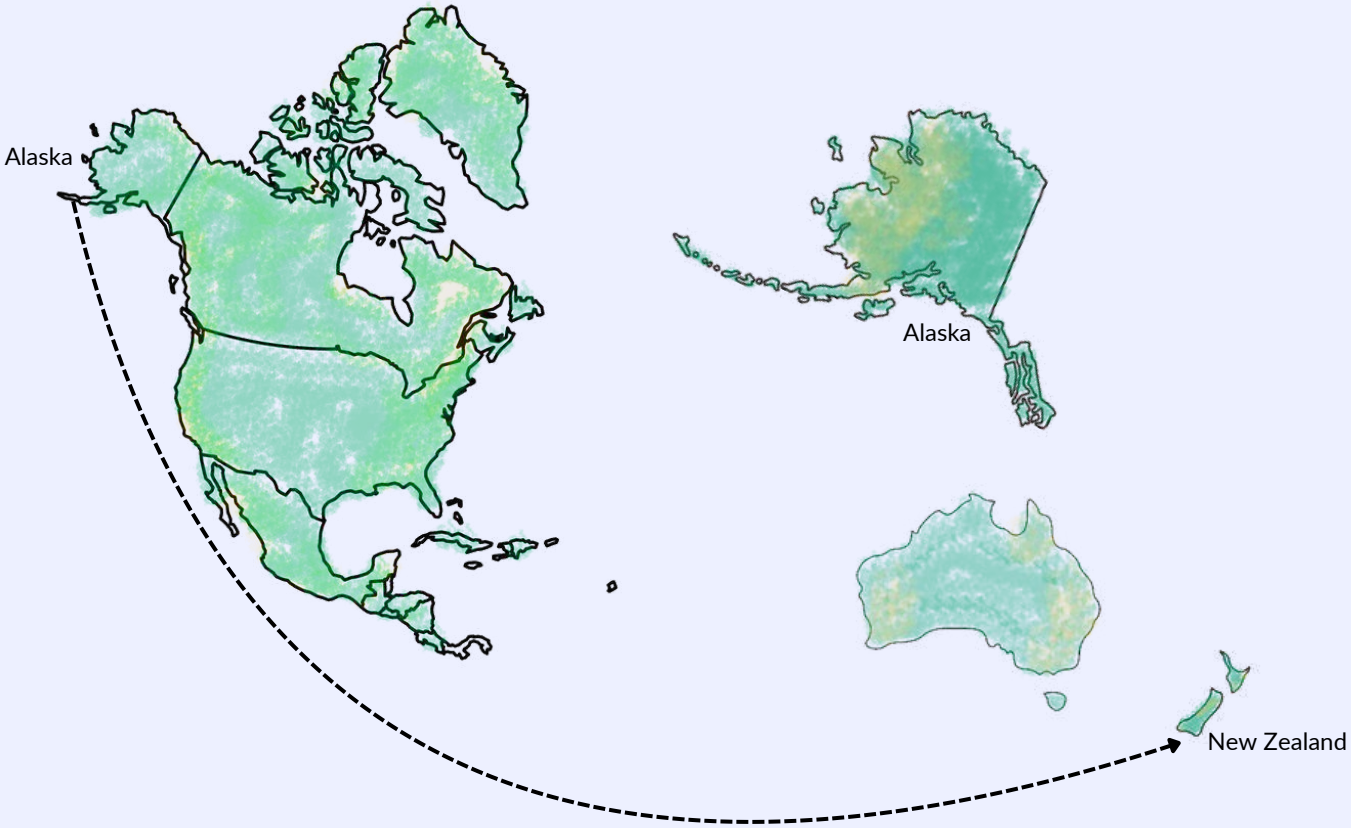
Magnetic Field
Migratory birds rely on Earth's magnetic field to navigate during migration, which helps birds stay on course along their routes. It guides them through directional cues, assisting them in distinguishing between north and south, which is crucial for long-distance migrations.

Landmarks
Landmarks play a vital role in navigating uncertain terrains as essential reference points for orientation. Birds can identify familiar landmarks such as mountain ranges, coastlines, rivers, and even man-made structures like buildings or towers.



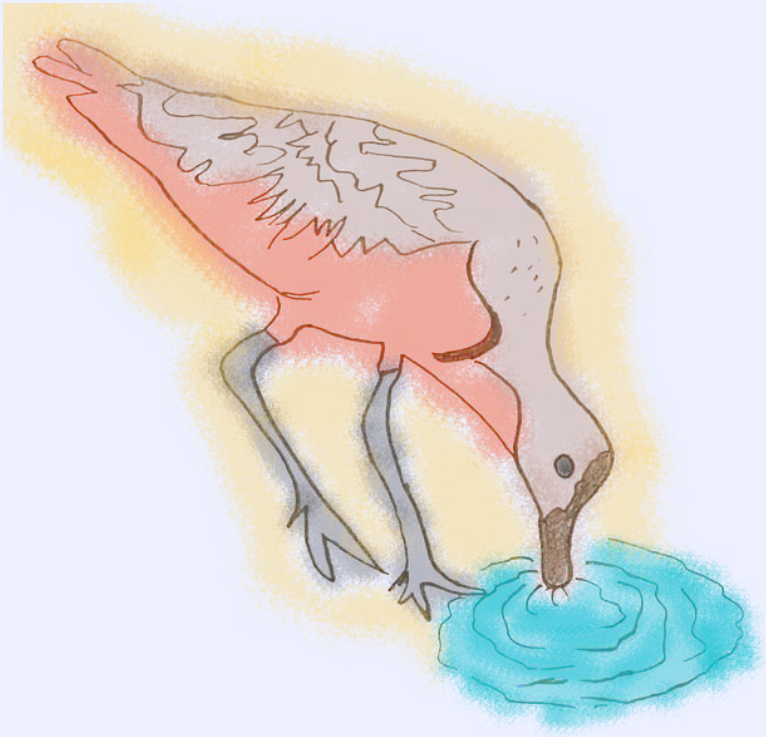
Bar Tailed Godwit: Longest Nonstop Solitary Migrator

The migration of the Bar Tailed Godwit is truly remarkable. This bird embarks on a solo nonstop journey covering over 11,000 kilometres, making it the furthest any known bird has ever travelled. This accomplishment showcases their incredible stamina and navigational abilities.



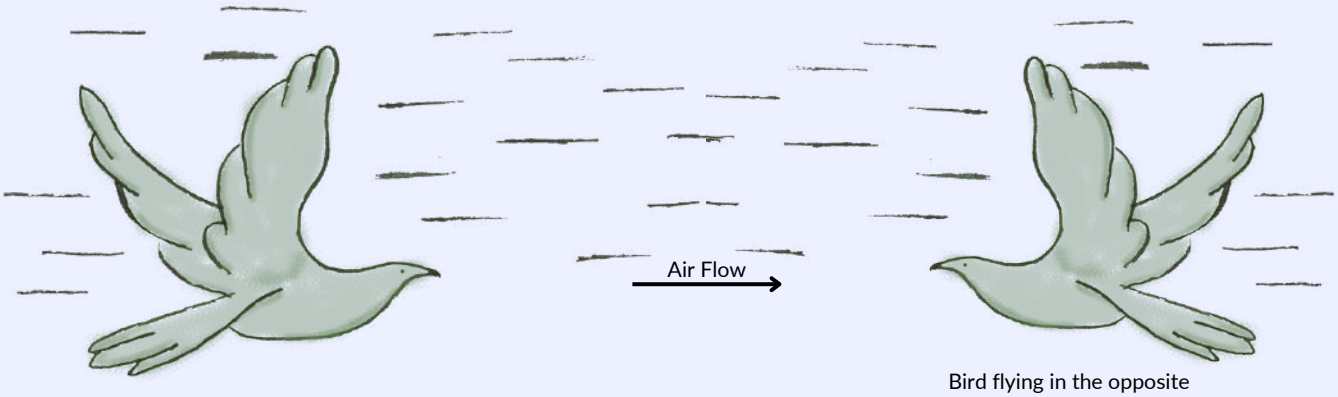
Physical Preparation before the flight

Before embarking on their journey, Godwits become more active than usual. They walk around, fluffing their feathers and bathing. They also increase their food consumption along the coast of Alaska in the fall or in China and Korea in the spring to store fat that provides energy for their continuous flight.



Altitude and Wind Resistance

Migratory birds have an incredible ability to predict weather patterns, allowing them to choose the best conditions for their migrations. They strategically use favourable winds to aid their annual journeys and show a sophisticated understanding of aerodynamics by flying at optimal altitudes with low air density, helping them reduce drag and avoid headwinds.

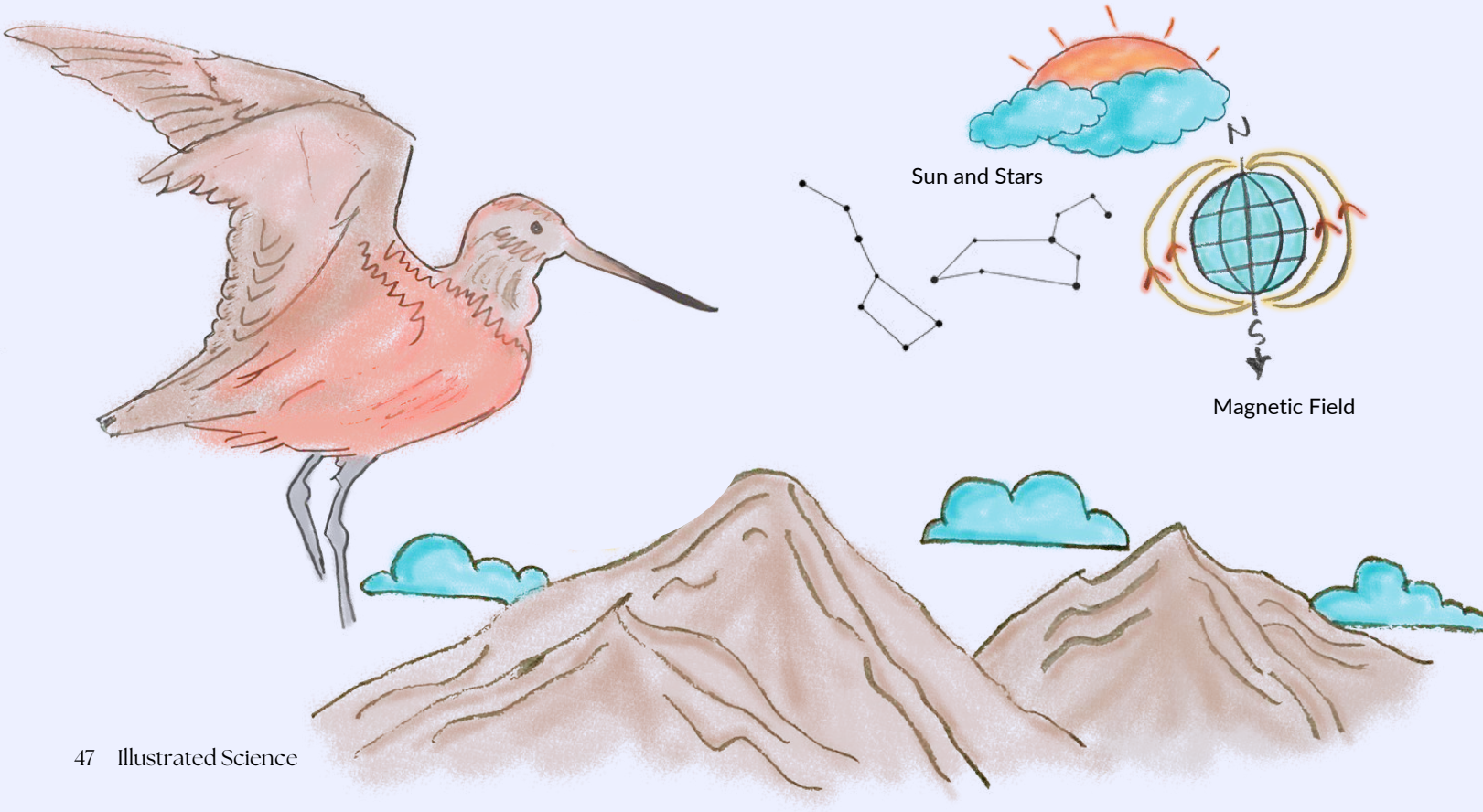


Birds fly in the direction of the wind flow, which facilitates them.

Bird flying in the opposite direction of the window flow

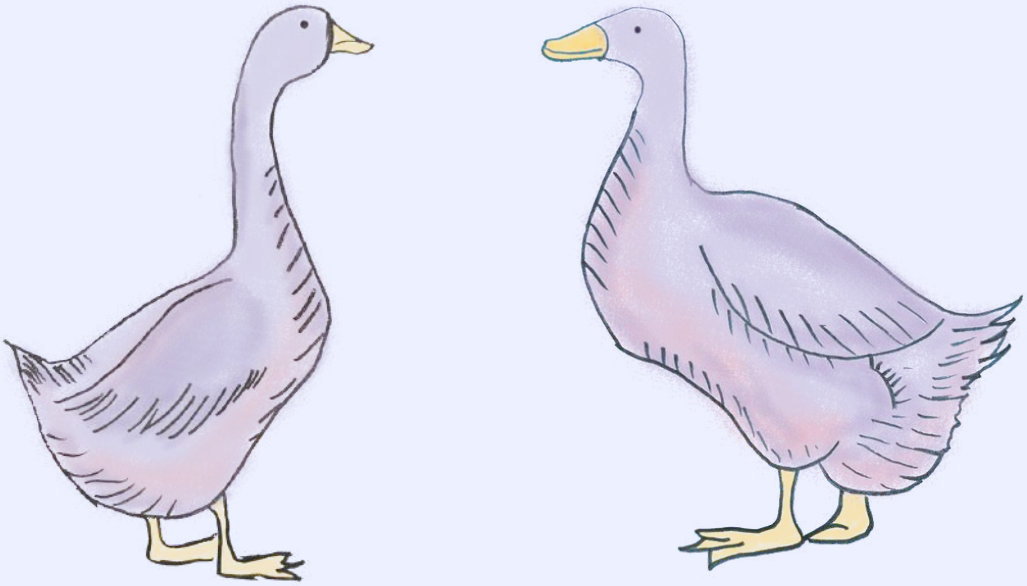
Navigating towards the destination

Bar-Tailed Godwits can travel great distances with remarkable precision thanks to their built-in navigation system. They rely on astronomical signals and an internal compass for direction, perceiving the Earth's magnetic field lines. Their exceptional sensory abilities enable them to detect even the slightest changes in the planet's magnetic intensity, making it easier for them to navigate. By using variations in magnetic intensity across different geographic regions as a guide, they can map their migratory route more effectively.



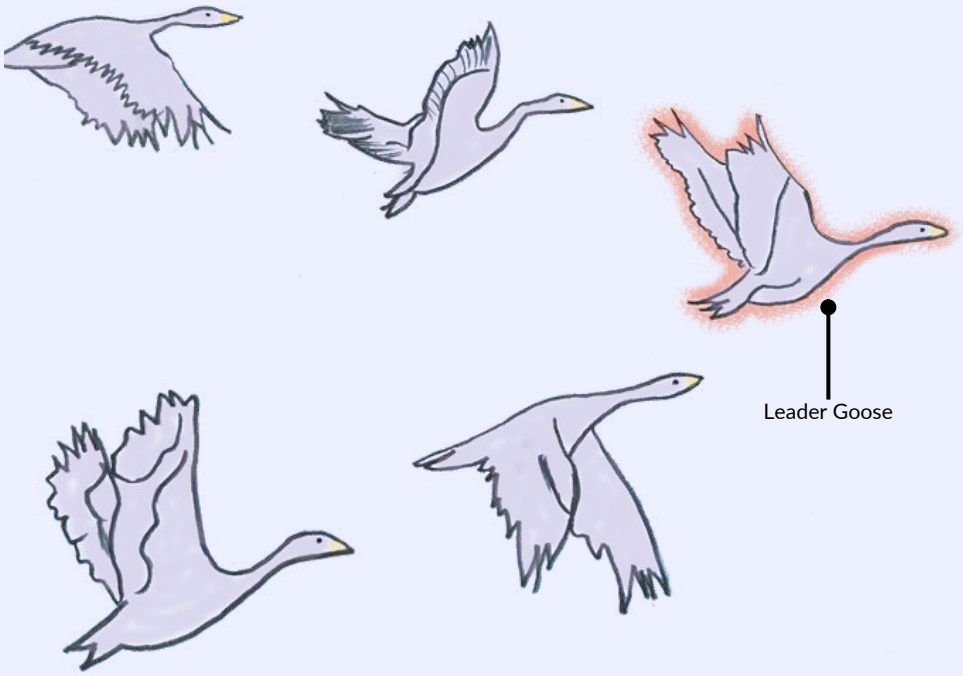
Geese: Group Migrators

The natural phenomenon of bird migration exhibits variation in its execution. For example, some species, like geese, prefer to migrate in flocks, while others, like the Bar-Tailed Godwit, make this voyage alone. Even though they use similar navigational cues, geese are known for their distinct 'V' formation flight, called the echelon formation. This arrangement is a strategic adaptation that enhances their flying efficiency.



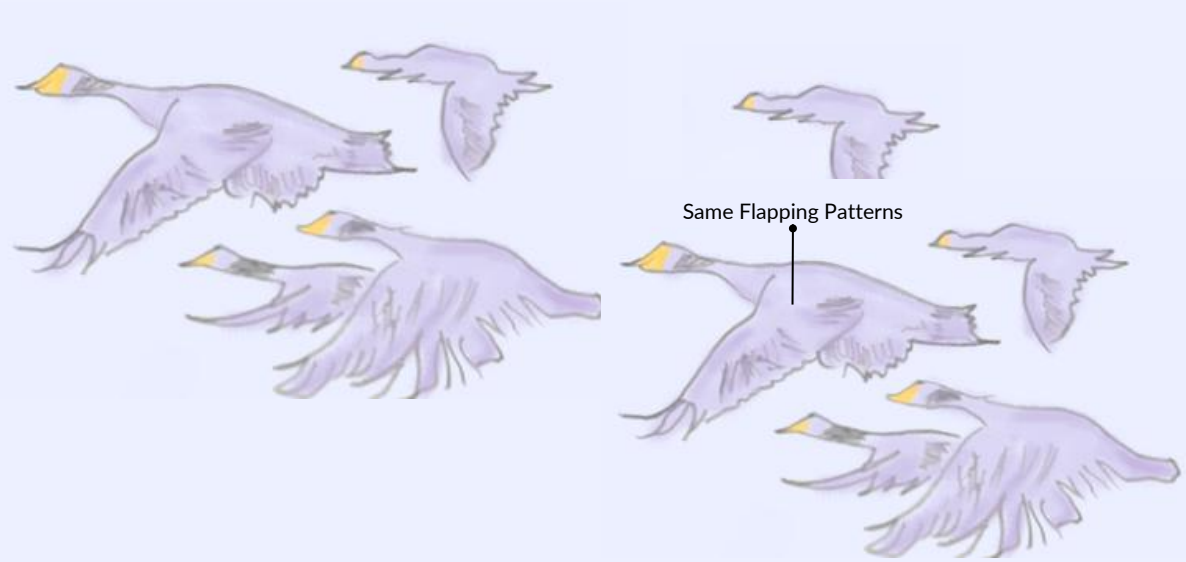
'V' Formation and Aerodynamics

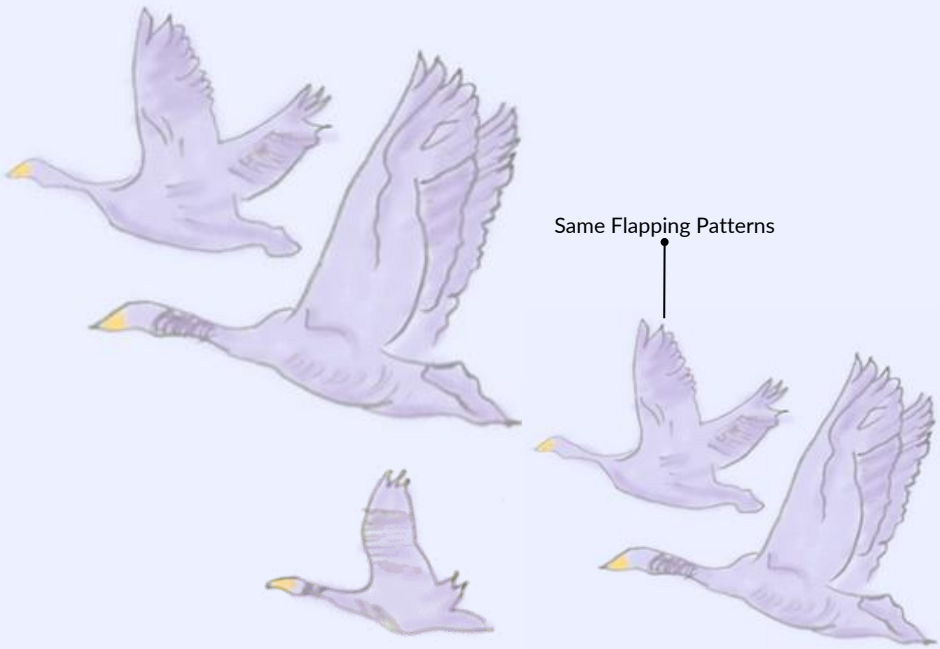
One example of cooperative aerodynamics is the V formation seen in migrating birds, such as geese. In this arrangement, one designated leader stays in front and initiates the flapping motion that the other birds in the flock follow. After a predetermined time, the group members swap to choose a new leader. This tactic improves their long-distance migration's overall effectiveness while saving energy. These birds' aerodynamic structure also reduces air resistance, greatly facilitating their movement. It illustrates bird species' complex social systems, survival techniques, and aerodynamics concepts.



Role of the Lead Goose

The lead goose sets the rhythmic flying pattern, and the other geese in the V formation follow. This synchronisation is a natural marvel; it's a strategic adaption for long-distance travel. Studies show that this development substantially decreases the flock's overall energy expenditure. The leader is essential in informing the group about the region's wind and air current patterns. This shared information highlights the interaction of a flock of Geese between instinct, adaptability, and cooperation by further optimising their flying endurance and efficiency.





The advantages of bird migration are not limited to birds; they have several ecological effects. These migratory birds are essential in pest management because they act as organic insecticides and keep insect populations in balance. They are critical to pollination because they help pollen move from one flower to another, which maintains the diversity and vitality of the plant. They also serve as dissemination agents, consuming seeds and leaving them behind in other areas. This technique facilitates the growth of plants and helps forests regenerate.

Bird migration is a process that is both profoundly beautiful and significant, demonstrating the fantastic elegance and accuracy with which avian species can travel great distances. Every migration, whether a flock of Geese or the lone Bar-tailed Godwit, narrates a tale of adaptability, resiliency, innate resolve, and perseverance in the face of challenges. Our duty as guardians of the planet is to protect the ecosystems and habitats that migrating birds depend on to preserve the magic of these incredible migrations for future generations while also fostering awareness about their importance among communities worldwide. We can protect the history of bird migration by working together to conserve natural spaces and promote sustainable practices for coexistence with wildlife.

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Krishi Bhojani is a student of Bachelor of Arts (Honours) at Ahmedabad University. He enjoys watching birds, especially the ones that travel in a group. Directions is not a cup of his tea which made him wondered how birds would travels across the continents? This question lead to the making of this digital illustration to explain this phenomenon.

Jitesh Jhawar is an Assistant Professor at the School of Arts and Sciences at Ahmedabad University. His research focuses on understanding group dynamics and underlying mechanisms that also fall under self-organisation in biological systems. His research is driven by fundamental proximal questions on animal behaviour while they are in groups. His research is also highly interdisciplinary, as he uses computer vision, motion detection, and machine-learning-based techniques for data collection from videos of animal groups. He completed his PhD at the Indian Institute of Science, Bengaluru (2019) and moved to the Max Planck Institute of Animal Behaviour and the University of Konstanz, Germany for postdoctoral work

Active safety in automobiles

Revolutions in Automotive Safety Industry

Writer and Illustrator **Vraj Mehta** | *Science Mentor* **Maryam Kaveshgar**

In a time when transportation is crucial for daily commutes, ensuring the safety of people travelling to work has become a major concern. The reckless use of vehicles poses risks to drivers, passengers, pedestrians and other motorists. To address this issue, automobile companies and researchers collaborate to introduce safety innovations to reduce or prevent injuries from traffic collisions. Initial focus was on passive safety features such as helmets, seat belts, hand brakes and airbags but with technological advancements active safety measures were introduced. As time evolved and the era of computers emerged, innovations led to the birth of active safety. Major automobile companies maintain dedicated research and development departments that study automotive design, construction, equipment and regulations to build safer vehicles.

Major Breakthroughs in Automotive Safety

1970
Ford introduced rear wheel anti-lock brake systems named "Sure-Track" for the back wheels

1978
Mercedes unveiled the initial electronic anti-lock braking system in its Mercedes-Benz S-Class

1981
Mercedes-Benz launched the first car in production with supplementary restraint system airbags specifically designed for the driver's seat

1987
Mercedes-Benz, Toyota and BMW presented traction control technology aimed at maintaining traction during acceleration

1991
Volvo rolled out its side impact protection system intended to distribute impact force across the entire side of the vehicle rather than a specific area

1994
Volvo implemented side impact air bags within the seat backrest to safeguard the chest.

2004
Volvo launched the Blind Spot Information System which utilizes cameras and motion sensors to prevent collisions during parking or lane changes.

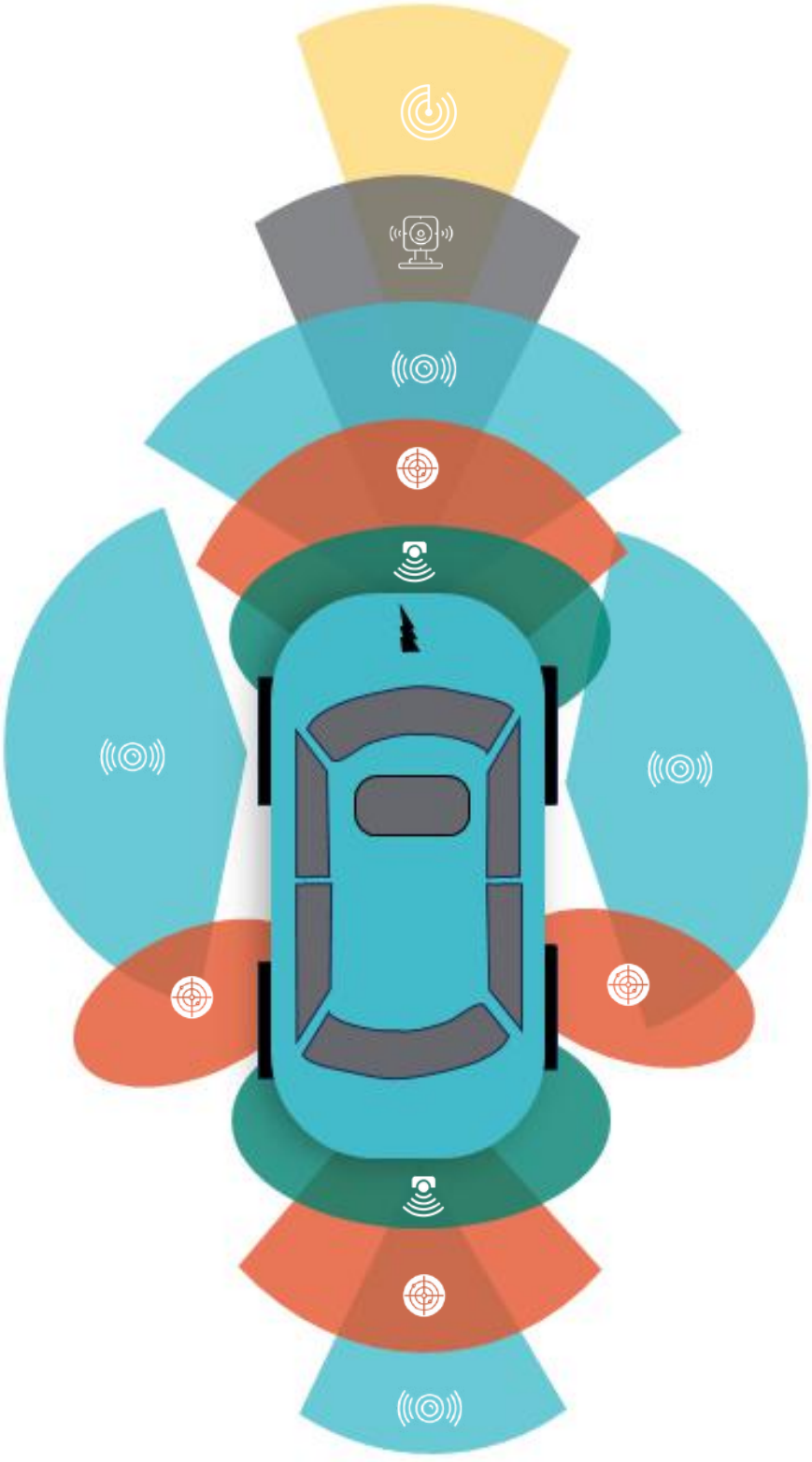
2008
Volvo introduced autonomous emergency braking to assist drivers in avoiding or minimizing collisions detected by sensors.

2009
Citroen and Bosch introduce intelligent anti-skid system called Snow motion, giving better vehicle control in snowy or icy conditions.

2010
Volvo developed a pedestrian detection system that triggers automatic braking when pedestrians are detected.

Sensors in Advanced Driver Assistance Systems

Sensors are integral to assisting advanced driver assistance systems (ADAS), as they constantly monitor the surroundings, and they contribute to safer, more comfortable and more efficient driving experiences for the passengers.



Lidar Sensor

Utilizes laser pulses to create high-resolution, accurate 3D maps of the environment, effective in low light and tracks obstacles to maintain safe distances

Short/Medium Range Radar (SRR/MRR)

SRR is utilized for blind-spot monitoring, lane-keeping support, and parking aid. MRR identifies obstacles within a range of 100 to 150 meters and facilitates automatic distance control as well as brake assistance.

Long Range Radar (LRR)

Operates at a frequency of 77 gigahertz, utilized to determine the distance and speed of other vehicles, as well as to detect objects within an expanded field of vision for cross traffic alert systems.

Ultrasonic Sensor

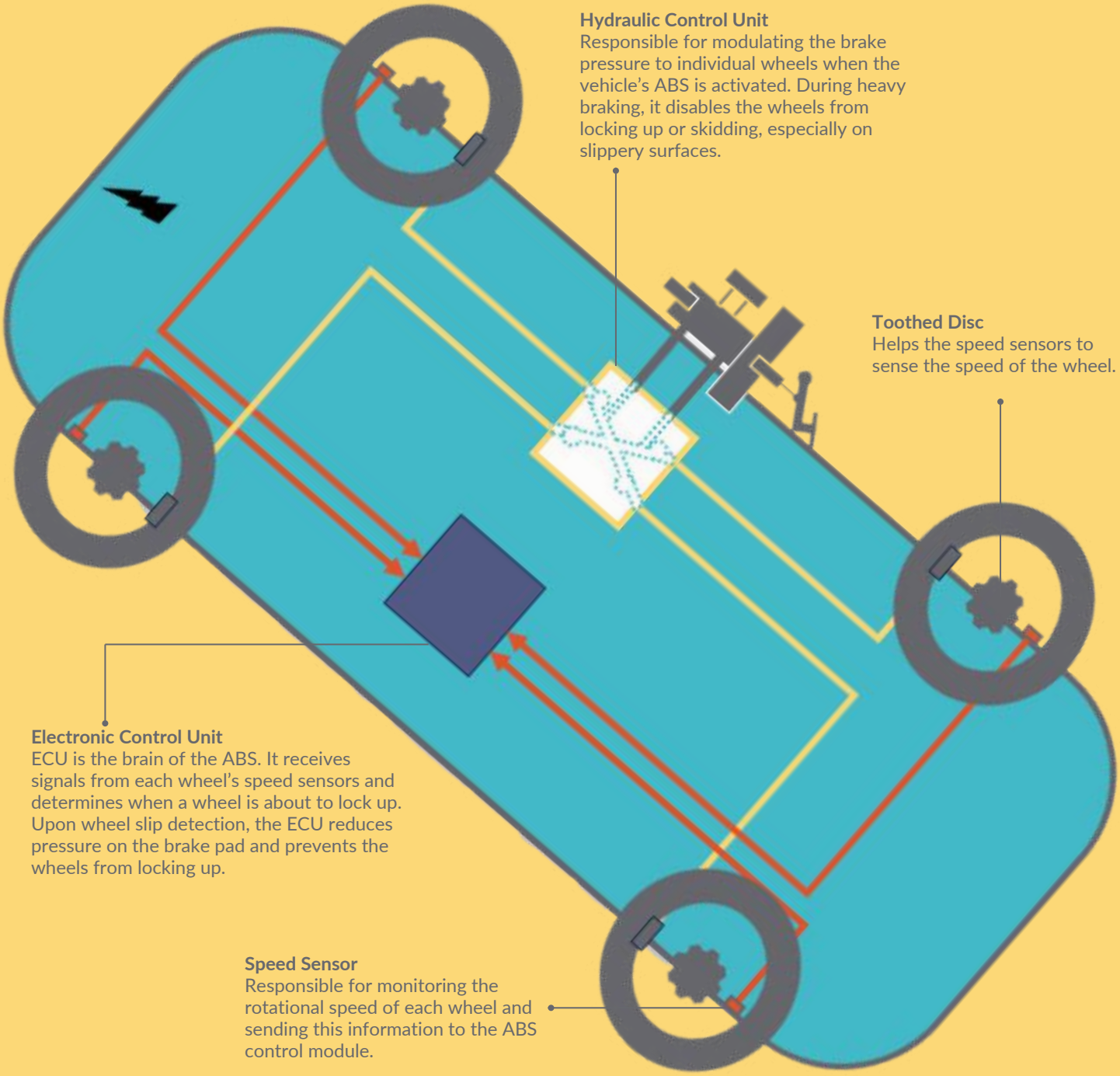
Employs high-frequency sound waves to measure distances to nearby objects, commonly used in parking assistance and collision avoidance systems.

Camera Sensor

Monitors surroundings and provide visual evidence in the event of accidents, traffic violations, and other road incidents. They play a crucial role in collision avoidance, parking assist systems, and other sensor-based security features.

Anti-lock Braking System

An anti-lock brake system (ABS) prevents wheels from locking up during sudden or aggressive braking. Driver can steer the vehicle while braking to preventing skidding. The system uses sensors to detect wheel lock-up and modulates brake pressure accordingly, improving steering control and reducing braking distance especially when it rains or snows.



Hydraulic Control Unit
Responsible for modulating the brake pressure to individual wheels when the vehicle's ABS is activated. During heavy braking, it disables the wheels from locking up or skidding, especially on slippery surfaces.

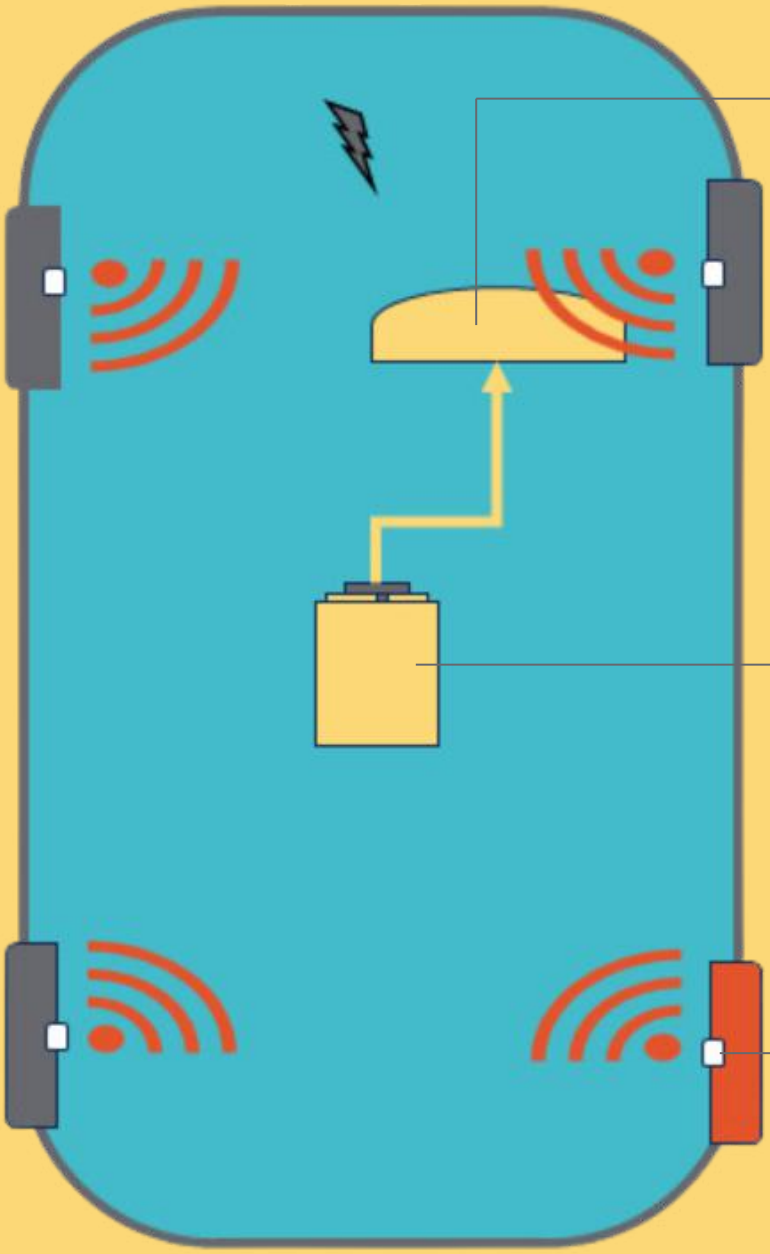
Toothed Disc
Helps the speed sensors to sense the speed of the wheel.

Electronic Control Unit
ECU is the brain of the ABS. It receives signals from each wheel's speed sensors and determines when a wheel is about to lock up. Upon wheel slip detection, the ECU reduces pressure on the brake pad and prevents the wheels from locking up.

Speed Sensor
Responsible for monitoring the rotational speed of each wheel and sending this information to the ABS control module.

Tire Pressure Monitoring System

Tire Pressure Monitoring System (TMPS) is a vehicle feature that monitors air pressure inside tires. It uses sensors fitted to each wheel that send real-time tyre pressure information to the driver. If the pressure drops significantly, a warning light on the dashboard alerts the driver, sending messages to fill the tyre. In some cars, a vehicle with accurate tyre pressure is illustrated to guide the driver in low tyre pressure situations to improve tyre wear and increase fuel efficiency.



Receiving Unit
Mounted near each wheel, it receives the information from the sensors. This information includes the tyre's air pressure and temperature.

Electronic Control Unit
Brain of the TPMS. It interprets the data from the sensors via the receiving unit. If the tyre pressure is too low or too high, an alert will be triggered on the dashboard.

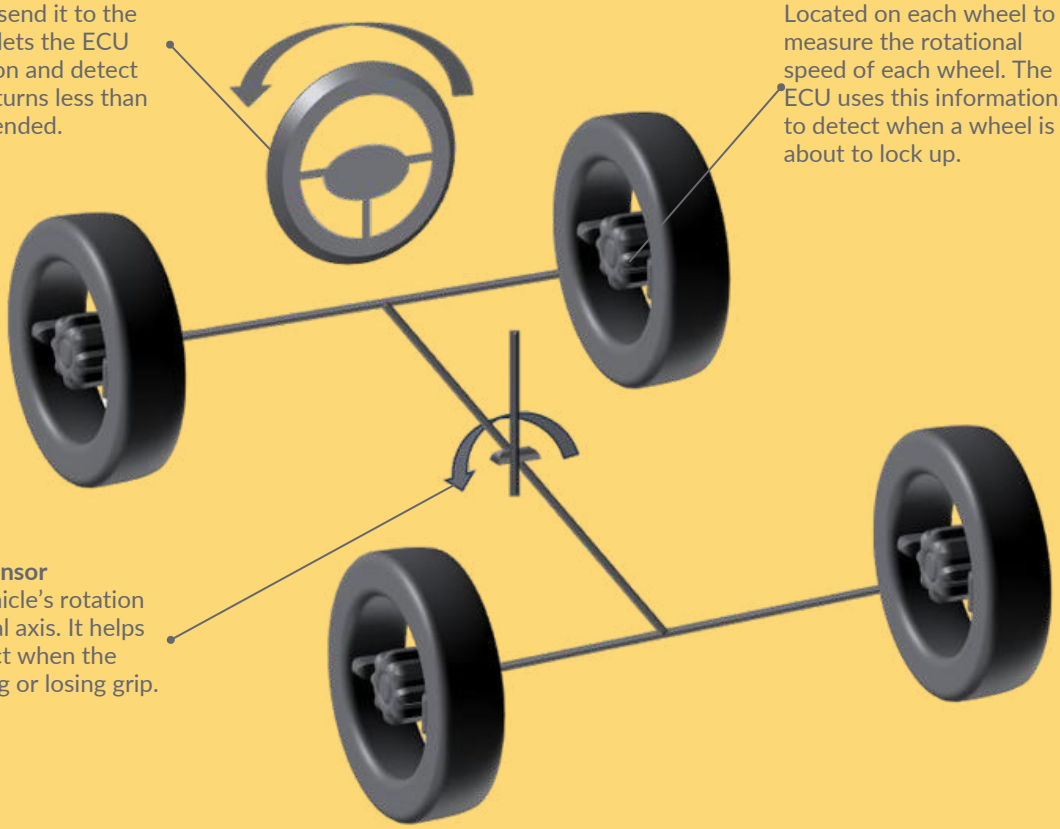
Sensor
The sensor measures the air pressure and sometimes the temperature in all tyres. It sends this information to the vehicle's onboard computer system.

Electronic Stability Control

Electronic Stability Control (ESC) is a safety feature in cars that helps prevent loss of control. It uses sensors to monitor steering input and wheel motion and automatically applies brakes to individual wheels or reduces engine power to help maintain the intended driving path. It's beneficial in slippery conditions or during sudden manoeuvres.

Steering Angle Sensor
It helps measure the steering wheel angle and send it to the vehicle's ECU. It lets the ECU know the direction and detect whether the car turns less than or more than intended.

Speed Sensor
Located on each wheel to measure the rotational speed of each wheel. The ECU uses this information to detect when a wheel is about to lock up.



Rotation Rate Sensor
Monitors the vehicle's rotation around its vertical axis. It helps the ECU to detect when the vehicle is skidding or losing grip.

What are the contributions of Automobile companies?

Many companies in the automobile industry have taken vital steps in paving the way for safety through active and passive safety features revolutionizing the safety industry in the past, and they, along with new companies, try to come up with newer technologies integrating with the upcoming cars.

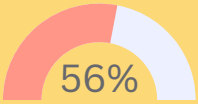
ZF Group: ZF has led by combining active and passive safety technologies to create integrated safety systems. These advanced systems enhance driver support, comfort, and convenience by providing user-friendly assistance features like occupant health monitoring.

Bosch: Bosch has played a vital role in advancing the Electronic Stability Control system, which assists drivers in maintaining vehicle control during challenging manoeuvres.

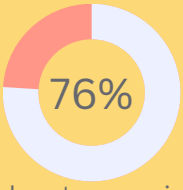
Nissan, Volvo, Mercedes, and Google: These companies are making significant strides in developing autonomous cars, which rely heavily on advanced active safety systems.

Toyota Motor: Toyota is another key patent filer in this space, contributing to the development and application of EV active safety.

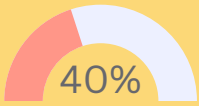
Automobile Safety Market



Reduction in risk of fatality with the help of ESC.



Lane departure warning was available on free ways.



Single car crash reduced with help of ESC.

It is evident through statistical data and company research how crucial it is that active safety is utilised to its complete potential. There can be a world without deaths due to accidents, as this is what big companies invest their time and money in. The potential for this market is limitless, and this must succeed in creating a future where road accidents are significantly reduced or eliminated.

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Vraj Mehta is a student of Bachelor of Arts (Honours) at Ahmedabad University. This project was a breath of fresh air for him as science communication is uncommon for a management student to study. He selected active safety for automobiles as a topic since it is present in our vehicles and most often needs to be understood how this technology works wonders in the safety department.

Maryam Kaveshgar is an Assistant Professor at the School of Engineering and Applied Science at Ahmedabad University. She received her PhD in Gyroscopes and Navigation Systems from Igor Sikorsky Kyiv Polytechnic Institute, National Technical University of Ukraine, after finishing her master's degree in Kyiv and undergraduate in Iran. She is motivated by driverless cars, autonomous driving, active safety, sensors, robotics, and control theory. She has published seven papers and presented her work at several international conferences.

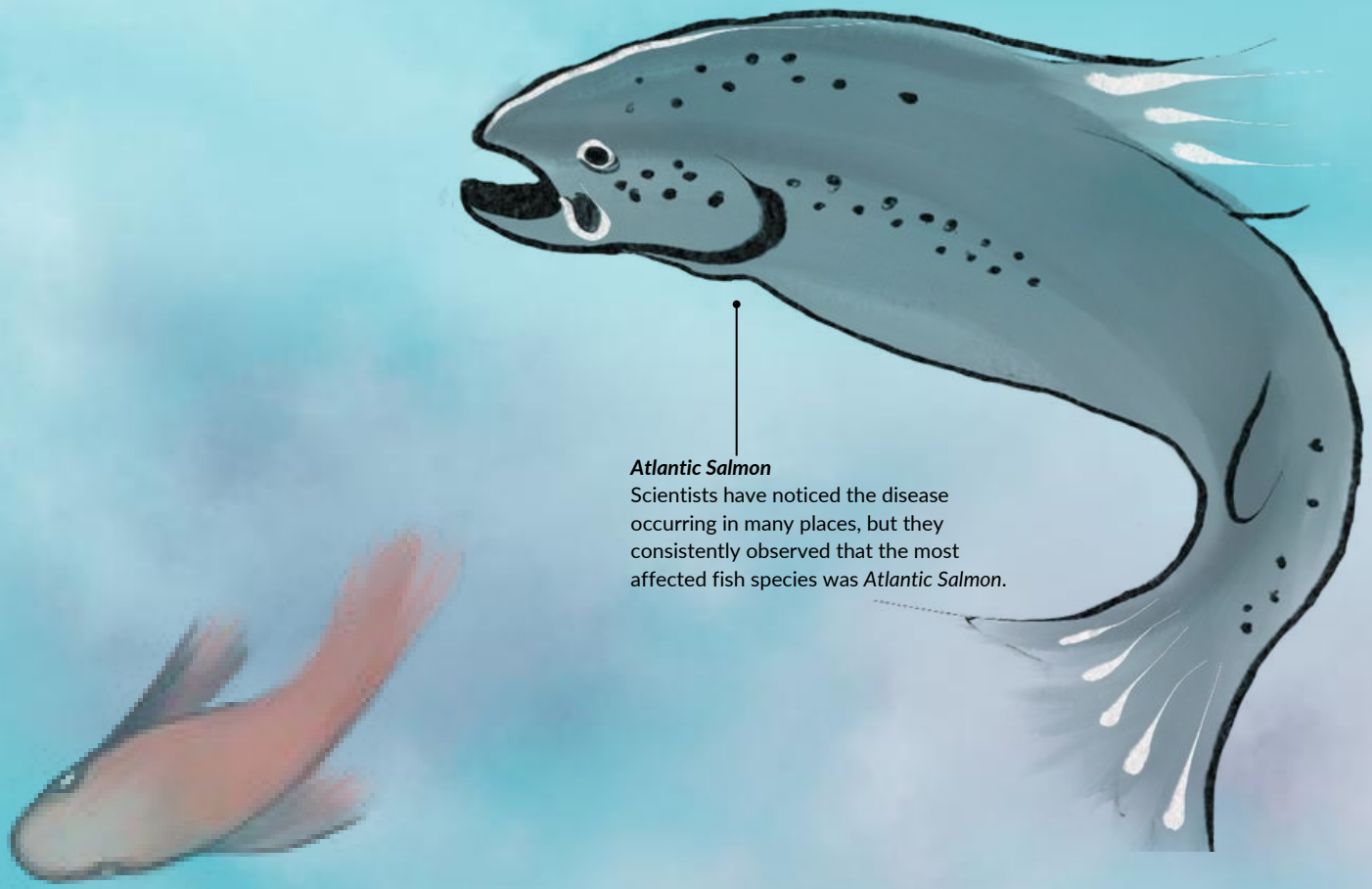
Underwater Hidden Killers

Disruption Caused by Amoebae on Fish Population

Writer and Illustrator **Hetvi Joshi** | *Science Mentor* **Souvik Sen Gupta**

Imagine a vibrant undersea city teeming with fish, turtles, and many other aquatic animals. However, there's a problem: strong microscopic amoebae are causing chaos. Especially in warm, nutrient-rich environments, they multiply and spread among the fish rapidly. Diseases resulting from this rapid expansion have the potential to affect fish populations as well as humans who rely on fish as a food source. What if the fish become ill and there aren't enough to catch? This could make it difficult for individuals to obtain sufficient food, especially in areas where fishing is a major source of income. Therefore, illnesses in fish can have an impact on people's ability to provide for their families and themselves while also affecting the wellbeing of the fish population itself.

These microscopic amoebae pose a significant threat to countless lives and are a major source of disturbance. But just how do these seemingly inconsequential species disrupt the generally well-functioning undersea environment? Scientists first noticed this disease in Tasmania, then in Australia, France, the USA, Canada, and recently in Scotland. They began exploring how amoebae cause sickness in fish and innovating approaches to reduce the detrimental effects of amoebic illnesses on fish.



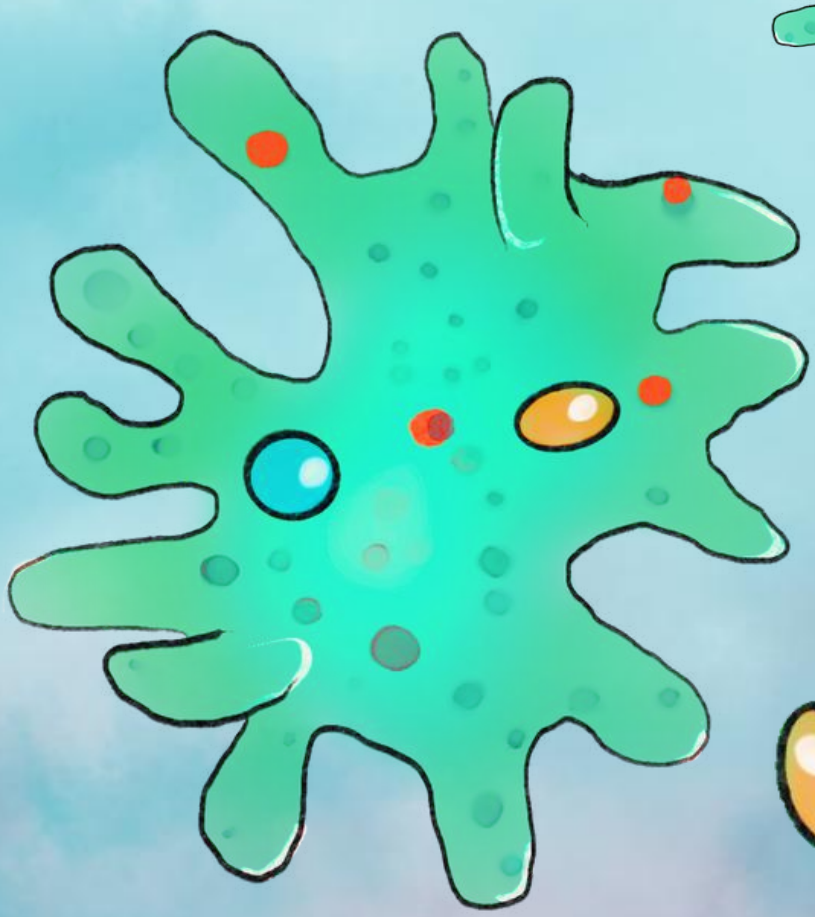
Atlantic Salmon
Scientists have noticed the disease occurring in many places, but they consistently observed that the most affected fish species was *Atlantic Salmon*.

Understanding Amoebae

Amoebae consist of a single cell that is visible only under a microscope. What makes them special are their pseudopods, which allow them to freely move around in moist environments such as industrial cooling towers, lakes, rivers, and soil. They can also attach themselves to other creatures they encounter. Amoebae are part of the larger group of organisms known as Eukaryotes and within the Eukaryotic kingdom called Protista, they belong to a group called Amoebozoa which includes various types of amoeboid organisms.

Brain of Amobae
The nucleus controls every action an amoeba takes and contains all crucial instructions for its growth. Genetic material inside the nucleus instructs the amoeba on living and developing.

Pseudopods: Enabling Flexibility
A flexible part of their body from which they can modify their shape, help them to move in different directions and to take food also. These flexible arms meet the amoebae's needs for protection, sustenance, and mobility.



Defense Mechanism in Amobae
Some amoebae can instantly extend their pseudopods to defend themselves when they feel threatened. They can grab and devour potentially dangerous things, such as small animals that try to consume them.

Vacuoles : Tiny Sacs for Storage
Vacuoles are located in the cytoplasm, the jelly-like material that makes up the cell. They are like small sacs that can shrink and grow They manage the amount of water in the cell. For instance, food vacuoles store the food that amoebae consume, while water globules act as a water storing tank in amoebae for future use.

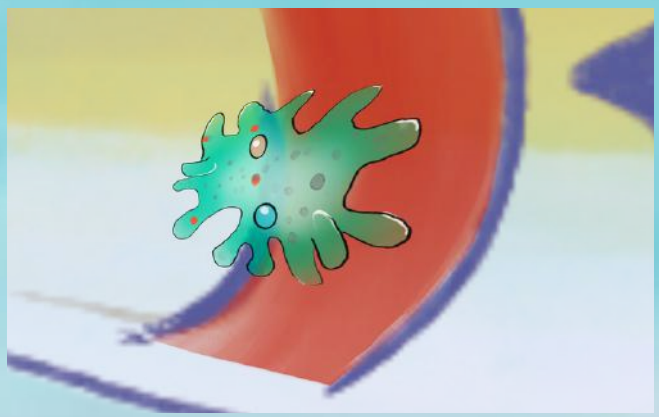
Cell Membrane: The Controller
The cell membrane is essential for maintaining the cell, controlling what enters and leaves it, and enabling the organism to move around and thrive in its surroundings.

What is Amoebic Gill Disease?

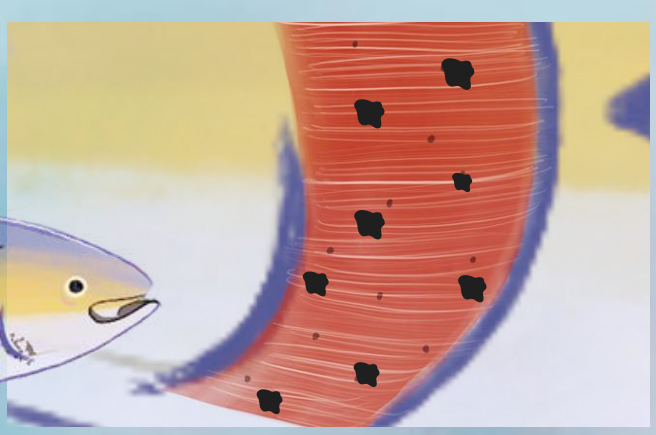
Amoebic Gill Disease (AGD) is characterized by the infiltration of amoebae into fish gills. When fish gills become infected with the parasite known as Neoparamoeba perurans, it results in Amoebic Gill Disease. The disease causes breathing difficulties for the affected fishes, as their ability to absorb proper oxygen and release carbon dioxide is hindered by a slime layer. Without specific treatment, infected fish may exhibit signs such as weight loss and can ultimately succumb to death. This poses challenges for fishermen in catching sufficient fish, resulting in reduced income within the fishing industry.

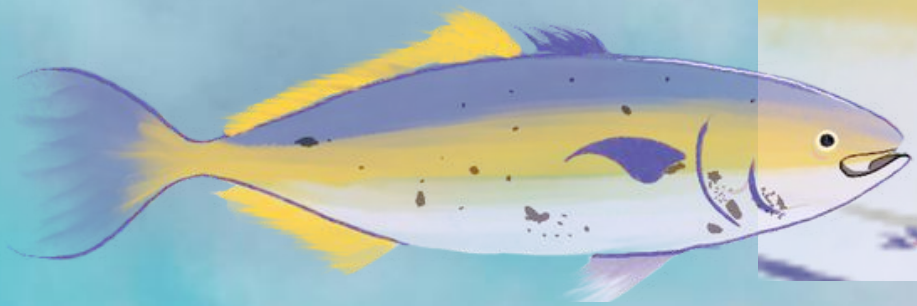
1 Neoparamoeba perurans is a species of amoeba that thrives in aquatic environments, particularly freshwater lakes. When it detects the presence of Salmonid fish, it moves towards them.

2 When the amoeba reaches the fish, it attempts to attach itself to the fish's gills and enter them. Once inside, it creates a thick layer called a slime layer on the gills.



3 It begins consuming part of the gill tissue, hindering the fish's ability to breathe properly. This disease also has adverse effects on the fish's body, causing it to become dirty.





Navigating Diagnosis and Management of AGD

When diagnosing amoebae-mediated illness in fish, scientists first closely monitor the affected fish and then take a tissue sample from the affected area to examine under a microscope for the presence of Neoparamoeba perurans. This process is also known as Gill Biopsy.

Fish populations can be controlled by taking precautions such as maintaining clean water and avoiding overcrowding, which can decrease the number of AGD-caused cases. Additionally, selecting naturally immune fishes and using medicated food can minimize symptoms in affected fish. It's important to avoid subjecting fish to high water temperatures because the optimal range for AGD is 10-18 degrees Celsius. In past research, bithionol treatment has been attempted by exposing affected fish to baths containing medications that reduce parasite load on the gills and alleviate symptoms. Two frequently used treatments for this disease are freshwater baths and hydrogen parasite baths.

Researchers continue their efforts towards understanding the exact process involved. As of now, researchers hypothesize that parasites affecting fish may produce toxins or trigger an adverse response from the fish's immune system exacerbating health issues. Hence it is essential to know about cellular functions and clean water maintenance as preventive measures against illnesses in fishes. Overall, our findings serve as a reminder regarding protecting marine life along with its habitat.

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Hetvi Joshi is a student of Integrated Master of Science at Ahmedabad University. As a life Science student, she always found it interesting to know about different types of disease and their mechanism. She believes that it is important for people to know about disease in fish since it indirectly impacts humans. Hence, the aim of her illustration is to inform people about the most dangerous disease called AGD (Amoebic Gill Disease).

Souvik Sen Gupta is an Assistant Professor at the School of Arts and Sciences, Ahmedabad University. He teaches Microbiology, Molecular Biology, Human Physiology, Human Protozoan Parasites and Animal Biotechnology. His research interests are in the field of molecular parasitology, DNA repair and anti-leishmanial therapeutics. He completed his PhD in Molecular Biology and Biochemistry of the parasite Leishmania in 2011 from Indian Institute of Chemical Biology, Kolkata, India. He moved to University of Aarhus, Denmark for postdoctoral studies in the field of eukaryotic replication with yeast as a model organism.

Swift Relief Therapy

kINPen: Redefining Wound Treatment with Plasma

Writer and Illustrator **Suyashi Pradhan** | *Science Mentor* **Bharat Kakati**

Constant natural selection has given man an adaptive advantage. A man's physiology has a natural regenerative capacity in case of damaged tissues. This natural process is popularly known as the wound-healing process. The human body's innate capacity to heal is truly remarkable. In recent years, there have been several advancements in wound healing. Cold Atmospheric Plasma (CAP) therapy is a newly emerged innovative therapy. It has multifaceted effects ranging from tissue regeneration and anti-inflammatory properties to possible anticancer properties. The current article dwells on the scientific understanding that CAP therapy effectively triggers the biological mechanism for tissue regeneration. Is there any significant difference in the cellular physiology of the wound that will increase the recovery rate?

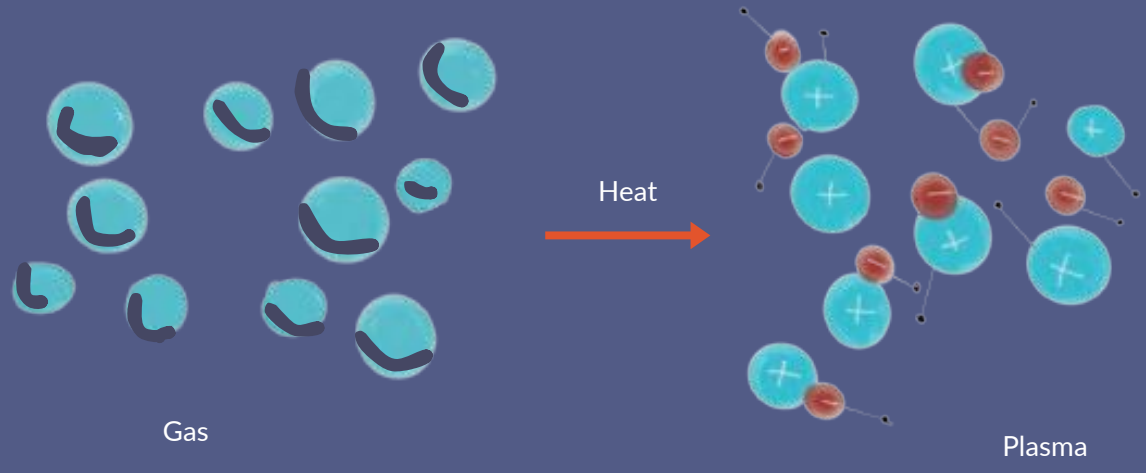
How this new technology is revolutionising wound healing?

Mr A is an 85-year-old patient who presented with a chronic wound on his lower right leg. Despite repeated surgical wound debridements, his wound did not improve. Therefore, the authors initiated cold plasma therapy for his chronic wound. Through repeated application of cold plasma, the wound was completely healed within eight weeks.

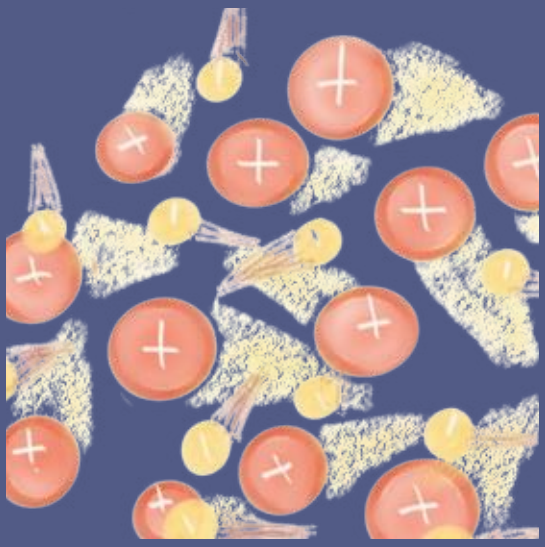
As a noninvasive procedure, the cold plasma treatment was well tolerated and had no adverse effects. This case report provides promising results and could be the basis for further studies to confirm the effectiveness of active wound dressings with cold plasma in treating chronic wounds.

What is Plasma?

Plasma, often called the fourth state of matter, emerges when heat transforms the gas into an electrically charged substance capable of conducting electricity. It comprises positively and negatively charged particles as well as excited atoms and molecules. Plasma can be broadly categorized into two predominant types: high-temperature plasma and cold atmospheric plasma (CAP).

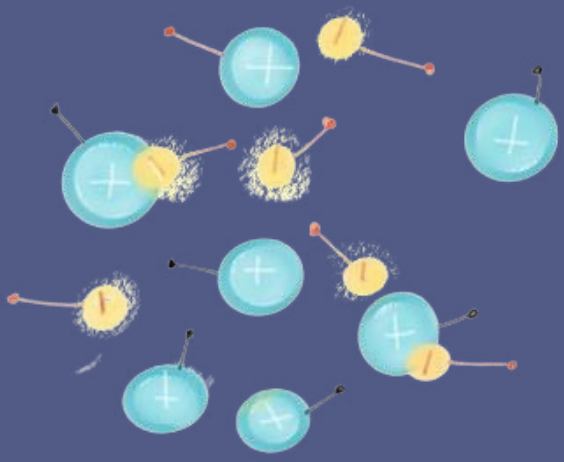


CAP Plasma Pen Therapy



Therml Plasma

- Examples in nature: Sun and stars.
- Operates at extremely hot temperatures.
- High temperature is crucial for ion activity.



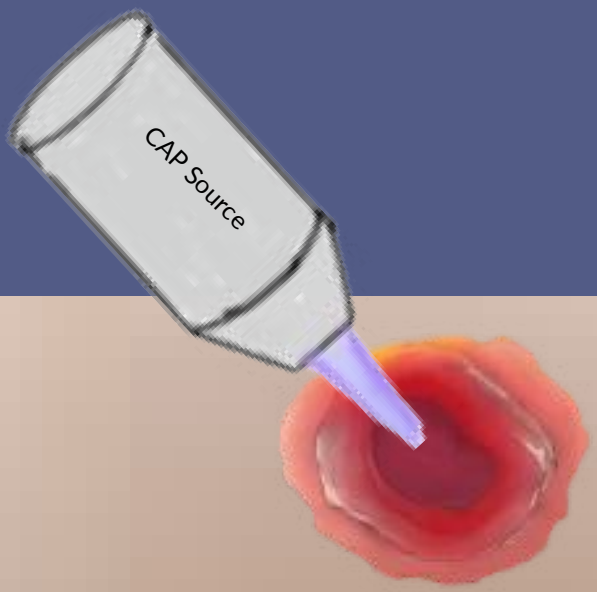
Cold Atmospheric Plasma

- Generated in the laboratory.
- Operates at room temperature.
- Minimal heat is produced, making it a viable option for treating damaged tissues

Types of Wounds

Non-chronic wounds are injuries to the skin that typically heal within a predictable timeframe, usually within weeks. These wounds result from trauma, cuts, burns, or surgical incisions and generally follow a standard healing process involving inflammation, proliferation, and remodelling. Proper wound care, including cleaning, dressing, and infection prevention, can support timely healing and reduce the risk of complications.

Chronic wounds are the injuries that remain in the inflammatory stage for three months. The ailments that could contribute to the formation of chronic wounds could include vasculitis, immune suppression, repeated physical trauma, excessive use of steroids, and diseases that cause ischemia. Chronic wounds seem to hit pause during the inflammation stage of the normal wound healing process, preventing progression to the next steps of repair. They're stuck in a perpetual state of inflammation, hindering the body's natural ability to heal.

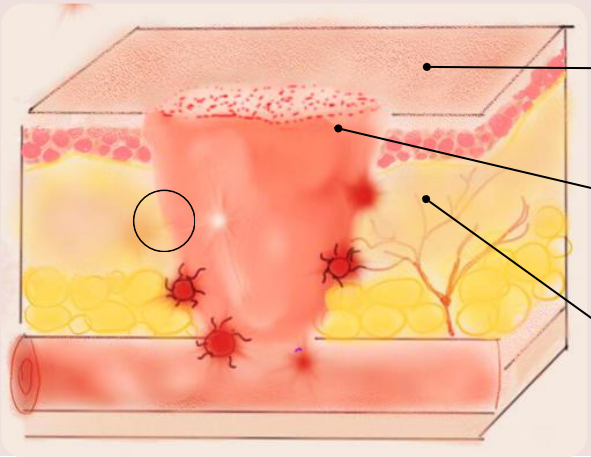


Chronic wounds

Three-step Process for Wound Healing in Non-chronic Wounds

The human body's innate capacity to heal is truly remarkable. In non-chronic wounds, it follows a three-step process to regenerate damaged tissues.

1 Swelling Phase

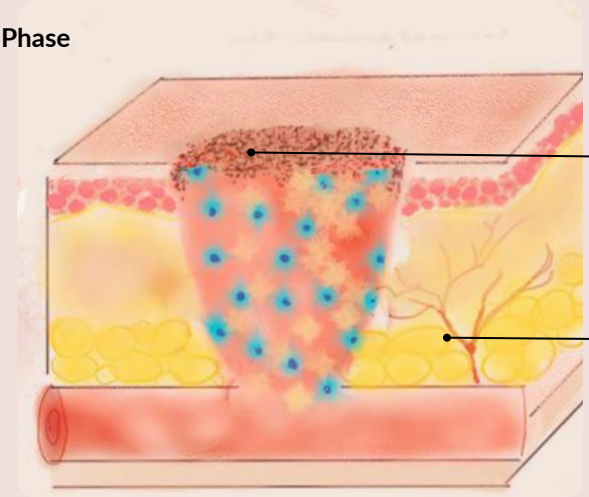


Epidermis - first layer of skin injury in this layer doesn't require 3 step process

Injury- tissue damage is beyond the first layer

Dermis layer of skin - wound in this layer undergoes 3 step process.

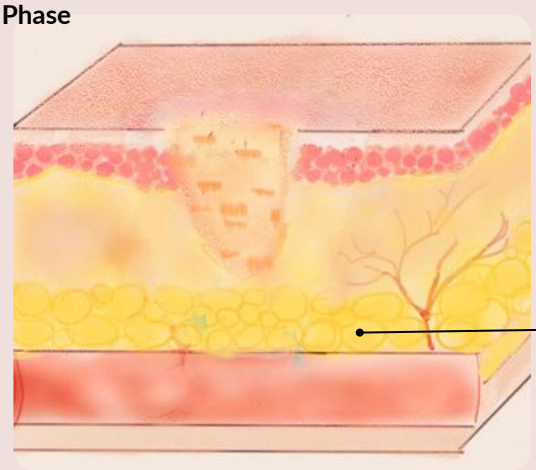
2 Tissue Building Phase



Scab Formation - a protective shield for the underneath healing tissue.

Subcutaneous Layer- consists of fat and connective tissue which acts as a cushion

3 Strength Building Phase



Blood vessels - a channel for transporting nuterients

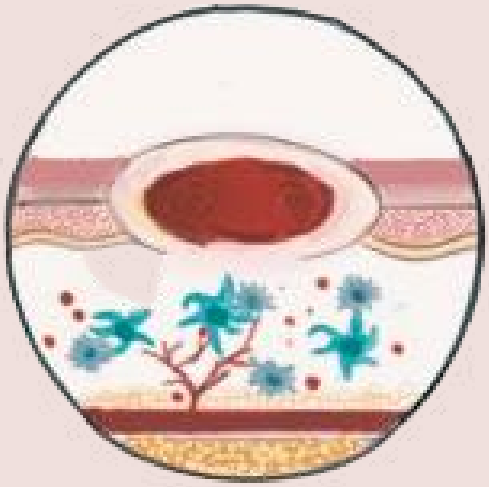
There are two main agents in this phase. Platelets are activated immediately after the injury to constrict bleeding. The second agent is the white blood cells (neutrophils and macrophages), which are responsible for combating infection and removing debris.

Platelets

Macrophages

Cytokins

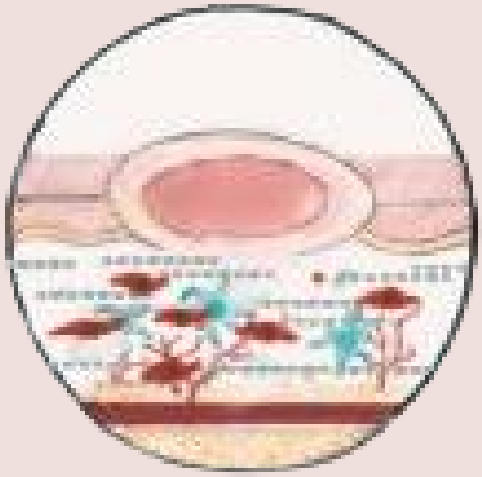
Neutrophils



The main goal is to restore and strengthen the skin's protective barrier. Granulation tissue develops with the help of fibroblasts, which produce collagen, a key protein for structure and resilience. This process also involves angiogenesis, creating new blood vessels to deliver essential oxygen and nutrients.

Activated fibroblast

Granulation tissues



This phase aims to increase the tensile strength and recover the normal tissue structure. The graduation tissue becomes scar tissue. Collagen fibres reorganize to enhance strength and flexibility. Gradually, the wound scar will shrink.

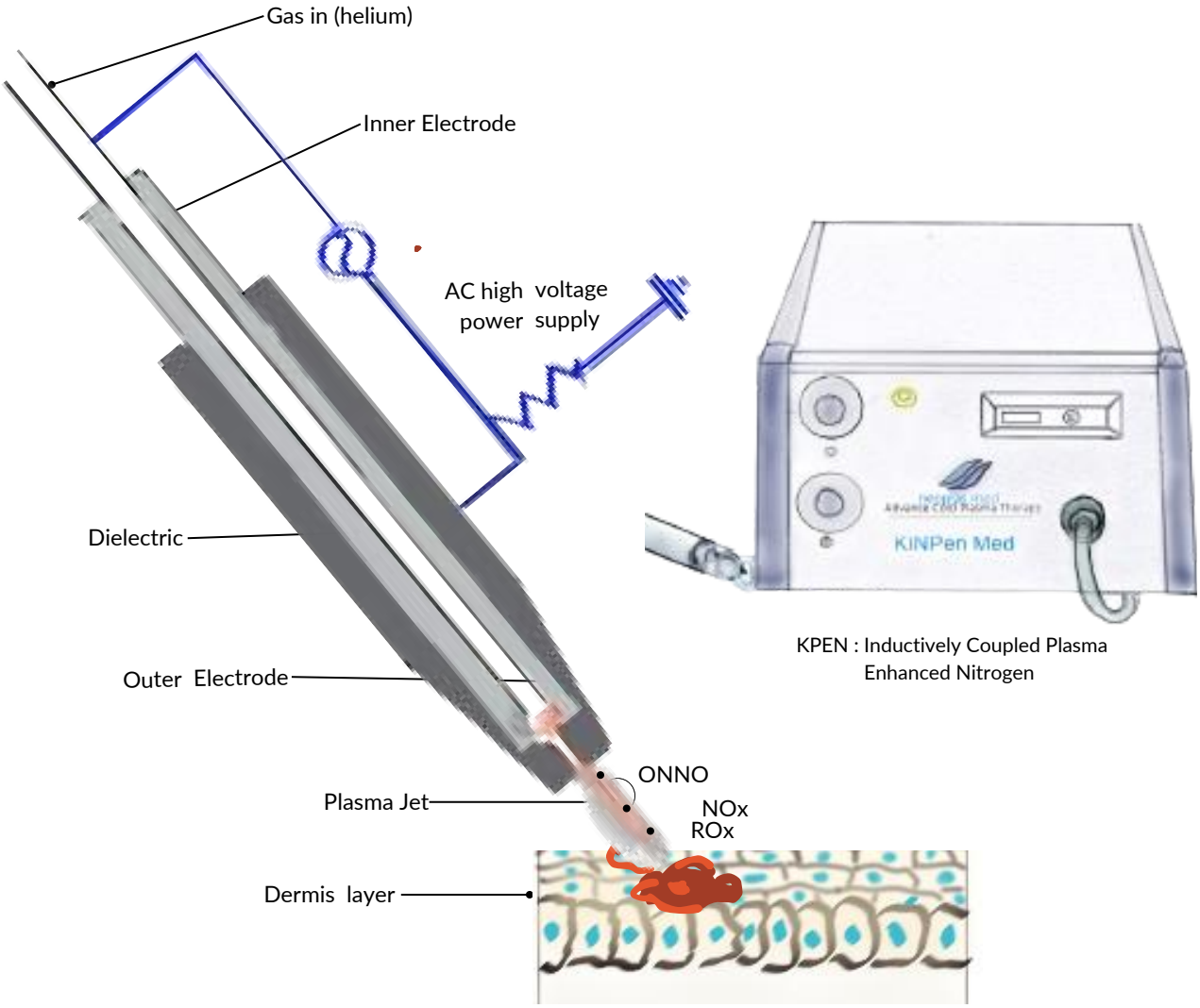
Resting Fibroblast

Collagen

CAP Plasma Pen (IKPEN)

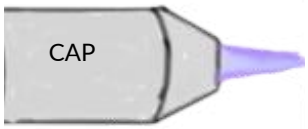
For non-chronic wounds, the body's natural healing process kicks in. But for chronic wounds, there's a device called IKPEN, a CAP device, that prompts the body to move into the proliferation stage, where new tissues form. How does it do this, and what does it target?

IKPEN technology device generates CAP which is also known as the cold atmospheric plasma. This revolutionary technology operates at atmospheric pressure (room temperature) and produces minimal heat. Thus avoids harming the damaged cells and tissues. By applying high-frequency voltage, gas gets ionized atoms and a cold plasma jet emerges.



KPEN : Inductively Coupled Plasma Enhanced Nitrogen

These agents help in the cellular functioning and wound healing process.



Generates reactive agents like

- Reactive Oxygen (ROx)
- Reactive Nitrogen (NOx)
- Hydrogen peroxide(ONNO

CAP helps effects

- Disinfection
- Proliferation
- Cell Migration
- Angiogenesis

The CAP therapy Effect: On Biolgical Wound Healing ?

IIKPEN, operating through Cold Atmospheric Plasma (CAP) therapy, demonstrates remarkable potential in advancing wound healing processes. Research, such as the study conducted by R.S. Tipa, underscores its efficacy in generating a reactive agent, hydrogen peroxide, which initiates healing by activating platelets and stimulating the growth and migration of epithelial cells.

Furthermore, IKPEN aids in the crucial re-epithelialization process, facilitating the rebuilding of the skin's outer layer. Notably, CAP treatment exhibits dual benefits, acting as a disinfectant for wounds and a catalyst for the accelerated proliferation of fibroblast cells. Evidence from 13 randomized clinical trials from 2010 to 2022 consistently supports the superior effectiveness of CAP therapy in reducing wound area compared to non-CAP treatments, thus advocating for its integration into contemporary wound care practices.

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Suyashi Pradhan is a student of Bachelor of Arts (Honours) Psychology Major at Ahmedabad University. She chose to explore Cold Atmospheric Plasma (CAP) due to her interest in the human body's regenerative abilities. CAP offers an innovative approach to wound healing, leveraging the power of plasma to facilitate the recovery of chronic wounds.

Bharat Kakati is an Assistant Professor at the Energy Engineering Division at the Assam Science and Technology University, Jalukbari, Guwahati, Assam since 2018. After completing his Masters in Physics from Tejpur University in 2005, he did his Ph.D. in Dusty Plasma Physics from Centre of Plasma Physics-IPR, Sonapur, Kamrup, Assam (India), then he was a project scientist there before moving to the Institute for Plasma Research for his post doctoral research. He has about 35 peer reviewed publications in international journals in the field of Plasma Diagnostics, Tokamak, Spectroscopy, Fusion Technology, Negative Ion Source, Dusty Plasma Physics, Low pressure Plasma and in Plasma Technology

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