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Science REPORTER

CSIR 79th Foundation Day

"Bringing value to the society through S&T"

Dr Shekhar C. Mande,
DG-CSIR

Plus

- Tributes to Dr Narender K. Sehgal & Prof. Govind Swarup
- Unravelling the Coronavirus Genome
- Testing Corona
- Drug Repurposing for COVID-19 Therapy
- GIS & COVID-19
- Alternative to Antibiotics
- Reading Food Labels
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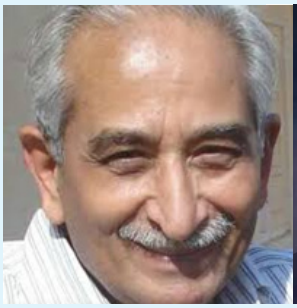

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DIRECTOR
DR RANJANA AGGARWAL

EDITOR
HASAN JAWAID KHAN

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SONALI NAGAR
MEHER WAN

LAYOUT & DESIGN
SARLA DUTTA
MANENDER SINGH

PRODUCTION
ASHWANI KUMAR BRAHMI
ARUN UNIYAL
ANIL KUMAR

BUSINESS DEVELOPMENT DIVISION
CHARU VERMA
RANBIR SINGH

COVER DESIGN
MANENDER SINGH

Seven Decades of the Council of Scientific and Industrial Research

A galaxy of visionaries and planners and some of the most eminent Indian scientists of the day played an important role in the establishment of the Council of Scientific and Industrial Research (CSIR), much before the country gained independence.

The driving force behind the setting up in April 1940 of the Board of Scientific and Industrial Research (BSIR), which preceded the CSIR, seems to have been Sir Arcot Ramaswami Mudaliar, a Member of the Governor General's Executive Council. The BSIR was set up to oversee research possibilities and to solve problems related to World War II, which was raging during those times. However, there were many research results that were beyond utilisation during the War but could be utilised by Indian industries. And thus, in early 1941 was set up the Industrial Research Utilisation Committee whose main function was to advise the government on the selection of industries that could utilise the research results. Successive developments would eventually lead to the establishment of the Council of Scientific and Industrial Research (CSIR) on 26 September 1942.

Apart from eminent scientists like Dr Jagadis Chandra Bose and Dr Meghnad Saha who guided the working of the BSIR there were other eminent scientists like Dr C.V. Raman, Dr S.K. Mitra, Dr J.C. Ghosh among many others who were members of the research committees. Sir Shanti Swarup Bhatnagar, the first chief of CSIR, enjoyed the complete support of India's first Prime Minister Pandit Jawaharlal Nehru. It was their association, often dubbed as the "Nehru-Bhatnagar Effect", which helped facilitate the roll-out of a chain of scientific laboratories immediately after independence.

The first Indian Governor-General, Shri C. Rajagopalachari, once said: "The Council of Scientific and Industrial Research is a national institution in the building of which every section of the Indian community has contributed." Today, 79 years down the line, we can confidently say that CSIR has also benefited every section of the Indian community.

Ever since it was established 79 years ago, CSIR has always taken up challenges arising due to technology denials, it has developed technologies to fulfil and suit the country's requirements during different periods of its independent journey, notching up several firsts to its credit. CSIR scientists have come up with practical solutions for the industry as well as the country's rural and remote areas. From genomics, drugs & pharmaceuticals to agricultural machinery and high oil-yielding varieties of crops such as Mint that have significantly boosted farmers' incomes, and from low-cost water filters & efficient stoves to harvesting wealth from the oceans CSIR's canvas of achievements spreads far and wide.

With its ensemble of 38 laboratories, CSIR is among the largest networks of scientific laboratories anywhere in the world. And with a legacy of scientific achievements of 79 years behind it, the organization strives to power ahead in the years to come with more scientific breakthroughs, innovations and technological solutions for the country.

Hasan Jawaid Khan

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For Editorial Queries: Ph.: 91-011-25848702; **Email:** sr@niscair.res.in; **Fax:** 91-011-25847062
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COVER STORY

CSIR CELEBRATES 79TH FOUNDATION DAY

"CSIR will continue to strive as the organisation that brings value to the society through S&T"

Dr Shekhar C. Mande, DG-CSIR

THE journey of the Council of Scientific and Industrial Research (CSIR) has been closely intertwined with the journey of independent India. Established on 26 September 1942, CSIR is an ensemble of 38 national laboratories that have played a partnership role at every stage in the struggle of a newly independent India to gain a scientific foothold in the world comity of nations.

On the occasion of the 79th CSIR Foundation Day to be celebrated on 26 September 2020, ***Science Reporter*** talks to **Dr SHEKHAR C. MANDE**, Director General of the Council of Scientific and Industrial Research (CSIR) as he recounts his association with CSIR, the evolving responsibilities of the organisation over the years, the role played in the scientific and technological progress of the nation, its stellar contributions during natural disasters especially during the current COVID-19 pandemic, and the future trajectory of an organisation that holds the distinction of being one of the largest networks of scientific laboratories in the world.

Science Reporter: **CSIR completes 79 years of its existence on 26th September this year. During the two years of your tenure as Director General, what has been your impression of CSIR as an organisation?**

SHEKHAR C. MANDE: Indeed, the 79th CSIR Foundation Day is upon us. CSIR has been in existence for close to eight decades now and its contributions to the country are numerous and varied. I was privileged to be a CSIR JRF and SRF during 1985-1990. In the early days of my career, I was a Scientist at CSIR-IMTech. I then moved out but have been associated with CSIR in one way or the other all through my professional career before taking over as DG-CSIR a couple of years ago. So, I have been aware of CSIR and its contributions since the early days of my professional career. As DG-CSIR, I have gained further insights into the real depth of its manifold contributions.

Before COVID-19 disrupted our lives, I was fortunate enough to visit nearly all 38 labs of CSIR and witness at first hand the highly motivated and talented scientists and students and the well-equipped CSIR labs. Hearing from industry leaders such as Baba Kalyani or from renowned academicians such as Prof. C.N.R. Rao of how CSIR has helped them, reaffirms my belief that CSIR has a glorious future ahead. I am indeed fortunate to have an opportunity to witness its strength, capacity and capability in several diverse areas and I believe that CSIR will continue to play a vital role in preparing India for today's COVID-19 challenges and beyond too.

Science Reporter: **How would you say the role and responsibilities of CSIR have evolved from the time it was founded?**

SHEKHAR C. MANDE: As we celebrate the 79th year of CSIR, we look back with pride at the innumerable occasions when CSIR scientists innovated, devised ingenious processes, and came up with practical solutions for the industry and also for the country's rural and remote areas. These interventions over the years have come to define CSIR and the scientific and technological interventions it has provided to the nation.

The example of the indelible ink developed by CSIR-NPL is a classic and earliest example of how CSIR wove itself into the very fabric of the Indian society leaving an indelible mark. That was just the beginning. Today, the country can recall several achievements and breakthroughs of CSIR — such as innovative and pathbreaking indigenous technologies and processes for developing infant baby food, zeolite catalysts, bulk chemicals, petrochemicals and affordable essential drugs including anti-HIV drugs and so on.

Today yet again, when the country and the world need affordable drugs for COVID-19, CSIR is once again leading the efforts and has developed process technology for repurposed drugs such as Favipiravir.

CSIR has many other firsts to its credit. It developed the country's first indigenous all-composite aircraft, Hansa, and India's first 14-seater plane Saras. CSIR also established for the first time anywhere in the world the 'Traditional Knowledge Digital Library', which is a documentation of the country's traditional wealth, accessible in five international languages, to prevent our wealth from being plundered through patents. Our scientists were also the first to sequence the complete genome of an Indian.

However, CSIR is not only about high science and technology. Some of our low-cost and innovative technologies have also found inroads into rural and remote

CSIR has contributed several innovative and pathbreaking indigenous technologies and processes including infant baby food, zeolite catalysts, bulk chemicals, petrochemicals and affordable essential drugs and even a Traditional Knowledge Digital Library to document and protect our traditional wealth

areas of the country. Our scientists have come up with low-cost water filters, alternative building materials, efficient stoves and even high oil-yielding varieties of crops such as Mint that have significantly boosted farmers' incomes. Our CSIR Aroma Mission has been striving to improve the livelihoods of farmers by introducing high yielding and economically attractive medicinal plants and by increasing their income. We are now launching a floriculture mission and also working towards promoting rural entrepreneurship. CSIR also has the CSIR-800/HARIT programme aimed at enhancing income generation and improving the living conditions of the poor.

In its endeavour to develop scientific human resource for the country, CSIR's Academy of Scientific and Innovative Research (AcSIR) promotes inter-disciplinary and trans-disciplinary research that is ordinarily not offered in regular universities. We are also actively engaged in imparting scientific curiosity and temper among school students through the Jigyasa outreach programme.

Keeping pace with global scientific and technological developments and focussed on the country's needs, CSIR has ventured into areas like big data, AI, precision medicine, next generation batteries, gene editing and many such cutting-edge technologies.

So, in a nutshell, the role and responsibility of CSIR since the time of its inception remains focussed on national development but as a scientific and technological organisation we have been continuously evolving on many diverse fronts.

"Keeping pace with global scientific and technological developments and focussed on the country's needs, CSIR has ventured into areas like big data, AI, precision medicine, next-generation batteries, gene editing and many such cutting-edge technologies."

— Shekhar C. Mande

"CSIR being an R&D organisation develops a wide variety of technologies, products and know-how in multiple areas ranging from aviation to energy to rural technologies."

— Shekhar C. Mande

CSIR scientists have come up with effective tractors, low-cost water filters, high oil-yielding varieties of crops and packaging & processing technologies for agricultural & horticultural produce to increase their shelf-life

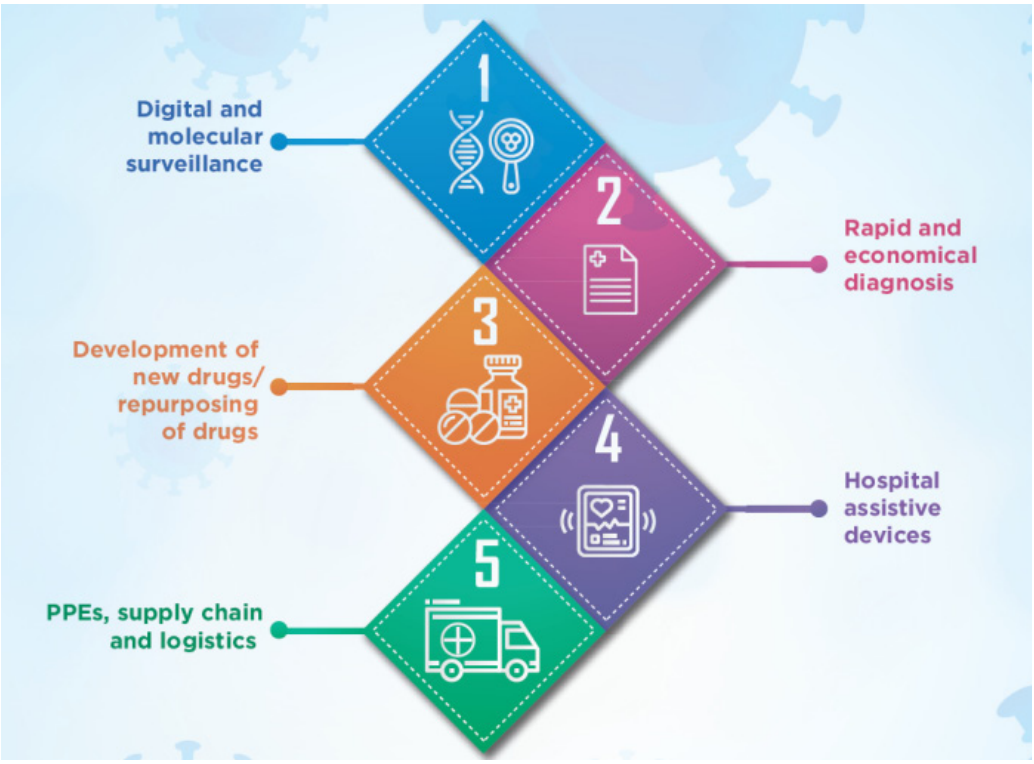
***Science Reporter:* Where does CSIR figure today in the overall science and technology landscape of the country?**

SHEKHAR C. MANDE: India has a vibrant S&T system that is growing from strength to strength. In recent years, many new S&T institutions have come into being, be it IISERs, IITs and so on. This augurs very well for the overall S&T system in India.

CSIR is uniquely positioned in the S&T system in India with its focus on fundamental research on the one hand and developing need-based technologies for and in collaboration with industries on the other as envisaged by its founding father Dr S.S. Bhatnagar. This is reflected in the growing numbers of high impact research papers, patents, technologies and the highly qualified manpower that CSIR contributes, year after year. One of CSIR's significant contributions has been the CSIR JRF/SRF and RA fellowship for researchers in India which has provided the huge talent pool that the country needs.

***Science Reporter:* How has CSIR strived to maintain a balance between developing technologies/processes for the Indian industry and its commitment to the country's small-scale businesses and entrepreneurs and farmers?**

SHEKHAR C. MANDE: CSIR being an R&D organisation develops a wide variety of technologies, products and know-how in multiple areas ranging from aviation to energy to rural technologies. CSIR works with industries big and small, MSMEs and other government agencies and many ministries for the deployment of the CSIR technologies. Depending on the technology and the end users, the technologies are licensed to big industries or MSMEs or given to entrepreneurs and farmers.



As a strategy to combat the COVID-19 pandemic, CSIR set-up five Verticals in the areas of Surveillance, Diagnostics, Drugs, PPE and Supply chain management

Very recently, a Memorandum of Understanding (MoU) has been signed between CSIR, Unnat Bharat Abhiyan-Indian Institute of Technology, Delhi (UBA-IITD) and Vijnana Bharti (VIBHA), New Delhi. The MoU seeks to provide access to CSIR rural technologies for UBA and is expected to lay the foundation for cooperation and joint action in the area of Unnat Bharat Abhiyan (UBA) for rural development of India. This will pave the way for the adoption of CSIR technologies and related knowledge base.

How CSIR has maintained a balance can be seen with the COVID-19 technologies that we have developed. We have so far developed over 100 technologies and our partnerships have been across the spectrum — from industry leaders like Tata Group and Reliance Industries to technologies for entrepreneurs and SSIs.

During the current pandemic, we at CSIR have been particularly concerned about the loss of jobs of migrant labour and the social disruption caused due to reverse migration. We have been equally concerned about the supply chain disruptions that have caused distress to farmers. A major part of our strategy to combat COVID-19, therefore, also centred around training & imparting skills and promoting entrepreneurship in rural areas. CSIR has also come up with digital platforms and applications to ensure farmers could supply their produce and also network with buyers digitally during the pandemic-imposed lockdowns.

Science Reporter: **Over the years, CSIR has stood up to many challenges that the country has faced. How is the current challenge posed by the coronavirus pandemic different from the earlier ones?**

SHEKHAR C. MANDE: While earlier events like floods, cyclones, etc. were localised events and were of a recurrent nature, the current pandemic is global, and there were several unanswered questions, to begin with. Not only did we have to provide immediate help and solutions, but we also needed to understand the nature and dynamics of the problem to be able to come up with long-term interventions such as drugs, vaccines, testing and diagnostic methods, etc. We needed to innovate with immediate solutions, such as formulating sanitisers & disinfectants; developing disinfection machines, masks & personal protective equipment, and at the same time reach out to the vulnerable segments of the society by distributing sanitisers and masks and also ready-to-eat fortified food products.

"From low-cost drugs, diagnostics, PPEs, disease surveillance and supply chain, we have the satisfaction of developing technologies, products and processes that have been well-received and have made a difference in India's fight against COVID-19."

— Shekhar C. Mande

Owing to the pandemic character of COVID-19, unlike ever in history, we adopted a pan-CSIR approach to address the multitude of issues, problems and challenges and I am glad that we have risen to the situation and delivered pretty well.

***Science Reporter:* What is the strategy that CSIR has adopted in dealing with the coronavirus pandemic?**

SHEKHAR C. MANDE: Just as COVID-19 began to take the shape of a pandemic, CSIR assessed the situation, reprioritized, activated and reoriented programmes and projects. One of the immediate steps was to set-up five COVID-19 Verticals in the areas of Surveillance, Diagnostics, Drugs, PPE and Supply chain management. We identified five Directors of labs as the Vertical Directors with a Coordinating Director. The very able team brainstormed, planned, collaborated and implemented pan-CSIR COVID-19 focused activities. This strategy has paid-off very well and the results are there to see. From low cost drugs, diagnostics, PPEs, disease surveillance and supply chain, we have the satisfaction of developing technologies, products and processes that have been well-received and have made a difference in India's fight against COVID-19.

***Science Reporter:* What would you consider as some of the significant successes so far in CSIR's fight against COVID-19?**

SHEKHAR C. MANDE: All technologies, processes and products developed by CSIR are useful in their own way, be it the sanitizers, masks, disinfectant units, software apps, surveillance systems and so on. When the nation faced a shortage of ventilators, CSIR was quick to develop the BiPAP ventilator in a record 36 days. CSIR also developed the coverall PPE in a record time which now is being manufactured by the thousands. We have also developed low cost diagnostic kits such as the paper-based diagnostic kit FELUDA and the RT-LAMP kit. We have been involved in clinical trials and have also sequenced more than 2000 viral genomes, carried out over 100,000 tests, trained manpower, developed processes for repurposed drugs and so on. We have also developed the Kisan Sabha and AarogyaPath App and Portal that is of immense help to farmers and health professionals and other stakeholders respectively. In fact, we have created a COVID-19 portal that gives an exhaustive account of multifarious contributions. The portal can be reached through the CSIR website.

***Science Reporter:* Are there some more successes in the offing that CSIR is working on and we should be hopeful about?**

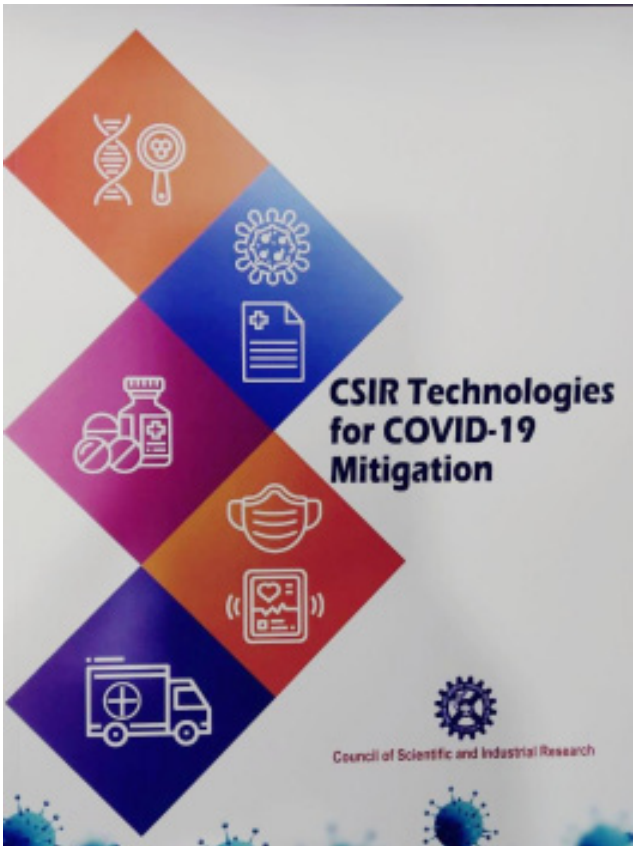
SHEKHAR C. MANDE: Disease surveillance is extremely important during a pandemic. Right from the start of the pandemic, CSIR has been working on the surveillance and we have been able to make rapid strides in this area and have amassed a wealth of information on the virus spread, clades and so on. We are now working on the surveillance in sewage and we are hoping to have important insights from this surveillance initiative. We are aware that the diagnosis of the disease has also been a challenging task given the complexity and cost associated with viral testing and diagnostic. We have innovated on this front as well as I mentioned earlier. But we are still working on other methods as we need to have an array of tools in our testing armoury. One such diagnostic is the Next-Generation Sequencing (NGS) based diagnostic that can test about 20,000 to 30,000 samples in one go. We are working with Syngene on this and hope to have success on this front. The pandemic as we know has thrown a new challenge of waste that is generated in the form of used masks, PPE kits and other hospital waste. We are also looking at developing solutions for managing the waste generated during the pandemic.

***Science Reporter:* The global nature of the coronavirus pandemic has been a learning experience for everyone and in every sphere. What are some of the key learnings for CSIR as an organisation?**

SHEKHAR C. MANDE: Yes, there have been many learnings. It is perhaps the first time in CSIR history that almost all the laboratories and institutes had a singular

"In a very short span of time, CSIR could churn out more than a 100 COVID-19 specific technologies which were a result of internal and external collaborations never seen on a scale before, the narrow time-frames and lock-down challenges notwithstanding."

— Shekhar C. Mande



In a very short span of time, CSIR could churn out more than 100 COVID-19 specific technologies which were a result of internal and external collaborations never seen on a scale before

focus – COVID-19. As we know, CSIR laboratories are known to specialize in focussed areas and the pandemic related problems brought together the varied strengths and the results have been noteworthy. In a very short span of time, CSIR could churn out more than a 100 COVID-19 specific technologies which were a result of internal and external collaborations never seen on a scale before, the narrow time-frames and lock-down challenges notwithstanding.

CSIR always strives for self-reliance on raw materials, molecules, equipment, etc. rather than depending on imports, as much as possible. This tradition of CSIR, of rising to challenges, manifested in the making of many technologies and products, be it ventilators or PPEs. We have also quickly deployed advanced technologies like AI & ML for assessing problems and problem-solving. For taking the technologies forward we have not just depended on large and medium industries and enterprises, but we have also vigorously catalysed local innovations and driven entrepreneurship.

Science Reporter: **Some experts are of the opinion that pandemics might become regular features in the coming years. Besides, the country faces calamities and disasters of varying nature at regular intervals. Has CSIR established some mechanism whereby such events trigger an automatic rollout of a centralised response from CSIR?**

SHEKHAR C. MANDE: As we know, pandemics and natural calamities are characterised by their unpredictability. What we need is preparedness and the country has been working on improving predictability and enhancing the level of preparedness through various ways and means. As far as CSIR is concerned, we have been in the thick of things whenever the natural or man-made calamities have hit us hard. Be it the Bhuj or Uttarkashi earthquakes, Chennai or Kerala floods, or even the Bhopal gas tragedy or the current COVID-19 crisis. From rolling out shelters for thousands, providing tonnes of food or gallons of drinking water or understanding the causes of a disastrous gas leak, CSIR has been at the forefront.

CSIR is partnering actively with disaster management organisations and it needs to be understood that managing a natural calamity or pandemic situation requires a hugely coordinated strategy and response. CSIR has vast experience, expertise and the knowledge base in handling crisis situations. We are constantly developing tools including AI-based predictive tools to handle crisis situations. CSIR's strategy of combating the current

"CSIR has been in the thick of things whenever the natural or man-made calamities have hit us hard. Be it the Bhuj or Uttarkashi earthquakes, Chennai or Kerala floods, or even the Bhopal gas tragedy or the current COVID-19 crisis. From rolling out shelters for thousands, providing tonnes of food or gallons of drinking water or understanding the causes of a disastrous gas leak, CSIR has been at the forefront."

— Shekhar C. Mande

pandemic has been a very successful one and this could serve as a template for action in the case of future pandemics.

Science Reporter: **The PM recently gave a call for an "AtmaNirbhar Bharat? What are some of the major areas you feel CSIR could focus on to make this happen?**

SHEKHAR C. MANDE: In recent years, affordable health care for all has emerged as one of the many major challenges. For commercial reasons more than anything else, advanced countries and multinational drug companies will always shy away from working on cures or vaccines for many diseases that typically affect countries in this part of the world. So, CSIR will focus with renewed vigour on such diseases and also future viral diseases, especially managing pandemics. Importantly, CSIR has decided to focus efforts on developing APIs and KSMs indigenously so that the country does not have to look towards other countries for drug molecules.

CSIR will also make efforts at delving deep into its traditional medicine systems to come up with immune-boosting molecules and develop drugs based on scientific rigour for diseases including Tuberculosis, Malaria, Filaria, Diarrhoea, etc.

Science Reporter: **As the Director-General of one of the largest networks of scientific laboratories in the world, how do you visualise the future of CSIR in the coming years?**

SHEKHAR C. MANDE: CSIR will continue to strive as the organisation that brings value to the society through S&T. Society in this sense has a wider meaning, which includes common people; sectors such as agricultural, rural, etc.; start-ups; small and medium industries and established industrial houses. In this entire spectrum of the society, CSIR will strive to be among the finest solution providers through its S&T research base. We hope that this will help in uplifting our people and help claim our rightful place in the global order. Thus, undertaking work in frontier areas of S&T, pushing the knowledge frontiers, and applications thereof for societal benefits will be the key objectives of CSIR in the coming years.

"CSIR will continue to strive as the organisation that brings value to society through S&T. Undertaking work in frontier areas of S&T, pushing the knowledge frontiers, and applications thereof for societal benefits, will be the key objectives of CSIR in the coming years."

— Shekhar C. Mande

FEATURE ARTICLE

UNRAVELLING THE CORONAVIRUS GENOME

Mitali Mukerji and Adita Joshi

THE Coronavirus genome will go down in history without doubt as the most sequenced genetic material of all times. All living organisms, plants and viruses possess a genome — their unique identity and passport to live and reproduce. The genome governs how an organism/plant/virus looks, functions and interacts with its environment. Sometimes minor alterations in the genome may give rise to major changes in the way organism functions.

A journey back to high school biology may remind you that humans have 23 sets (pair) of chromosomes which are made up of DNA, a biochemical molecule. It is simple to visualize genome as '*The book of life'*, written in the language of DNA. Some viruses have another biomolecule called RNA as their genome.

Now, how does a coronavirus genome function? SARS-CoV-2 or coronavirus is a positive-sense single-stranded RNA virus. Positive sense means the RNA can directly be converted into a protein. SARS-CoV-2 is an RNA based genome with the spike, membrane and envelope proteins wrapped around it.

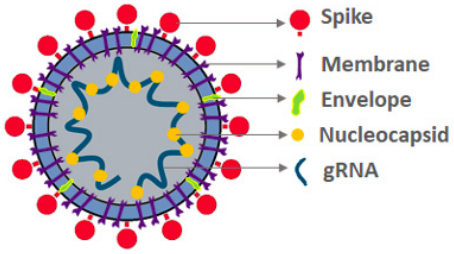
Upon entry into a human cell, SARS-CoV-2 reproduces (makes copies of its RNA genome) and uses the production machinery of the host cell for making the surface protein covering and other proteins. Thus, the RNA genome is copied and about twenty-nine proteins are synthesized in the host cell. This process is rapid, can produce a million copies of the virus in a short time, and is called viral replication.

SARS-CoV-2 also has one of the largest viral genomes (32 Kb) among infectious viruses such as rhinoviruses (7-8.5 Kb), HIV (9.5 Kb), Dengue (11 kb). Most RNA virus genomes have a single open reading frame (ORF) that is translated as a single polyprotein. This polyprotein is chopped into other smaller viral proteins required for specific functions. An open reading frame is a sequence that can be converted into a protein by the production machinery of a cell.

Coronaviruses contain as many as ten ORFs and replicate in a unique two-step process. The first step is a translation of the biggest ORF which gets translated into a protein called replicase (enzyme). The replicase works together with the reading machinery of the cell to read the remaining viral genome to produce several smaller messenger RNA (mRNA) molecules. These mRNAs are then translated into structural proteins which make new viral particles.

Does the genome of SARS-CoV-2 undergo change? How do new strains (types) of coronavirus form?

The coronavirus genome can reassort at a very high frequency to produce newer strains. Reassortment means if a host is infected with a coronavirus and other viruses together, the genetic material of coronavirus can recombine with that of any positive-strand RNA virus. Thus, a new coronavirus strain or 'virus type' is created and this process is called reassortment.



While newer coronavirus strains may be produced at a high frequency, a coronavirus strain would mutate at a low frequency. Coronavirus has a much slower rate of mutations compared to the flu virus. As different coronavirus strains are formed and as they gather new mutations, coronavirus groups or 'clades' emerge. A clade gives information on all the evolutionary descendants that have arisen from a common ancestor, similar to how a family tree is formed. All this information on 'clades' is generated using leads from coronavirus genomics.

Genome Sequencing

Genome sequencing is a technique used to sequence or reads the bases (A, T, G, C) in their exact order in DNA and RNA based genomes. The last two decades have seen unprecedented and accelerated progress in the advancement of sequencing technology and a reduction in cost.

Genomes are sequenced in a machine (genome analyser) commonly called a 'Sequencer'. DNA or RNA

samples are isolated from the source (plant/animal/virus), subjected to certain chemical reactions (Pre-processing) and transferred onto the sequencer. RNA needs to be converted into complementary *DNA* (cDNA) for sequencing. A DNA sequencer reads the DNA sequence and records the data. The data is later analysed using computer-based algorithms. Multiple DNA samples can be sequenced at a given time in a sequencer.

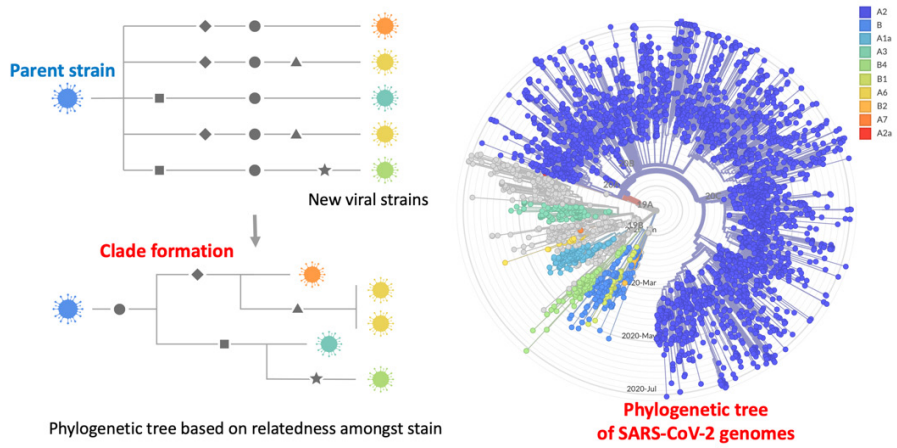
Genome sequence data is stored in genome repositories and can be accessed by scientists and researchers. Global Initiative on Sharing All Influenza Data (GISAID, *www.gisaid.org*) is an open platform, where genome researchers from all over the world (~70 countries) are submitting hCoV-19 (Human coronavirus-19) genome sequence data. The data is publicly available for use in epidemiological, vaccine and therapeutic research.

GISAID received its first coronavirus sequence from Wuhan in China in December 2019. Since then ~78,000 coronavirus genome sequences have been submitted to GISAID as of August 2020. India has submitted 1,861 coronavirus sequences to GISAID so far and has identified a new A4/A3i 'clade' from coronavirus strains active in the country.

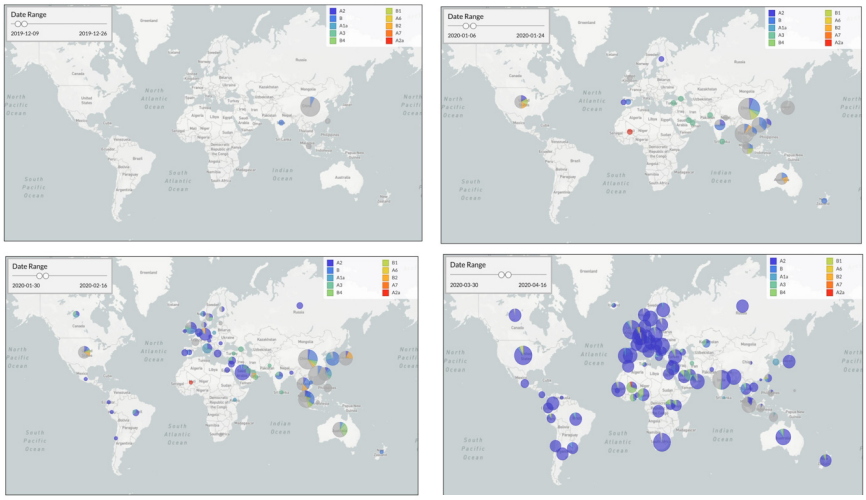
Phylodynamic Analysis of SARS-CoV-2 Genomes

What kind of information can be obtained from coronavirus genome sequencing? Genome scientists compared the sequences of coronavirus with that of the already known viruses. A comparison across other viral genomes confirmed the novel nature of SARS-CoV-2.

Genome sequencing could identify if a single strain is infecting our population or multiple strains are hopping around? So far, based on the sequencing information, the coronavirus strains across the world are grouped into 10 clades: A1a, A2, A2a, A3, A6, A7, B, B1, B2 and B4. The *A clade* represents the coronavirus strains that originated in Europe whereas the *B clade* evolved in 'East Asia'. Thus, coronavirus genomics has helped us understand the evolution and spread of SARS-CoV-2 across the globe ever since it debuted in Wuhan, China.



Evolution of SARS-CoV-2 genome with the transmission. A schematic of *'Clade'* formation: The diamonds, circle and square represent different mutations which a coronavirus (parent strain) gathers while moving from one human host to the other. Some of the strains would have and retain common mutations as they evolve. The grouping into clades is done by analysing genome sequences for such mutations. Phylogenetic tree of evolution of different clades of SARS-CoV-2 across the global population is represented.

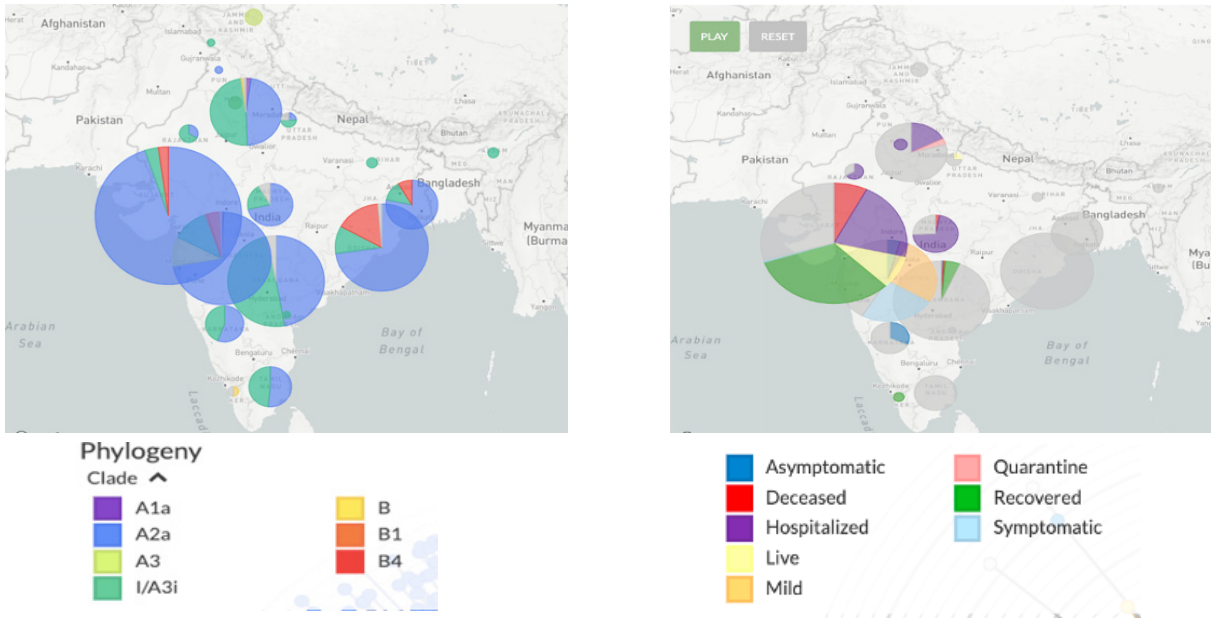


Phylodynamic Analysis of the SARS-CoV-2 Genomes across the globe. The four panels in the figures show the real-time data for the emergence of various SARS-CoV-2 clades across the world. In the first month of reporting one of the clades is reported from China and India. The spread in the subsequent months is represented in the later panels. The date range is indicated at the top left of each panel and the clades on the top right. *(Source: nextstrain.org andwww.gisaid.org)*

Coronavirus genome sequencing can provide other benefits and advantages. Availability of genome sequence data forms the basis of developing different diagnostic tests for precise detection of COVID-19 infection. The popular gold standard diagnostic test – RT-PCR – would not have been developed without prior genome sequencing information on SARS-CoV-2. Coronavirus vaccine development and discovery or repurposing of drugs for treating COVID-19 rely to a large extent upon genome sequencing information.

It is pertinent to ask or question if a single vaccine would work against all the coronavirus strains? Vaccines are typically designed by using the sequence information on viral proteins. The immune system recognizes the viral proteins upon virus entry into the body and starts its action to eliminate the virus. Thus, the viral proteins work as *'antigen'* against which the immune system produces *'antibodies'* to counter it.

Most vaccine projects in India and abroad are using the spike, membrane and envelope protein of the coronavirus for vaccine design. Although the rate of mutation of SARS-CoV-2 is low, yet it is



The pie chart indicates the relative proportion of genomes from each country with unassigned clades indicated in grey. The first panel represents the Pan-India distribution of various clades of SARS-CoV-2 strains and the second panel represents the genomes vis-à-vis disease status.
Source: GEAR-19 @ CSIR-CCMB

important to look for specific mutations in its proteins. Knowledge about these mutations can aid a better and specific vaccine design strategy which takes into account a few major mutations that may be present in the '*India clade*'.

Sequencing the Virus in India

India ranks third globally to have the maximum cases of coronavirus infection (2.7 million cases as of August 2020). However, Indian science is moving on amidst the grim state of affairs. A group of CSIR laboratories have come together to start a Pan-CSIR SARS-CoV-2 sequencing project. The broad objective is to capture the spectrum of variations in SARS-CoV-2 genome across the country and identify host-pathogen molecular signatures.

Pan-CSIR SARS-CoV-2 Sequencing Project Partner Institutes

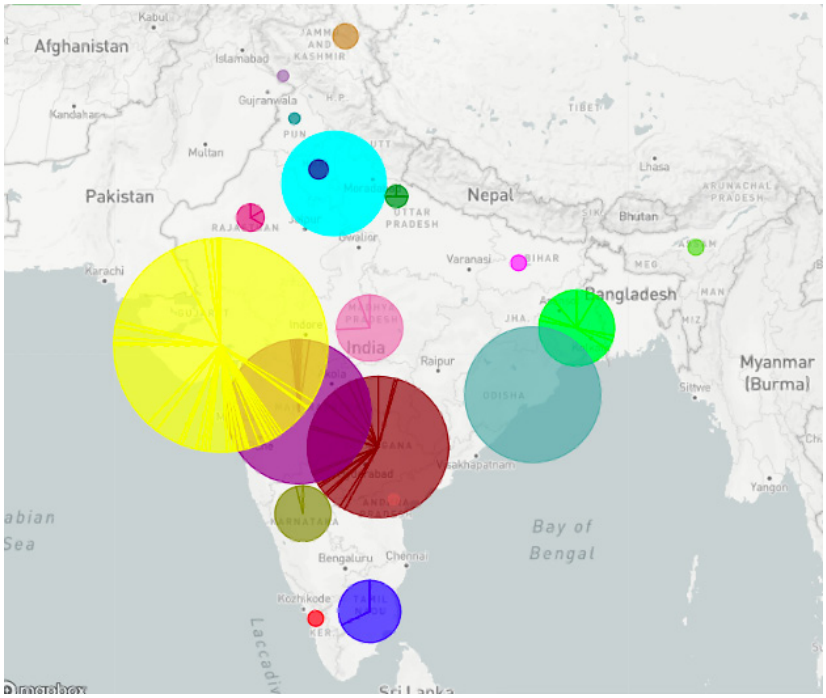
- **CSIR-IGIB**
- **CSIR -CCMB**
- **CSIR-IMTECH**
- **CSIR-IITR**
- **CSIR-IHBT**
- **CSIR-CDRI**

All the above institutes are government authorised SARS-CoV-2 testing centres.

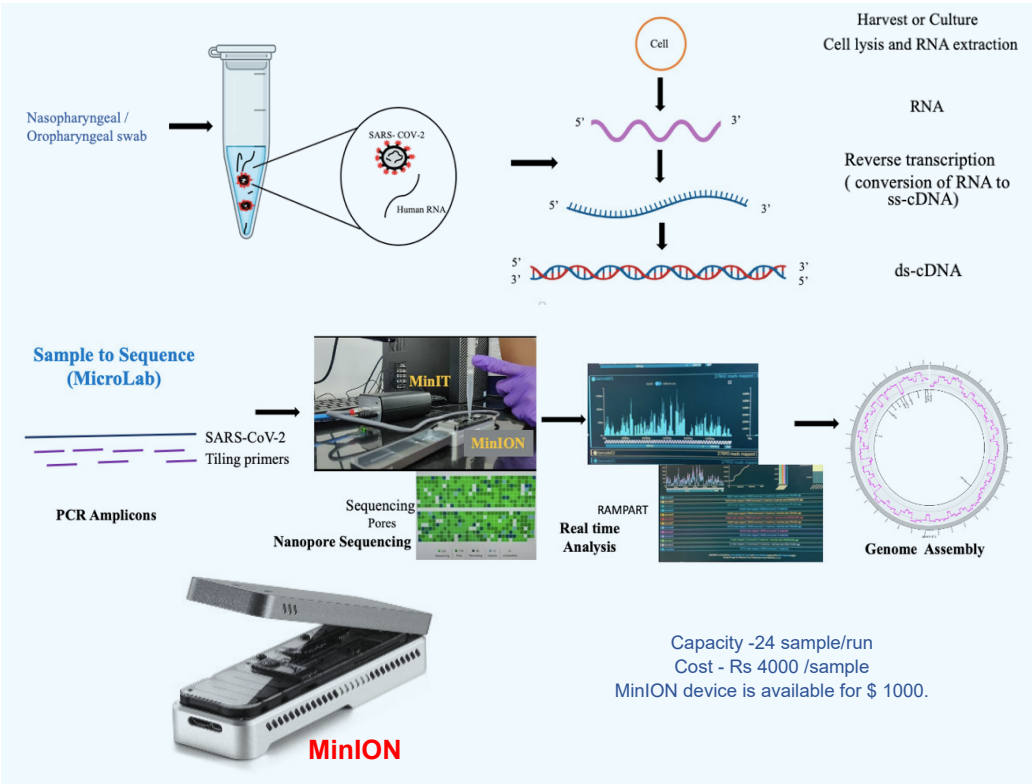
~ 1000 clinical isolates

SARS-CoV-2 positive samples from in-house screening and other positive samples from local clinical networks are being processed for genome sequencing. In addition, sequencing of host genomes and transcriptomes (mRNA) is being carried out under this effort. An understanding of multiple genomes from SARS-CoV-2 strains would enable fast-tracking research in the areas of low cost and quick diagnostics, epidemiology, tracking and surveillance and to support Indian vaccine development efforts.

The Pan-CSIR SARS-CoV-2 Sequencing Project has uncovered several pieces of important information. The project has mapped the geographical distribution of different coronavirus strains across the map of India. A new clade A4/A3i not reported elsewhere in the world is identified to be active in India. Further, it is apparent from the sequencing data that no one clade is dominant in India. Multiple clades have been discovered in coronavirus isolates from one geographical region. The project has collated information



The distribution of SARS-CoV-2 Clades in India
Source: Bioinformatics Centre, CSIR-CCMB



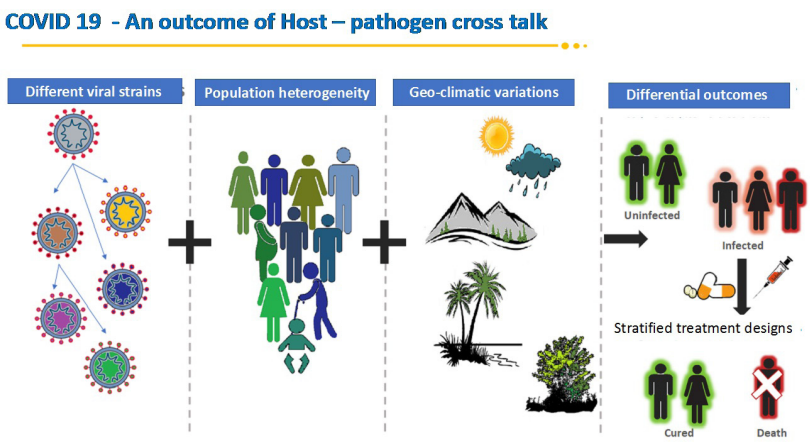
on disease status in terms of patient type (symptomatic, asymptomatic, mild disease), patient recovery and morbidity (live vs deceased).

The COVID-19 pandemic presents a complex and dynamic situation with many active permutations and combinations at the host-virus- environment level. Coronavirus genomics has pinpointed that several strains of SARS-CoV-2 virus are active in the human host. The population response to SARS-CoV-2 infection is heterogeneous in terms of age, gender, blood groups and co-morbid conditions. The virus strains are propagating in varied geographies irrespective of differences in physical and chemical factors of environment and seasons.

SARS-CoV-2 infection itself has varied manifestations with positive symptomatic (people who carry the virus and develop the classic disease), mild symptomatic (people who are positive but show very mild symptoms) and asymptomatic (people who carry the virus but never develop the disease). Disease severity and progression is different which leads to varied outcomes in individuals who have contracted SARS-CoV-2 infection.

The novel nature of SARS-CoV-2 and the COVID-19 disease have posed serious challenges on the therapeutic front. Drug treatment regimen for COVID-19 is changing with the pace at which the virus is evolving and as more people are getting infected to seek treatment. Though many drugs such as hydroxychloroquine, remdesivir, and dexamethasone have made news with respect to treating COVID-19, the search for a drug treatment regimen that would work across COVID-19 patients is still on.

Knowledge of SARS-CoV-2 genomes, as well as genomes of infected/recovered/dead individuals, can throw light on specific host-pathogen interactions. A single viral strain could be fatal to one person and may not result in disease in another. Some strains could be more virulent than others while others may be more prominent in specific ethnic and geographical backgrounds.



Information on patient clinical data (age, sex, co-morbidity, pre-existing respiratory illness, other illness, post-recovery health patterns) can provide a focussed roadmap towards answering challenges of COVID-19 disease heterogeneity, risk assessment, drug discovery and vaccine design. Coronavirus genomics can help simplify these layers of complexity in understanding the infection, disease progression and heterogeneity in host-pathogen interactions.

The Pan-CSIR effort should not just stop at sequencing 1,000 coronavirus genomes; rather it is the start. As we sequence more genomes, our knowledge built up on some of the above-mentioned challenges of the COVID-19 disease and SARS-CoV-2 infection will become more precise and backed by genome evidence.

Dr Mitali Mukerji (mitali@igib.res.in) is Chief Scientist at Genomics and Molecular Medicine Division at CSIR-Institute of Genomics and Integrative Biology (CSIR-IGIB), New Delhi and Dr Adita Joshi (aditayugaljoshi@gmail.com) is Scientific Consultant at CSIR-IGIB

TESTING CORONA

Neha Tripathi

TEST... Test... Test... in the last six months, this word has become trivial. If you sneeze or cough, have a headache or body ache, feel like nausea or congestion, feel sore throat or lose the sense of taste or smell, have fever or diarrhoea symptoms, you may have been attacked by a deadly virus.

If you have any or all of these symptoms, you need to get a test done for COVID-19, irrespective of the fact that some of these symptoms are very common and can occur in many conditions other than COVID-19 like weather change, food poisoning, overburdened with work, depression, anxiety, bad eating habits, allergy due to dust, smoke or pollution, etc.

Since March till date, the situation has worsened. Earlier there were less number of COVID-19 cases in India, but the fear of getting an infection was high. Today it is vice versa. Number of cases has broken all records, but the fear among people has vanished.

We have taken a leap from Lockdown to Unlock. Still, it is difficult to analyse whether we are testing enough COVID-19 cases or the Coronavirus is testing our patience. Since its arrival in our lives, it has tested our medical expertise, our doctors and hospital staff, the medical infrastructure in our country, and the people.

COVID-19 tests are critical to measuring the spread of the disease and determining how to handle the pandemic. The dilemma is no country including India, knows the total number of people infected with COVID-19. All we know is the infection status of those who have been tested. All those who have a lab-confirmed infection are counted as confirmed cases. This means that the counts of confirmed cases depend on how much a country actually tests. Without testing, there is no data.

The National Institute of Virology (NIV), Pune, reported the first case of COVID-19 in India on 30 January 2020. The next two cases were also reported by NIV. Soon after, NIV proceeded to empower 13 Virus Research Diagnostic Laboratories (VRDLs) across the country. Testing protocols were shared, reagents were sent out and via daily video-conferences, NIV was able to equip more VRDLs to join in the battle against COVID-19. Today, 107 VRDLs perform testing contributing to a total of 905 government-run laboratories across the country.

What are the tests for COVID-19?

There are two ways to test for COVID-19: Viral Test and Serology Test.

A viral test is an oral or nasal swab or saliva test that looks for evidence of an active viral infection. Early in the infection, the virus grows in cells at the back of the nose and throat, taking about 5-14 days before symptoms appear. A swab of the nose or throat can be taken and the nucleic acid of the virus can be detected. The virus is detectable several days before symptoms appear and up to eight days after symptoms appear.

However, everything depends on how well the sample was taken and the amount of virus present at the time of swabbing. Once the antibody response begins, the virus is cleared from the body. Once the virus is no longer present in the nose/throat, the test will be negative.

And this is where the samples for viral tests are taken from:

- Lower respiratory tract: sputum, lavage, aspirate
- Upper respiratory tract: nasopharyngeal and oropharyngeal swabs; nasopharyngeal wash/ nasopharyngeal aspirate
- Nasopharyngeal and oropharyngeal swabs

Samples should be taken within 14 days of the person's last documented contact with a COVID-19 case. Viral tests do not indicate whether someone was infected in the past.

Viral test is further of two major types: RT-PCR test and an antigen test.

RT-PCR test (Reverse Transcription Polymerase Chain Reaction test) looks for the presence of a virus's genetic material. RT-PCR is a laboratory technique combining reverse transcription of RNA into DNA and amplification of specific DNA targets using Polymerase Chain Reaction (PCR).

The RT-PCR technology is a fairly expensive method. It requires RNA extracting machines, a laboratory and trained technicians. A minimum of 30 samples are needed to make it economically viable. The cost of chemicals and importing elements required for the test is also high.

The antigen tests that have been approved for COVID-19 diagnosis in India give results in 30 minutes. Antigen tests produce results quickly but may be less sensitive.

These tests look for the 'spike protein' present on the surface of the coronavirus and which facilitates its entry into the human cell. For the antigen test, a nasal swab is collected. For analysis, it is immersed in a solution that deactivates the virus. A few drops of this solution are then put on a test strip. This has to be done within an hour of the immersion of the swab in the solution. The test strips contain artificial antibodies designed to bind to coronavirus proteins. If a person is infected with coronavirus, the test lines will appear on the paper strips within 15 minutes.

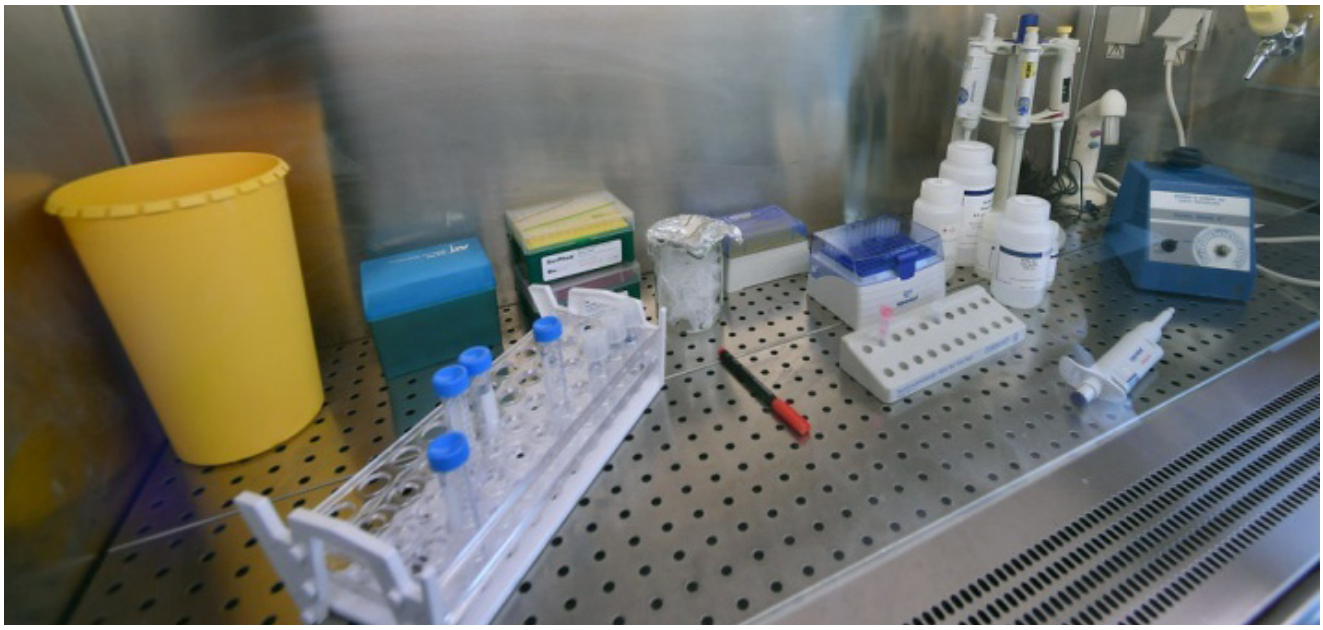
The advantage of using this test is that it reduces the burden of relying on just RT-PCR tests to identify COVID-19 patients. Experts are of the opinion that antigen testing is useful because even if it is less sensitive, it is rapid and the results that are positive will be positive. So, patients who test positive can get into isolation faster.

Professor Priya Abraham, Director at National Institute of Virology advocates, "World over the preferred test for detecting Coronavirus is the real-time PCR assay. In India as well the recommended test is the real-time PCR assay. However, for the purpose of screening in containment zones and hot spots, the antigen test has been used. The main feature of the antigen test is its ease of use and result being ready in 30 minutes."

The major drawback of this test is that if the swab samples lack enough antigen material, it may result in false-negative tests. For this reason, if a person tests negative through antigen testing, they still need to get an RT-PCR test done for confirmation.

Serology test/Blood test/Antibody test

These tests are used to find out the presence of virus in a body. In this method of testing, blood samples are used to find antibodies. This process also detects the quantity of antibodies that are produced by the immune system. It is an indirect method of testing as it cannot find the virus, but can determine if the immune system has encountered it.



Is Coronavirus Testing Similar to other Virus Testing?

The answer is YES. Coronavirus testing is similar to that for other viruses with one difference. Dr Anurag Agrawal Director, CSIR-Institute of Genomics and Integrative Biology (CSIR-IGIB) decodes this question, "In many other viruses like Dengue, the virus can be found in the blood. Coronavirus is primarily in the respiratory tract and oral cavity, so early blood test is less likely to work. Antibody blood tests take time to become positive." So, viral tests play an essential role in the testing scenario.

Antibodies can show up between 9-28 days after the infection has set in. By this time, an infected person can spread the disease, if not isolated. This test even looks for evidence of prior infection with the virus. The test provides evidence that someone may have been exposed to the virus in the past, potentially even if they did not have symptoms, by detecting antibodies specific to the virus. The test does not diagnose an active infection or identify who is protected from reinfection.

Dr Shekhar C. Mande, Secretary, Department of Scientific and Industrial Research (DSIR) and Director General, Council of Scientific & Industrial Research (CSIR), admits that "India's testing capacity has increased over the last few months. Still, there is a need to ramp up the testing capacity further given our population and the growing infections and all agencies including ICMR and CSIR labs are working towards it."

He gives a futuristic approach to the testing techniques as well. He foresees, "The desirable development of testing is a quick and cheap diagnostic that can be done similar to testing of blood glucose levels or a pregnancy test which can be done at home. It is likely that in the near future, tests which could be an antibody or nucleic acid-based will be developed that can be done at PHC or local diagnostic centres which will ensure that tests are widely available to all those who need to be tested."

The ICMR had validated the usage of TrueNat/Cartridge Based Nucleic Acid Amplification (CB-NAAT) based tests,

Testing at CSIR-CCMB

commonly used for detecting tuberculosis, for conducting coronavirus tests. For the TrueNat test, the swab is collected and dipped in a viral transmission medium where it gets neutralised. It is then shifted to another liquid in which the cells break and the impurities are removed. Finally, it is transferred into a cartridge where the process of RNA extraction takes place.

TrueNAT is an indigenously developed, portable version of CB-NAAT. TrueNAT is battery operated and portable, while CB-NAAT machines need an uninterrupted power supply and air conditioning, and hence cannot be deployed in containment zones.

These tests are different from the conventional tests in their speed, cost, as well as convenience of application. The machine is portable, and experts find it useful in remote districts from where collecting and sending swabs to big laboratories may not be possible generally. This allows teams to set up mobile testing centres or kiosks in containment zones, instead of having to transport samples to labs.

Storage & Transport of Samples

For some tests, results may be available at the testing site in less than an hour. For other tests, samples must be sent to a laboratory for analysis, which may take 1-2 days once the sample is received by the lab.

So, after the samples are collected, they need to be taken care of till they are tested and analysed. There are specific centres for sample collection and other centres for sample testing. The duration between sample collection and sample testing is very critical. For accurate results, the collected sample has to reach the testing centres within the permitted time frame. For example, if the specimen reaches the laboratory in less than 72 hours, it can be stored and shipped at 4°C. But if the specimen reaches the laboratory in more than 72 hours, it needs to be stored at -80°C and shipped on dry ice or liquid nitrogen.

Now, let's see how the actual testing procedure proceeds. The lab will acquire one of the following samples from you:

- **Swab test:** The lab will take a special cotton swab and collect sample from the inside of the throat or nose.
- **Nasal aspirate:** The lab will inject a saline solution into your nose, then remove the sample with gentle suction.
- **Tracheal aspirate:** A thin, lighted tube called a bronchoscope goes into your lungs, from where the sample is collected.
- **Sputum test:** Sputum is a variation of mucus from your lungs that can be coughed out or sampled from the nose with a swab.
- **Blood test:** The collected sample will be analysed for the virus, either through a blanket test for all variants of the coronavirus or through a specialised gene sequencing test that locates the marker for the novel coronavirus.

What happens to the sample after collection? Dr Rakesh Mishra, Director, CSIR-Centre for Cellular and Molecular Biology (CSIR-CCMB), Hyderabad, explains, "Most of the COVID-19 testing is based on taking RNA out from the virus, converting it into DNA, amplifying the DNA so that we can

What Happens during a COVID-19 Test?

Who can answer this question better than those who have experienced the procedure. Monika Sharma, a housewife, tested positive for COVID-19 along with her two daughters, Riti 12 and Shrestha 7 years. She says, "All the facilities were good, doctors and hospital staff were very co-operative but seeing my babies in the hospital was very distressing. The kids at times got scared seeing the hospital staff in PPE kits. The testing procedure was easy going for us."

About the testing procedure she recalls, "Everyone in the testing lab was in PPE kits, we could not see their faces or make out their gender. They had trays ready with all the necessary equipments."

The kids Riti and Shrestha recount their experience, "At first we were a bit reluctant but when we saw the simple procedure, and the uncle in PPE kit told us all about the simplicity of the test, we agreed. The second and third time, it was not that scary."

Nupur Prakash, Manager at an SBI branch, who tested COVID-19 positive on 17th May and was admitted to a Government hospital, quarantined from family, could not believe the test results as she was asymptomatic. Nupur remembers, "The test procedure was very normal, but obviously when the swab is taken from the throat or nose, it is a bit irritating and the trauma of being tested positive is threatening."

Nupur had to stay in the hospital for more time as seven COVID-19 tests continuously tested positive. After the eighth test was negative she could return home with another 14 days of quarantine at home. Nupur has now joined back at work. But, she still wonders how she was testing positive again and again without showing any symptoms.

Seventy-year-old Umesh Chandra Prakash, who had mild symptoms like pain in chest and legs, describes the test as being normal with all the precautionary measures taken by the laboratory staff. He was appreciative of the special care and attention given to the old.

Testing & kit validation at CSIR-CCMB

visualize it. Taking the RNA out from a virus is a tricky thing because it requires specific biosafety standards. And such facilities are available in basic research institutes. Besides, such techniques are routinely used for other work in these institutes."

The procedure is complicated and lengthy, says Dr Mishra and emphasises that the most important asset that the institutes designated for testing samples bring with themselves is the pool of experiences researchers, acquainted with advanced technologies, and who can keep up with the wide literature in these unprecedented times. "It does require reorientation and reorganisation at the institutional level," he says. "But it is also the right time for basic research institutes to rise to the next level to address the COVID-19 pandemic. After all, basic researchers are trained to address unsolved problems."

Sometimes there can be test errors. For example, a test can be false positive which means the test is positive, but the virus is not present, or false negative, which means the test is negative, but the virus is present.

Dr Anurag Agrawal, Director, Institute of Genomics and Integrative Biology (IGIB) explains, "Negative tests do not always mean that infection is not there. This problem is less with RNA tests because they can be amplified. Later, one can detect an infection by the immune response to the virus. This happens about a week after infection."

Sometimes, negative results might be obtained from an infected individual for various reasons:

- Poor quality of the specimen
- Specimen collected late or very early in the illness
- Specimen not handled and shipped appropriately
- Technical reasons inherent in the test, e.g. virus mutation or PCR inhibition

If a negative result is obtained from patients with a high index of suspicion for infection, new specimens from the lower respiratory tract are collected and tested. Experts, however, stress that regardless of whether you test positive or negative you should continue to take steps to protect yourself and others.

Innovations in Testing

Dr Anurag Agrawal helped list the following innovations at different steps of testing:

- **Sample collection:** In many countries, saliva is now shown to be as good as swab for testing. This opens up the possibility of self-collection kits that patients can use. Problems in India may be due to *paan, supari*, etc.
- **Sample processing:** It is now shown by many labs and also confirmed at the Council of Scientific and Industrial Research (CSIR) that it is possible to skip RNA extraction from samples. Such methods can make testing faster and cheaper. This is not possible with the current sample collection method in viral transport media so the entire system needs to be changed.
- **Testing:**
  - *Nucleic acid:* There are now methods such as COVID-seq where Next Generation Sequencing (NGS) can be used to test thousands and even tens of thousands of samples daily, using nucleotide barcodes to identify positive samples.
  - *Oxford Nanopore MinIon* is a small device about the size of a large stapler that can go from sample to sequence-based diagnosis for a few hundred samples in about 6 hours. The advantage is a low capital investment of only 2 lakhs and greater resistance to mutation-related false negatives than rtPCR.
  - *Microfluidic PCR platform* (Fluidigm Biomark) with an assay for SARS-CoV-2 is already in use in many leading global laboratories as a Lab-developed Test (LDT). Advantages of this assay over conventional qPCR assays are very high-throughput with minimal manual labour. With full automation, it can reach a throughput of up to 6000 samples/day.

There are also smaller and faster PCR machines. And there are tests that don't require PCR machines at all like CRISPR-based paper diagnostics – SHERLOCK, DETECTR, FELUDA. These workflows and tests are now becoming available in India.

India is mostly using swabs collected in Viral Transport Media (VTM), followed by rtPCR. Most countries follow similar protocols. But some nations are using a mix of methods including very high throughput systems as well as very rapid systems like Reverse Transcriptase-Loop Mediated Isothermal Amplification (RT-LAMP), and trying saliva, antigen tests, etc. All these tests are available in India as well.

Ms Neha Tripathi is a freelance science journalist and filmmaker. Address: Sector 2 C, House No. 207, Vasundhara, Ghaziabad-201012. Email: mail_neha@icloud.com

FEATURE ARTICLE

Drug Repurposing for COVID-19 Therapy

M. Saleemuddin

"It is within the power of man to eradicate the infection from the earth": Louis Pasteur

Discovery of drugs for the treatment of human ailments continues to remain an arduous, expensive and slow process. Loss of over a 6 lakh lives and destruction of the economy globally caused by COVID-19, however, warrants fast-tracking of the discovery process. Drug repurposing seems to be an attractive alternative and major drug companies, research institutions and universities are currently making impressive efforts to repurpose drugs developed for other ailments to alleviate human suffering caused by COVID-19. While some successes for containing COVID-19 in patients with mild, moderate and severe symptoms are emerging, only additional investigations will decide on the usefulness of their efficacy.

THE task of taking drugs from discovery to the market requires durations up to 10 years and costs around 2.5 billion US$. If a virus spreads to 213 countries in a six-month time period, infects over 15 million people, killing over six hundred thousand people, fast-tracking of the process is imminent. This explains the unprecedented exigency being shown in finding a cure for the new disease caused by the SARS-CoV-2 (named CoronaVirus Disease discovered in 2019, COVID-19).

The first case of human infection of COVID-19 was reported by Chinese officials in December 2019. Beginning from early January, scientists all over the world are striving hard to develop drugs and vaccine candidates for prevention and/or treatment of COVID-19. Due to the impending urgency, drugs that have already gone through all the time-consuming screenings during their development for the treatment of other diseases are being focused upon. According to the Austrian Institute of Health Technology Assessment, the majority of the 155 drugs in the pipeline for COVID-19 are those developed for the treatment of other diseases.

WHO is coordinating some efforts aimed at finding a cure for COVID-19, although many countries are carrying them out on their own. The Solidarity Trial is one such Clinical Trial effort announced by the WHO on 18 March 2020, with anticipated participation of over 100 countries. As on 2 June 2020, 35 countries with over 400 hospitals had recruited more than 3500 COVID-19 patients. The trial aims to cut down multiple small trials and accomplish rapid worldwide comparison of various unproven but potential treatments for the disease. The Randomized Evaluation of COVID-19 therapy trial (RECOVERY) is the UK's large clinical trial of promising coronavirus treatments. The University of Oxford and the Nuffield Department of Population Health are coordinating the effort.

Given the pandemic situation, drug regulators from all over the world, including India, are ready to push the bar lower by waiving off data on animal and toxicity studies, ensuring speedy clearance for the clinical trials and approval of manufacturing license within days if convinced of the potential of the drug. For example, Gilead Sciences initiated phase II studies of the Ebola drug remdesivir against COVID-19 at the end of February 2020, in the US, Asia and Europe and in May 2020 the US Food and Drug Administration (FDI) granted the drug Emergency Use Authorization (EUA).

Unfortunately, we are also witnessing developments like the publication of researches on COVID-19 without peer review by reputed journals (between January and May 2020 over 30,000 works were published, a large fraction of which were not peer-reviewed), retraction of the publication even by the most reputed journals like *The Lancet* and *British Medical Journal*, endorsement of drugs with unproven efficacy by practitioners of indigenous medicines and heads of states, recruitment of a large number of COVID-19 patients for hurriedly planned clinical trials and granting/withdrawal of permissions for emergency uses of anti-COVID-19 drugs by drug regulatory authorities all over the world.

Repurposing of Drugs

Employment of a drug, previously developed for the treatment of a specific disease, for new therapeutic purposes, constitutes drug repurposing (also termed repositioning, retracking and

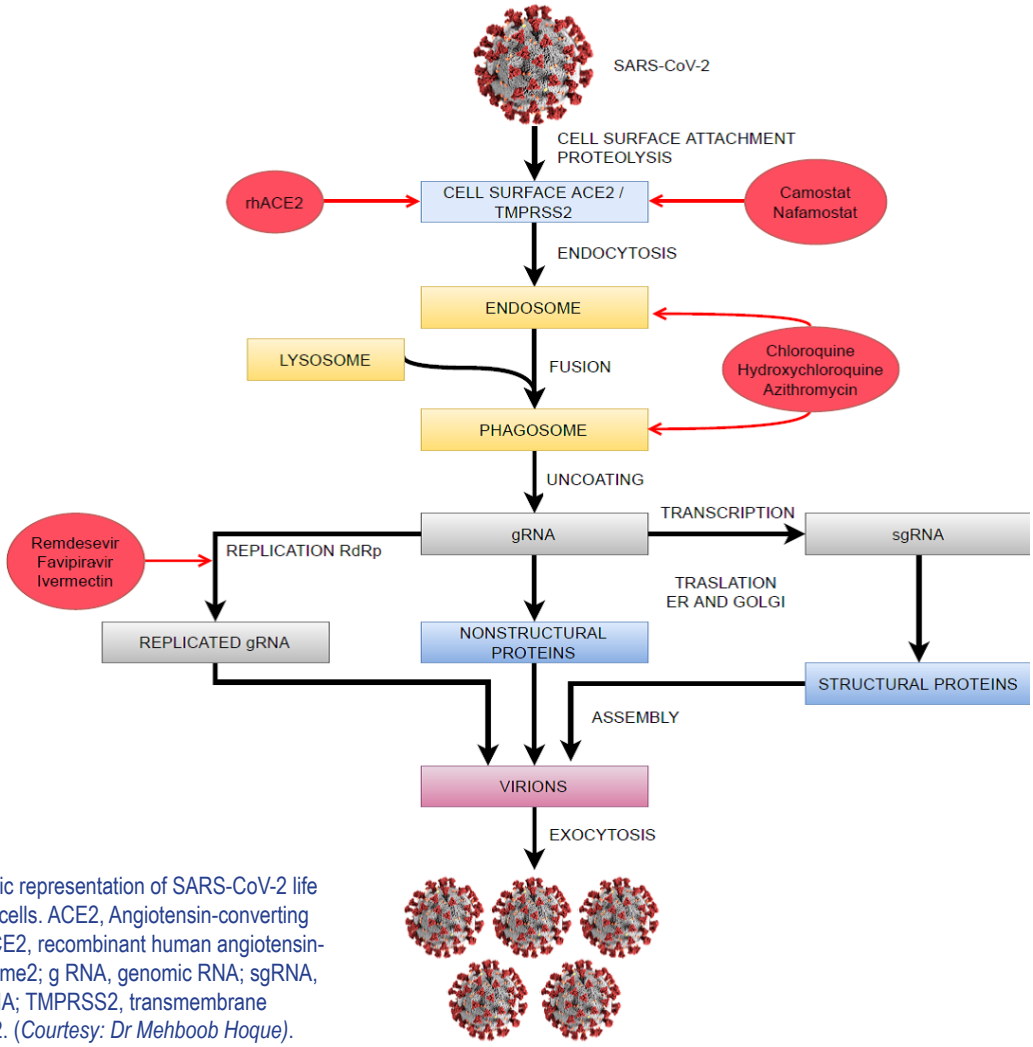


Fig. 1. Schematic representation of SARS-CoV-2 life cycle in human cells. ACE2, Angiotensin-converting enzyme 2; rhACE2, recombinant human angiotensin-converting enzyme2; g RNA, genomic RNA; sgRNA, subgenomic RNA; TMPRSS2, transmembrane proteaseserine2. (*Courtesy: Dr Mehboob Hoque*).

therapeutic switching). Repurposing if successful cuts short the time and resources required for drug development, by doing away with most toxicity studies and animal experimentation as these were done before the drug received the original approval. For repurposing an approved drug, scientists can directly investigate the effects in patients of the new disease i.e. to stage II or III clinical screening (see box *What are Clinical Trials* for details).

Repurposing additionally facilitates convenient formulation and distribution of the drug by the pharmaceutical companies already familiar with the task. While it is true that a drug developed for a specific disease rarely proves effective against an unrelated ailment, some remarkable success stories do exist. Viagra (sildenafil), originally developed by Pfizer for heart-related chest pain, turned out to be extremely popular for the treatment of erectile dysfunction in men and pulmonary arterial hypertension two decades after its marketing. Similarly, thalidomide promoted as a drug for anxiety, disturbed sleep and morning sickness later emerged effective against multiple myeloma and some drug-resistant forms of TB.

To develop a treatment for COVID-19, initially, researchers looked at drugs developed for the treatment of other viral diseases. According to the US National Institute of Health Ecology chief Vincent Munster, "The general genomic layout, general replication kinetics and biology of MERS, SARS and SARS-CoV-2 viruses are similar, so testing drugs which target relatively generic part of coronavirus is a logical step." The search, however, has been extended to other drugs not related to viral treatment. Taking into account the known details of the structure of SARS-CoV-2 proteins computer modelling and artificial intelligence are also being applied for the development of anti-COVID-19 drugs.

SARS-CoV-2 Virus & Anti-COVID-19 drugs

SARS-CoV-2, like other coronaviruses, contains single-stranded RNA as the genetic material. The now-famous structure of the virus shows a lipid membrane surrounded spherical entity (125 nm diameter) dotted on the surface with several proteins including the spike glycoprotein. The endocytic entry of the virus is facilitated by the binding of the spike protein to the human cell surface Angiotensin-Converting Enzyme-2 (ACE-2), that induces endocytosis.

The resulting endosomes may fuse with the lysosome and the resulting

Table I. Some drugs undergoing clinical trials for their anti-COVID-19 efficacy

Drug	Approved as	Mode of action	Lead for anti-COVID-19 screening	Developed by
Hydroxychloroquine Chloroquine	Antimalarial Immunomodulator	Acidifies endosomes, lysosomes	In vitro studies on coronaviruses	Bayer Laboratories
Remdesivir	Anti-Ebola Anti-SARS-CoV	Restricts viral RNA replication	Blocks growth of coronaviruses *in vitro*	Gilead
Dexamethasone	Anti-inflammatory, anti-arthritic, anti-cancer	Restricts WBC from reaching areas of swelling, promotes apoptosis	Stops anti-cytokine storm	Recovery trials, Government of UK Generic drug
Favipiravir (Avigan) Avifavir	Anti-influenza	Inhibits RdRp	In vitro studies on coronaviruses	Toyama Chemical (Fuji film group) Generic drug
Tocilizumab/ Atlizumab (Actemra)	Immunosuppressive Anti-rheumatoid arthritis	Binds to interleukin-6 receptor (IL6R)	Preliminary studies on human subjects	Hoffmann-La Roche/Chugai
Itolizumab/ (Alzumab)	Psoriasis	Lowers circulating interleukin (IL)-6 and C-reactive protein	Preliminary studies on humans	Biocon India
Lopinavir, Ritonavir	Anti-HIV/AIDS	Inhibits chymotrypsin-like protease $3CL^{pro}$	*In vitro* anti-SARS-CoV-2 activity, anti-MERS	Developed by Abbott
Ivermectin	Broad spectrum anti-parasitic	Blocks Cl^- channels, inhibits SARS-CoV-2 in vitro	A preliminary study on COVID-19 patients in Bangladesh (also given Doxycycline)	Merck Institute of Pharmaceutical Research, USA
Nafamostat	Anticoagulant for chronic pancreatitis, post-operative gastric reflux	Inhibits TMPRSS2, interferes with virus entry	Blocks SARS-CoV-2 cellular entry *in vitro*	Japan Toba Co, Ono Pharmaceuticals, Japan
Recombinant human ACE-2 (APNO1)	Drug for acute lung injury, pulmonary arterial hypertension	Competes with virus for cell surface ACE-2	Protects against influenza (H7N9), inhibits SARS-CoV-2 in vitro	APEIRON Biologics AG
Famotidine (pepsid)	Antacid	Binds to a protease involved in entry of SARS-CoV-2 entry	COVID-19 patients previously on famotidine showed better recovery	Developed by Yamanouchi Pharmaceutical Co, Japan
Azithromycin	Antibiotic	Inhibits translation of bacterial mRNA; Blocks autophagosome clearance	*In vitro* active against Zika and Ebola viruses	Plivad.o.o., Croatia
Haloperidol	Anti-psychotic-Schizophrenia	Blocks dopamine and serotonin type 2 receptors	*In vitro* activity against SARS-COV-2	Janssen Pharmaceuticals, Belgium
Acalabrutinib (Calquence)	Non-Hodgkin lymphoma Leukemia	Inhibits Bruton tyrosine kinase BTK	Preliminary studies on COVID-19 patients	Astra Zeneca
AQCH	Anti-dengue		*In vitro* inhibition of SARS-CoV-2	Sun Pharma
Ashwagandha (plant extract)	Ayurvedic medicines	Overall health improvement, immunity booster	Withanone, a constituent blocks *in vitro* SARS-C0V-2 replication	Ministry of Ayush, ICMR, CSIR, UGC

acidification and proteolysis by cathepsin L lead to the fusion of viral envelope with the lysosomal membrane. Post fusion, the nucleocapsid passes into the cytoplasm and the viral genome is released. The released single-stranded RNA acts as mRNA and two-thirds of the genome is translated into two large protein complexes which in turn are cleaved into 16 non-structural proteins. Important among these are the RNA dependent RNA polymerase (RdRp), helicase and an Exoribonuclease (EXON). The RdRp is directly involved in the replication and transcription of RNA from the viral genomic RNA. Translation of the coat and structural proteins takes place in the ER and Golgi apparatus and a large number of virions are assembled using the synthesized mRNA proteins and lipids before they are released out the cell by exocytosis (Figure 1).

During the early infection phase, SARS-CoV-2 multiplies inside the body and induces symptoms resembling common cold/flu. This is followed by the pulmonary phase in which the host immune system is challenged resulting in respiratory symptoms including cough, breathlessness and blood clot formation. The third phase described as hyperinflammatory phase is characterised by a "cytokine storm" in which a hyped immune system attacks the body's own tissues causing serious harm to heart, lung, kidney and other organs. This results in Acute Respiratory Distress Syndrome (ARDS) that accounts for a significant number of deaths among COVID-19 patients. As of today, there are no approved drugs available to contain COVID-19. Table 1 shows a list of some potential anti-COVID-19 drugs, which have received EUA from the US FDA and similar agencies in several other countries and are undergoing clinical trials. These include drugs approved earlier for the treatment of various bacterial infections, malaria, rheumatoid arthritis, HIV, diarrhoea, heartburn and cancers. In the rush to find out a cure for COVID-19 and availability of a large number of patients, weak evidences and even anecdotal supports have been in some instances adequate to obtain the permission of drug regulators for the conduct of clinical trials in some countries.

What Are Clinical Trials?

Development of drugs is a lengthy, complex and expensive process, full of failures and risks. The journey of a drug candidate from its discovery to the market requires about a decade and currently costs about 2.5 billion US$. This involves exhaustive studies in the laboratory, on experimental animals, and finally on human subjects that constitute the clinical trials. Only companies with huge resources can, therefore, undertake the endeavour.

The US Food and Drug Administration (FDA) and similar agencies in other countries lay down norms for the conduct of clinical trials of drugs, scrutinize them and once satisfied, approve their marketing. The Drug Controller General of India (DCGI) under the Ministry of Health and Family Welfare, approves licenses of drugs in India. In order to conduct clinical trials, companies in the USA are required to file Investigational New Drug application (IND) listing all details of the drug including its structure, investigations in the laboratory and on experimental animals showing its efficacy and safety. The FDA model, which is widely followed by drug regulatory agencies in most other countries, has three major phases of clinical trials.

In phase I, studies are done on a small number (< 100) of healthy volunteers in order to primarily assess the safety of the drug candidate. The studies also examine how the human body processes the drug (pharmacokinetics) and the impact of the drug on various body functions (pharmacodynamics). In addition, assessment of safe drug dosages and side effects, if any, are also made.

In phase II, studies are conducted on larger cohorts (100-500) of patient volunteers. Effect of the drug candidate is compared with other available drugs for the treatment of the disease as well as placebo (placebo is a substance that is designed to possess no therapeutic value). Optimization of drug dosage and schedule of administration as well as investigation of short-term side effects on patient volunteers are undertaken.

In phase III, large numbers of patient volunteers (1,000-5,000) are included from across trial sites around the world. Fine details of efficacy safety of the drug in patients and overall risk-benefit ratios are examined.

Some studies continue after a drug is marketed. Those that delineate risks, benefits and optimal use after making the drug available in the market constitute phase IV.

Remdesivir is an antiviral agent originally developed for the treatment of Ebola infection against which it was not highly effective. It is however used as an anti-influenza drug in some parts of the world. Remdesivir inhibits synthesis of viral (MERS-CoV and SARS-CoV) RNA by the RdRp, hence the multiplication of the SARS-CoV-2. Remdesivir also inhibits the 3',5'-exoribonuclease, the proofreading enzyme which removes any wrong bases accidentally incorporated into the RNA. *In vivo* mouse models of the viruses and rhesus monkey model have shown the impressive anti-viral and prophylactic effect of the drug.

A clinical trial that showed that hospitalized COVID-19 patients recover faster earned remdesivir EUA from the US FDA for its use outside clinical trials. Remdesivir, however, did not impact mortality. Clinical trials continue although remdesivir has been approved for use on serious patients of COVID-19 in several countries including India. Indian pharmaceutical companies Cipla and Hetero Pharmaceuticals have received permission from Gilead Pharma to manufacture the drug in the country. Cipla will market the drug under the brand name Cipremi, while Hetero Pharma will sell its product as Covifor. Remdesivir is recommended to be used for serious hospitalized patients on oxygen and its use as prophylactic is not recommended.

Two potential plant sources of anti-COVID-19 drugs. (Left, the broom creeper (*Cocculus hirsutus*) and right, Ashwagandha (*Withania somnifera)*

Favipiravir (Avigan) has approval as an anti-flu drug in Japan and recently received EUA in several countries including India. It also inhibits the RdRp of the viruses. Glenmark Pharmaceuticals Ltd. will sell the drug under the name FabiFlu and undertake phase III clinical trials of a combination of other drugs. Favipiravir is recommended for mild to moderately ill COVID-19 patients but not as a prophylactic or for pregnant and lactating women.

Dexamethasone is a widely used anti-inflammatory steroidal drug. Dexamethasone has been shown to exhibit life-saving potential in critically ill patients according to a study conducted in the UK. This is the first drug shown to have the potential to cut down death by about 30 per cent, according to the lone UK clinical trial on 21,000 participants. The drug has already been approved in the UK and WHO has recommended further studies on the extremely inexpensive drug that is produced in many countries for the treatment of other diseases. The UK Government has authorized the drug use on hospitalized patients, those that require oxygen and are on ventilators. In June end the drug received approval for use on COVID-19 patients in India. The impact of the UK work as anti-SARS-CoV-2 is so strong that the WHO fears hoarding of the drug and speculative procurement may lead to global scarcity.

Several in vitro studies suggest that chloroquine/hydroxychloroquine interfere with entry, virus-endosome fusion, uncoating, assembly of the viruses including the coronaviruses. It also inhibits the replication of coronaviruses including SARS-CoV-2 in cell cultures. WHO suspended its clinical trial on HCQ under its solidarity program because of the potential toxic effects on cardiac function. The decision to suspend trials was triggered by a study published in the journal *Lancet* that HCQ or HCQ with the antibiotic azithromycin has no beneficial effects for COVID-19 patients. However, in the face of worldwide criticism from the scientific community, the study published in the journal was withdrawn and the WHO decided to reconsider its decision to suspend the trials.

The antibiotic azithromycin showed some promise as an anti-COVID-19 drug but has since been dropped from studies in several countries including India.

Tocilizumab marketed as Actemra by Roche is a monoclonal antibody that blocks a cytokine interleukin-6 receptor. High levels of IL-6 portends respiratory failure and deaths. Itolizumab, developed by Biocon India, is also a monoclonal antibody and like tocilizumab interferes with the induction of cytokine storm. After infection by SARS-CoV-2 inflammation and cytokine storm begin from the second week and experts advise administration of tocilizumab and similar drugs that fight cytokine storm after eight days of infection.

The anti-HIV/AIDS medication lopinavir/ritonavir in spite of promising *in vitro* studies have not so far yielded encouraging results in clinical trials on COVID-19 patients.

AQCH is a phytopharmaceutical derived from the tropical climber *Cocculus hirsutus*, developed for dengue but has broad anti-viral effects. ACQH has been developed by CSIR-Indian Institute of Integrative Medicine (CSIR-IIIM), Jammu and DBT-ICGEB and is active against all four subtypes of dengue virus. This is the first phytopharmaceutical to receive the approval by the DCGI for EUA against COVID-19. AQCH has inhibitory action against SARS-CoV-2 *in vitro*.

The other plant-based drug that is being investigated for anti-COVID-19 role is Ashwagandha (*Withania somnifera*), a plant that is widely used in Ayurvedic system of medicine in India. The ministry of Ayush and CSIR (India) are initiating clinical trials on four Ayush formulations – Ashwagandha, Yashtimadhu (Mulethi), Gaduchi +pippali (giloy) and Ayush-64 developed as an anti-malarial.

It is true that the exponentially increasing cases of COVID-19 with millions of human lives at stake warrant fast-tracking of the search for remedies, but it is important not to abandon scientific reasoning. At the time of the outbreak of EBOLA pandemic, WHO recommended that "it is ethical to offer unproven interventions with as yet unknown efficacy and adverse effects, as potential treatment or prevention keeping in view no vaccine or antivirals were available."

Major economic and political gains, however, prompt the promotion of drugs with questionable efficacy and safety, risking millions of innocent lives. While it is the duty of governments to ensure that this does not happen, some governments and heads of states, unfortunately, themselves become a party. Madagascar's President Andry Rajoelina has recently promoted a herbal tea consisting of the extract of sweet wormwood, *Artemisia annua* and other components being marketed as COVID-Organics which the country is offering as preventive to all citizens including school children. Scientists and the WHO are concerned that COVID-Organics has not gone through the laid down norms of clinical trials. Nearly all countries have traditional systems of medicine. But these should not be promoted as cures for COVID-19 without adequate screening essential to establish efficacy and lack of toxicity.

Prof. M. Saleemuddin, Professor and Coordinator (Retd), Interdisciplinary Biotechnology Unit, Aligarh Muslim University, Aligarh. Address: Apartment #209, My Home Glory Apartments, Masab Tank Hyderabad-500028, Telangana. Email: msaleemuddin47@gmail.com

SHORT FEATURE

Role of GIS in Managing COVID-19

Ananya Bhatia, Mohit Kumar & Rohit Magotra

A Geographic Information System (GIS) is a framework for gathering, managing, and analyzing data. Rooted in the science of geography, GIS integrates many types of data (https://www.esri.com/en-us/what-is-gis/overview). Geographical Information System is an analysis tool which helps to analyze the complex data captured by the satellite imageries.

In other words, GIS is a technical system that collects, stores, manages, calculates, analyzes, displays, and describes relevant geographic data in all or part of the earth's surface (including the atmosphere) with the support of computer hardware and software systems. From the perspective of the application, GIS is a tool for solving spatial problems. From the perspective of discipline, GIS includes geography, cartography, surveying and computer science.

Since much of the information is inseparable from its geographic location, GIS finds application in urban planning, infrastructure planning, resource planning, surveying and research, image analysis, environmental assessment, power, and disaster management. It has evolved as an important tool for policymakers.

India has been a forerunner in using modern spatial technologies. In the early 90s India launched the Indian Remote Sensing satellites and used image-based mapping for creating GIS databases and applications. Some major GIS initiatives taken in India are Natural Resources Information System, National Spatial Data Infrastructure, Bhuvan Image Portal of Department of Space, Delhi State Spatial Data Infrastructure, National Urban Information System, Establishing Government to Government GIS, modernization of land records under NLRMP (National Land Record Modernization Programme), Restructured Advanced Power Development & Reform Program and various City GISs among others. Transport management, Land Record Management, Smart City planning, distribution of infrastructure and utilities, agriculture, India's National River Linking Project are some other GIS initiatives.

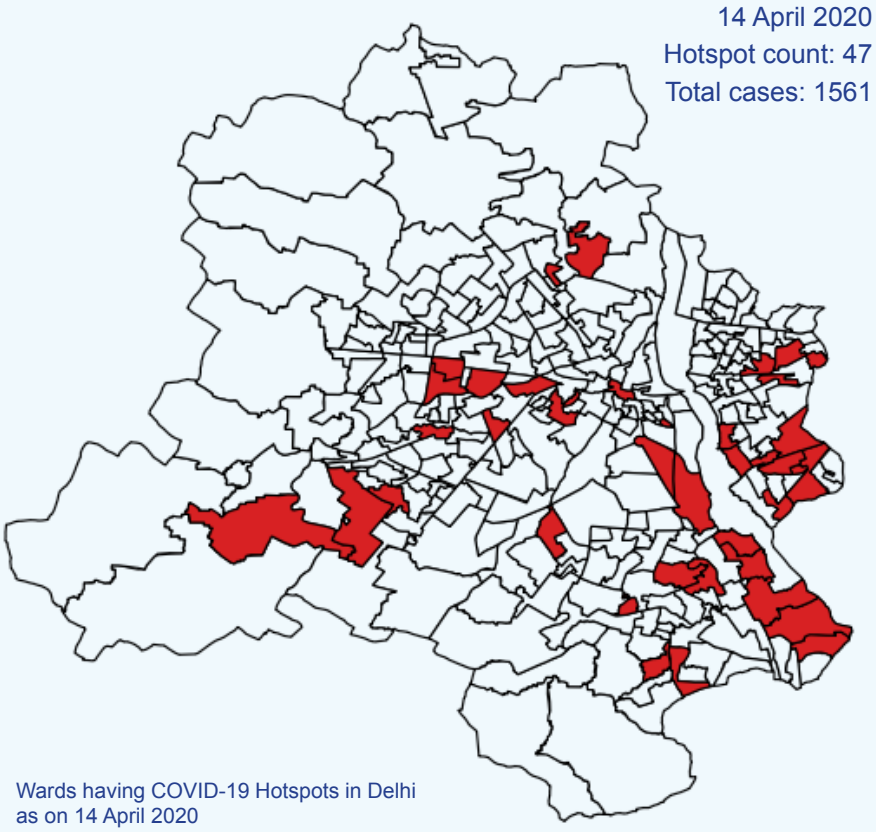
Most recently, the Aarogya Setu App launched by the Government of India is another important application of GIS technology for COVID-19 management. The app is a contact tracing app developed by the National Informatics Centre that prompts users to take a Self-assessment Test and then uses the location of users to issue alerts about positive COVID-19 cases in the vicinity. This app also provides a list of all helpline numbers related to COVID-19 for India. There is also a feature that plots the daily and cumulative cases reported across different districts of the country.

The Aarogya Setu app uses the phone's Bluetooth and GPS capabilities. It keeps a record of all other Aarogya Setu users that it detected nearby using Bluetooth. It will also use a GPS log of all the places that the device had been at 15-minute intervals. These records are stored on the phone till the time any user tests positive or declares symptoms of COVID-19 in a self-assessment survey in the app. In such cases, the records are uploaded to the servers. Aarogya Setu app has helped millions in the country to trace, track and geographically map the incidence of COVID 19 in India.

Role of GIS in COVID-19 Response

GIS tools have been used to reveal the spatial propagation pattern, spatial and temporal transfer of the COVID-19 hotspots. It was noticed through the information maps that almost in all cases at the city level, the concentration of infected persons occurred in clusters.

One user case on the application of GIS for COVID-19 incidence mapping at ward level in Delhi was done by Integrated Research & Action for Development (IRADe). IRADe mapped the COVID-19 incidences on the ward level shapefiles for the period 8 April to 14 April 2020. Through mapping, it was identified that there were 47 COVID-19 hotspots distributed in 37 wards of Delhi. This analysis shows that containment measures should be more strictly implemented in 37 wards distributed in nine infected districts. Combining with socio-economic data



Wards having COVID-19 Hotspots in Delhi as on 14 April 2020

of the infected wards, further potential population under risk can be estimated. Such an analysis is also the starting point of modelling the future spread of the disease.

However, the spread of infectious diseases in an area is not subject to administrative boundaries, and the hotspot centre and its border should be divided according to the actual spread of infectious diseases in space. The quantitative division of the hotspots, clusters and the direction of the spread not only helps to understand the true spatial spread of the virus but also provides a scientific basis to formulate optimal prevention and control measures.

In India, GIS mapping and location tracking is being used for this. The Centre has tested the COVID-19 Quarantine Alert System (CQAS), an application that uses telecom data to trigger emails and text-message alerts to the authorities if a person has jumped quarantine (*The Hindu, April 3, 2020*). Kerala, Gujarat, Telangana, Punjab among other states have developed excellent GIS-based monitoring, tracking and alert systems.

GIS tools for Pandemic/ Epidemic Management

Using GIS capabilities such as spatial analytics, mapping, and location intelligence, health officials and government agencies can map confirmed and active cases, fatalities, and recoveries to identify where COVID-19 infections have occurred (https://cio.economictimes.indiatimes.com/).

For example, the centre point of COVID-19 cases can be found by using the central feature tool in the ArcGIS spatial statistics tool and compared by the average, median, and minimum centre value. This will give an idea about the vulnerable population and the critical infrastructure in the zone. The location-specific data for the infected cases need to be available for this.

Using the ArcGIS spatial statistics tool distribution, the direction of the spread can be calculated to reveal the trends, dispersion and direction trend of infection. Combining the demography, spatial data and real-time case data helps to understand how the infection is spreading and in what areas immediate actions are required.

Demography data related to age, social vulnerability, and slum areas can be mapped to identify the most vulnerable population at risk. Critical infrastructure mapping will help to manage resources efficiently. The power of user-friendly GIS visualization in the form of thematic illustrated maps, web maps, and interactive maps helps everyone to understand the situation in a better way.

The world is changing. It is becoming more technology-dependent. GIS, as a state-of-the-art technological solution offers many potential applications. This technology is becoming pivotal for management of COVID-19. Test, trace, isolate and treat are the major pathways to manage a pandemic like COVID-19, and GIS is offering key support in tracing the positive cases which could then be isolated and treated.

In addition, GIS is helping in creating hotspots/containment zones by suggesting which geographic location and to what extent needs to be isolated from the rest of the city. In the coming days, planning and management of cities will involve an aspect of pandemic management, and GIS will play a huge role in designing cities that are safe from the impacts of upcoming pandemics.

Ananya Bhatia (abhatia@irade.org) is Research Associate, Mohit Kumar (mohitk@irade.org) is Research Analyst, and Rohit Magotra (r.magotra@irade.org) is Deputy Director, Integrated Research and Action for Development (IRADe), C-80, Shivalik, Malviya Nagar, New Delhi-110017. The authors are currently involved in projects dealing with disaster resilience in Himalayan cities; mapping of thermal hotspots in Indian cities; applications of Remote Sensing and GIS in the identification of Dengue hotspots in cities, and mapping of ward-level COVID-19 hotspots in Delhi.

OBITUARY

Govind Swarup

Innovator, Mentor & Motivator

(23 March 1929 - 07 September 2020)

Somak Raychaudhury

ONE of the pioneers of science research and education in India, Govind Swarup passed away in Pune on 7 September 2020.

Today India is one of the world's leading communities in studying the Universe at radio wavelengths, and it is largely because of Govind Swarup's groundbreaking achievements. This he achieved by conceiving and constructing some of the most innovative telescopes and instruments ever built for the purpose, and by inspiring generations of young engineers and physicists, whom he taught not only to dream of impossible things, but also how to achieve them.

Govind Swarup grew up in a small town in Uttar Pradesh, and when he went to study at Allahabad University in 1945, it had one of the best Physics departments in the country, built from scratch over a decade by Meghnad Saha. Even though Saha had left by then, many of his students and colleagues taught and mentored the bright crop of students the department continued to attract. Half a century later, talking to us, Swarup often fondly remembered his teachers – B.N. Srivastava, who wrote the seminal textbook on Heat, along with Saha, that is still used in Colleges all over the country; K.S. Krishnan, who had worked with C.V. Raman in Calcutta on the discovery of the Raman Effect, and many others.

After independence, K.S. Krishnan moved to Delhi as the founding Director of the CSIR-National Physical Laboratory. In 1950, having finished his MSc, Swarup joined him there. Krishnan was at that time interested in the quantum theory of magnetism. Only a few years before, Yevgeny Zavoisky had been awarded the Nobel prize for the discovery of electron paramagnetic resonance. Krishnan set Swarup the task of measuring the spin resonance in materials at microwave frequencies. Swarup set about making the equipment from scratch, in less than two years, from radar parts left over from the Second World War to make measurements at a wavelength of 3 cm. This was the first sign of the innovativeness that became so much the "Swarup brand" throughout his entire life. If Indians are known for "*jugaad*", Govind Swarup was its embodiment.

At the URSI General Assembly in Sydney in 1952, Krishnan met some of the pioneering radioastronomers who were also modifying advanced radar equipment to build antennae to study the Universe. Greatly inspired by his talks upon his return, Swarup ventured to Australia to work at Potts Hill in Australia with Joseph Pawsey, building an array of 2 m dishes to receive signals at 500 MHz. After his return to India, Swarup set off to the USA to learn more, first at the Fort Davis station of the Harvard Observatory in Texas, where he built equipment to detect a radio burst from the Sun, and then at Stanford University in California, where he worked on his doctoral thesis with the famous R.N. Bracewell.

After his PhD, Swarup joined the Stanford faculty, but in his heart he wanted to return to India, where the country's post-independence infrastructure for science and technology was just being set up. He was one of four Indian radiophysicists working in top laboratories in the USA, who wrote to research Institutions in India about their plans to join in this effort. Fortunately, a positive response from Homi Bhabha led Swarup to join the Tata Institute of Fundamental Research (TIFR) in Bombay, and establish a unique radioastronomy group there.

Under the leadership of Swarup, the TIFR group first set up a solar array with the 32 antennae that he had worked on in Australia, and had since been shipped to India. This was at Kalyan, near Bombay, following which Swarup, and his increasingly confident group of students and engineers, found a slope of a hill near Ooty that exactly matched the latitude of the place. Here they built the first unique giant telescope of Swarup's design – made of fine wire mesh on a monolithic parabolic cylindrical frame, half a kilometre long and 30 m wide. This was built ingeniously on this natural Equatorial

The Giant Metrewave Radio Telescope (GMRT) – established under the leadership of Prof. Govind Swarup for radio astronomical research at metre wavelengths
(*Source: http://www.gmrt.ncra.tifr.res.in/*)

Prof. Govind Swarup (extreme left) with Professor Jayant Narlikar while naming a road after Vainu Bappu

mount, such that tracking celestial sources would be largely done by the rotation of the Earth, with a motor drive required for just one axis. Swarup also chose 327 MHz as the operating frequency, in the range of radio-frequencies that hadn't been well studied before.

The Ooty Radio Telescope (ORT), which started to operate in 1969, made many pathbreaking measurements and discoveries, including that of new pulsars, quasars and gravitational lenses, and is still operational. Some of the measurements of the counts of radio sources made by Kapahi and Swarup, made with the ORT, went on to provide strong support for the Big Bang theory of Cosmology.

The ORT did not just put India on the world map of Astronomy, it also produced a confident and ingenious bunch of young engineers and scientists, which, inspired by this visionary, was ready to take up any challenge. They moved to Pune to set up to build the world's largest radio-telescope array at low radio-frequencies – thirty 45-m light-weight wire-mesh dishes, spread over 30 km of vineyard territory along the Pune-Nashik highway. They operated at frequencies as low as 150 MHz, aimed at finding the spin-flip transition of hydrogen, ordinarily at 1420 MHz in the lab, but redshifted to much lower frequencies, at distances as far away as 90% to the edge of the Universe, to detect diffuse hydrogen before it collapsed to form galaxies.

The Giant-Metrewave Radio Telescope (GMRT) is now one of the top astronomical facilities of the world for two decades, studying all sorts of sources from planets, stars to radiogalaxies and supermassive black holes. Observers from all over the world compete for time on this facility, which is over-subscribed three times over. As a Professor at the University of Birmingham in the UK, my students and I used to come several times a year to Pune to observe with the GMRT, and upon my return to India, I still use this unique instrument, which has now been upgraded, in which Swarup continued to play a role. The GMRT is now a pathfinder observatory for the Square Kilometer Array – the Next Big Thing in Radioastronomy.

Govind Swarup won many accolades in his life – the Shanti Swarup Bhatnagar award, the Padma Shri, the Grote Reber award and the Fellowship of the Royal Society, to name a few. But his greatest reward seemed to be in mentoring generations of peers and younger students, and he was very generous with his time and ideas.

I first met him as an undergraduate, visiting the Ooty telescope on my scholarship tour. His unbridled enthusiasm was so infectious that half of the group, at the end of the day, wanted to be an astronomer like him! I cannot recall a single conversation with him in which he hadn't been excited about new things, managing to infect everybody around him with his enthusiasm.

The frugality of Swarup's approach was outstanding – he and his group came up with innovative ideas to build things at a fraction of the usual cost, making it possible to make these world-beating facilities with the small budgets typical of our institutions. Equally remarkable was the way his mind worked – he could in an instant work out complicated physical models in his head in a very own intuitive approach. Rajaram Nityananda gives an example: "…I remember a serious debate on the force that wind exerts on a cylinder – my number was 20% higher than his, which meant a design for a radio telescope he was proposing had to be heavier to withstand wind forces. We even went to an institute of wind engineering in Chennai. He was right, of course."

Till his last day, everybody around him felt that breathless excitement with which he could infuse all who interacted with him. A hundred years from now, he will be remembered as the Man who came up with all the ideas, and knew how to turn these visions into the very tangible legacies he has left for us.

Dr Somak Raychaudhury is Director, IUCAA (Inter-University Centre for Astronomy and Astrophysics), Pune, Ganeshkhind, Post Bag 4, Puné-411007.
Email: somak@iucaa.in

A Tribute to
N.K. Sehgal

Anuj Sinha

Unesco Kalinga Prize Winner – 1991
Dr. Narender K. Sehgal

Widely Known and Recognized as the Architect of India's Internationally Acclaimed Science Popularisation Programme
&
A Crusader in Popularising Science for the Masses.

[Born: 7 the November, 1940, Lahore (now in Pakistan) ….]

NARENDER was a rationalist and a visionary. His role in promoting scientific temper was quite natural, passionate and creative. He also supported efforts at exposing ill-effects of superstitions, blind faith and magic tricks that are presented as miracles.

One needs characteristics like curiosity, drive, self-confidence and persistence in equal measure to be considered creative. Such rare persons are often remembered as difficult because they are critical, outspoken and demanding on themselves as well as others with whom they interact. Narender was all this and more. We were neighbours, colleagues, team members and friends for almost three decades.

The first two decades of his professional journey (till 1982) were as a leading researcher in the Particle Physics Group at TIFR Mumbai. This was preparing him for the role that brought him many challenges and immense satisfaction for the next four decades.

He shaped the NCSTC (National Council for Science and Technology Communication) with the vision that it would be an overarching body guiding science communication in basic research, industrial and agricultural research, health, development and welfare communication and more. He involved street theatre artists, radio script writers and documentary filmmakers besides the print media journalists in the campaigns. As TV made inroads, science filmmakers were nurtured to produce interesting and creative programmes.

The TV serial *Bharat Ki Chaap* found generous sponsors and this capital was the seed for Vigyan Prasar. He worked to shape the institution with enthusiasm. He was at his desk till late evening every day of the week. The foundation he built has proved robust over the three decades.

Besides his many academic accomplishments, he had full command on both Hindi and English. Yet he was open to learning and studied the editorial pages of English and Hindi dailies mainly to polish his skills. His editorials were always thought provoking in the monthly newsletter *NCSTC Communications* from NCSTC, DST and the popular science magazine *Dream 2047* from Vigyan Prasar.

The valuable lessons from regional Gyan Vigyan Jathas were exciting and he shaped the *Bharat Gyan Vigyan Jatha* taking both science and more importantly 'the method of science' to the common man. NOSTC (Network of Organizations for Science and Technology Communication, Delhi) owes its origin to the need for a network of academic, government and non-government organisation for conceptualizing and implementing *Bharat Jan Gyan Vigyan Jatha* during 1992. Many other initiatives took shape using the mandate, strength and flexibility of each organisation. His high personal integrity ensured that there was never a flicker of doubt in the operations of these organisations.

Science Center (Gwalior) organised Children's Science Congress in 1991 and 1992. Impressed by its impact, Narender worked out a national programme and shaped the National Children's Science Congress in 1993. This has been held annually and many active scientists today recall their first positive research experience to this forum. Teachers' Science Conference has a similar beginning and benefitted from Narendra's touch to become a vibrant biannual forum.

His leadership role could best be categorised as a Nurturing Parent as he shaped and guided scientists turning them into science communicators, including the author. Actions, decisions and alliances were encouraged in the team and displayed fair-play. His sharp intellect was always on display in public and personal interactions.

He was a keen researcher and engaged with scientists and institutions of 'public understanding of science.' He chose a research question on 'minimum science for the common man' around 2008/09. Recommendations of this multinational study, sponsored by UNESCO, will be a launch pad for the coming decade.

He undertook a monumental assignment in the last few years of translating an 'Encyclopedia of Fertilizer Terms and Technology' in Hindi and diligently completed a set number of terms daily. Narender led a spartan but regular life and spent leisure time with his granddaughter. His passing away is a great loss to the society and the community of science communicators.

I remember some little known facets of his personality.

He agreed to guide software development for the Year of Scientific Awareness (2004) working in the registered society NOSTC under a grant-sin aid when I was Head NCSTC, DST. To his credit, we functioned as a great team although we had reversed our roles.

An employee of NOSTC met a fatal road accident. There were outstanding advances and loans against him. Narendra first appealed to colleagues to settle the dues voluntarily. He quietly settled balance dues and ensured that the family did not face hardship.

He would return mementoes gifted by organisers despite the embarrassment, refuse token honorariums, split and distribute gifts among all team members. He would send cheques from his savings account of the estimated value of the gift. He used hired taxis, his own pen, staple pins and stationery for personal work. He was always setting standards for others and leading by example.

Many will envy our long and close association even as I will miss his sharp repartee and wisdom.

Er Anuj Sinha is a science communicator. He has worked as Advisor and Head NCSTC, DST New Delhi and Director, Vigyan Prasar, NOIDA. He is currently Hon'y Chairman NOSTC Delhi. Email: cpranuj@yahoo.com

Dr Narender K. Sehgal

Scientific Precision Meets Communication Excellence

Manoj Kumar Patairiya

DR Narender K. Sehgal had been at the forefront of anything and everything on science communication for over two decades. Be it the widely acclaimed Bharat Jan Vigyan Jatha, National Children's Science Congress, science serials on All India Radio like *Vigyan Vidhi* (Methods of Science), *Manav Ka Vikas* (Human Evolution), or television serials *Kyon Aur Kaise* and *Kudratnama* or the National Science Day, Science Communication through Traditional and Non-traditional Media, and even the mega campaign built around the Total Solar Eclipse.

Founding Head of the National Council for Science & Technology Communication (NCSTC), founder of Vigyan Prasar and NCSTC Network of government and non-government organizations that started a chain of Science Clubs in India, Dr Sehgal was awarded the UNESCO-Kalinga Prize for Science Popularization, an international recognition given to a person who has made original and outstanding contributions to the field of public interpretation of science.

While the developed world was focusing on science centres, museums and expensive exhibits, Dr Sehgal adopted India's very own and organic model of science communication where human-to-human contact at the grassroot level was central imbued with a problem-solving approach. He clearly believed that science communication in the developing world and in countries like India must connect with the masses and that is why he encouraged programmes like Vigyan Jatha, Public Understanding of Science at Sangam in Kumbh Mela, Science Mela at the famous Nauchandi Mela in Meerut where people at large could be benefitted.

It is a coincidence that he was born on 7 November 1940, the birthday of Sir C.V. Raman who won the Nobel Prize in 1930 for his discovery of Raman Effect. He had an excellent academic career and got merit scholarship in matriculation in 1956, graduated with BSc Physics in 1960 winning merit certificate, joined Bhabha Atomic Research Centre Training School and completed one-year postgraduate course in physics in 1961. Later he was appointed as a Scientific Officer in Theoretical Reactor Physics, BARC. In 1963 he found another opportunity to join University of Hawaii, Honolulu, USA and obtained MSc in Particle Physics in 1965 and later PhD from the University of Wisconsin Madison, USA in 1969.

In an interview given to Mr Biman Basu and Mr Pallava Bagala published in *Science Reporter,* Dr Sehgal revealed that in August 1972 he started bringing out a quarterly magazine *Scientific Opinion*. He informs that although the magazine had subscribers from almost every state, the print order was still small. He sustained the magazine from his meagre earnings from his writing assignments. He was a regular contributor in *Nature*.

Dr Sehgal eventually came into contact with Prof. Yash Pal, a well-known physicist and science communication pioneer, and thus began a golden era for science communication in India when two giants of science and communication came together laying the foundation of a series of programmes and institutions.

Dr Sehgal was instrumental in creation of the National Science Day. In a conversation, he informed that the idea emanated from a letter from a science enthusiast suggesting celebration of "National Scientists' Day". According to Dr Sehgal, after discussions it emerged that instead of a Scientists' Day, there should be a National Science Day with a much broader perspective.

Dr Sehgal was a man of many facets with an excellent sense of humour, humanism, simplicity with analytical approach, minute observation and sharp memory. He had mastery over Hindi and English, was a hard taskmaster and did not appreciate mediocrity. He himself practiced scientific temper, remained upright throughout, and maintained high values and ethics in all walks of his life.

Often, we used to sit together in a small group in the DST office to coin titles for forthcoming books, programmes, slogans, website, etc. We never saw him sad or anxious. He would assign us challenging tasks with a smile, without radiating any tension. It was a great learning experience.

On 24 October 1995, NCSTC organized a countrywide awareness campaign built around the total solar eclipse. We travelled to Akbarpur near Alwar in Rajasthan. Dr Sehgal took his family to Akbarpur to enjoy the spectacular celestial event, but not with him in his official car. When the villagers saw us, hundreds of scientists, researchers, amateurs, teachers and students on top of a hill near Akbarpur village to witness the eclipse, they too ventured out of their houses!

Dr Sehgal planned to have breakfast along with all the participants and experts during the eclipse to debunk the misbelief that one should not eat or take anything during an eclipse. As the climax of the totality was approaching, all of us were excitedly waiting to capture the moment. As I watched through a solar filter, suddenly I found Dr Sehgal's hand on my shoulder. He said, "Don't take it for granted, watching the sun for longer duration even through the solar filters can be harmful."

He authored, edited and coordinated publication of many extraordinary books. He was of the firm opinion said that NCSTC should bring out publications that were not of interest for commercial publishers but important for the people at large. He was also appointed the Chairman of the National Organizing Committee of the Year of Scientific Awareness 2004, after superannuation, which brought out a number of popular science books under his guidance.

Dr Narender K. Sehgal left for his heavenly abode after an ailment, which became known to him only two months before his death. He died on 8 September 2020. He is survived by his wife and daughter.

Dr Sehgal left behind him a great legacy of pioneering and innovative projects and a vision for science communication that needs to be realized in the years to come. He would say, "In India, if you want to spread science over a large area, there is no way that you can do it in English. There is an urgent need for embarking on large-scale translations of Indian scientific content from one Indian language to another."

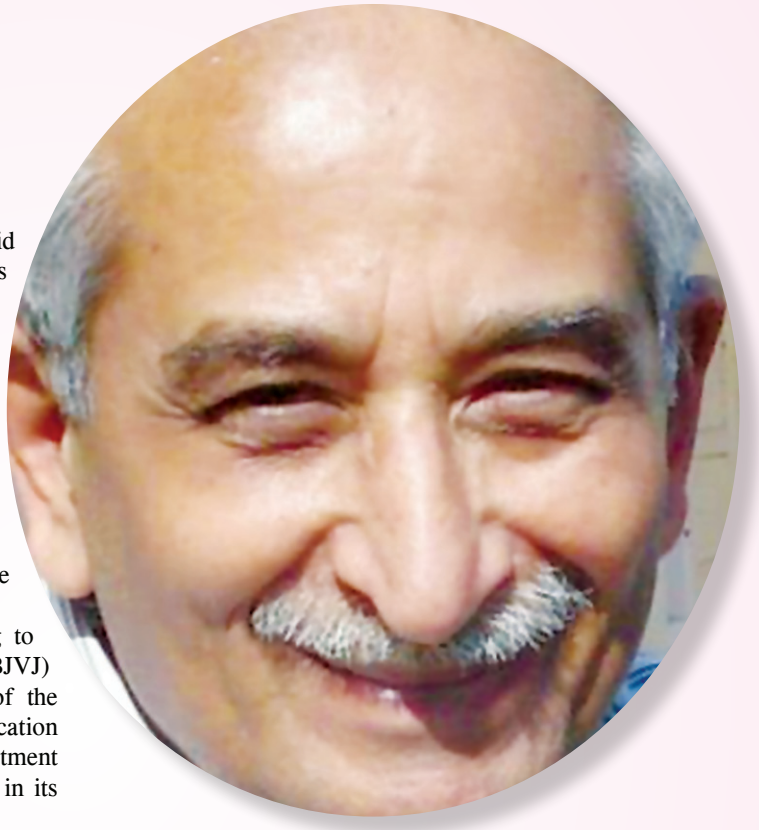
He also said, "I say this in all seriousness, I would like to see NCSTC close down…because when science awareness and scientific temper become the way of daily lives of people and the society adopts it as a cultural affair just like Ram Leela, organizations like NCSTC may not be required."

Dr Manoj Kumar Patairiya is Head & Adviser, National Council for Science & Technology Communication, Dept of Science & Technology, Govt of India, Technology Bhavan, New Mehrauli Road, New Delhi-110016.
Email: manojpatairiya@yahoo.com; mkp@nic.in

Dr Narender K. Sehgal

Proponent of Research in Public Understanding of Science in India

Gauhar Raza



A few days back Er Anuj Sinha rang me up and said "Dr Sehgal is suffering from cancer and is going through treatment." Subsequently, all my efforts to ring him up and enquire about his health were in vain, which was understandable in these difficult periods of COVID pandemic, and then I received the information that he has passed away. It was shocking news for many reasons. First of all, many of his friends and colleagues could not meet him or talk to him when he was passing through the most difficult period, secondly we would have liked to participate in his last rites and thirdly many of us feel helpless because we cannot even organise a meeting in his memory.

I met Dr Sehgal in 1983 when the first meeting to organise the national level Bharat Jan Vigyan Jatha (BJVJ) was held. He was appointed as the first Director of the National Council for Science & Technology Communication (NCSTC), a newly constituted entity under the Department of Science & Technology (DST), and which was still in its infancy.

Under his leadership, NCSTC actively supported efforts of the Delhi Science Forum and the Kerala Sastra Sahitya Parishad (KSSP) to bring more than 40 NGOs on one platform and undertake the biggest science communication project in India. A project which materialised in 1987 and intensely impacted public understanding of science. More than 500 scientists and artists directly communicated science to the public and touched more than 5 crore citizens of the country.

Dr Sehgal did not just act like the head of a funding agency. He was personally involved in implementation of the project since its inception. Finally, it was decided that there would be five processions which would start from five different cities, travel for 40 days, stop in different cities and villages, hold events and culminate at Bhopal. During this period we almost became personal friends and I remember him as a tireless worker.

After the event some of us were grappling with serious theoretical questions such as, is science communication a cultural activity, why certain scientific facts and laws lend themselves to faster communication through cultural methods whereas other tenets of science don't or what is public understanding of science and how can we measure it.

I was at the CSIR-National Institute of Science, Technology & Development Studies (CSIR-NISTADS) where I initiated a project to study public understanding of science and organised a survey at Kumbh Mela. Dr Sehgal was very excited about the study. Getting grants in government is always a tedious process. In almost all subsequent survey studies NCSTC supported us; it was his legacy that continued for 25 years. I will always remain indebted to him for his support.

Without his support, we could not have initiated and sustained research in the area of public understanding of science and come up with the 'cultural distance model of science communication' and challenge the 'deficit model' proposed by the US scholars.

Dr Sehgal not only gave a major boost to science communication activities in the country but also played a vital role in supporting research in the area of public understanding of science. I am sure that the younger generation will recognise his significant contributions. I urge NCSTC and Vigyan Prasar together to institute an award for science communication in his memory.

Mr Gauhar Raza retired as Chief Scientist, CSIR-National Institute of Science Communication and Information Resources (CSIR-NISCAIR), Dr KS Krishnan Marg, New Delhi

BACTERIOPHAGE ENDOLYSINS

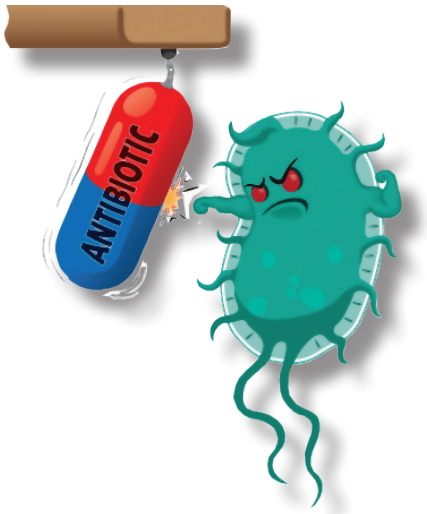
Alternative to Antibiotics

Pallavi Baliga, Malathi Shekar & Girisha Shivani Kallappa

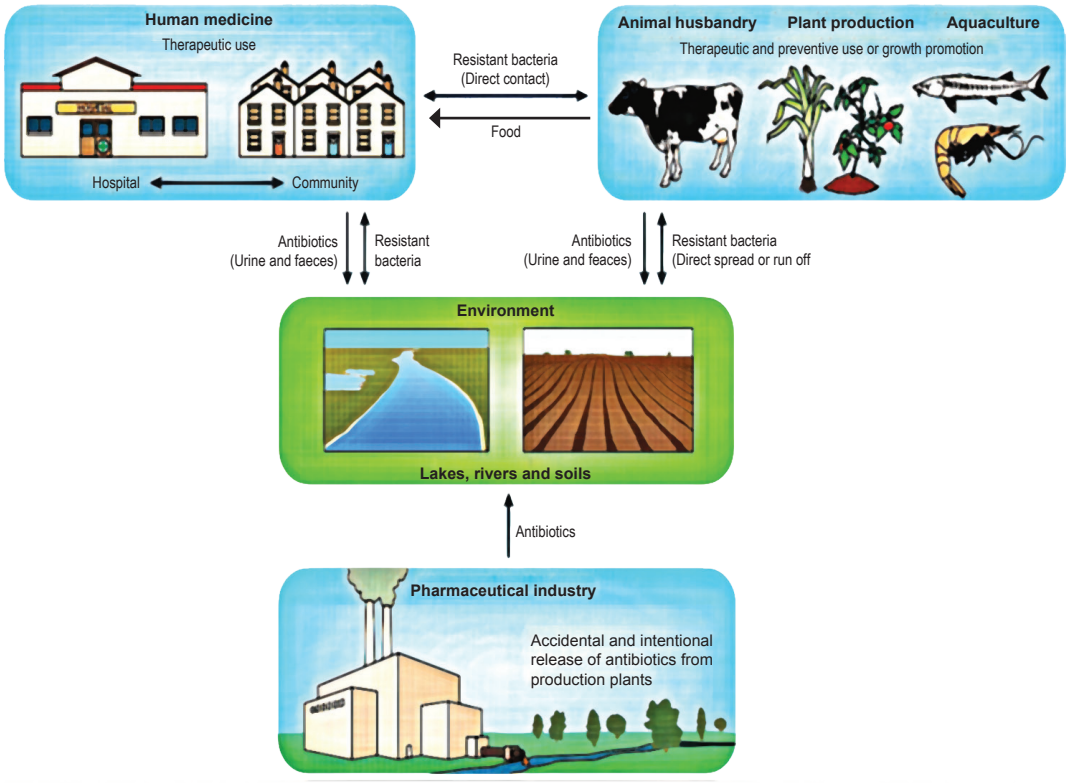
BACTERIAL diseases have been one of the greatest threats to humanity since historical times. Bacteria were responsible for several major epidemics like cholera, typhoid, bubonic plague, etc. which killed millions of people in a short span. With the discovery of antibiotics, humanity finally had a weapon to fight these deadly diseases.

Antibiotics have been prescribed as a primary cure for several decades now in the battle against pathogens in humans as well as in animals. However, as with any good thing, easy and unrestricted access to antibiotics has led to its pervasive misuse. The indiscriminate use of antibiotics has been the major contributor to the global crisis of antibiotic resistance.

Antibiotic resistance occurs when bacteria evolves, rendering the antibiotic ineffective. This evolution comes from modifications or mutations of the bacterial DNA, from the acquisition of foreign antibiotic resistance genes or over-expression of resistance genes. The resulting bacteria are resistant to all available clinical antibiotics and are aptly named "Superbug".



Drug-resistant bacterium (Superbug)
Source: https://www.medlife.com



Spread of antibiotic resistance (Infographic by Andersson, D. I., & Hughes, D. in Nature Reviews Microbiology 2014)

Based on the response to laboratory staining technique, most bacteria are graded as Gram-positive or Gram-negative. Gram-positive bacteria such as Methicillin-resistant *Staphylococcus aureus* (MRSA) which causes skin infections, Vancomycin-resistant *Enterococcus faecium* which causes intestinal and urinary tract infections, *Streptococcus pneumoniae* which causes ear infections and pneumonia are featured on the "priority pathogens" list released by the World Health Organization (WHO).

Gram-negative bacteria are more difficult to treat as they have an outer membrane that shields them from antibacterial agents and molecular pumps which expel any antibacterial agents that do get in. Some of the Carbapenem-resistant Gram-negative pathogens that were included in the list are *Acinetobacter baumannii* associated with fatal lung, blood or wound infections, *Pseudomonas aeruginosa*, which infects people with the weakened immune system and the opportunistic Enterobacteriaceae members that include *Escherichia coli* and *Klebsiella pneumoniae* responsible for deadly hospital-acquired infections of the urinary tract, bloodstream and also pneumonia.

The so-called 'golden age' of antibiotics is set to end with the growing list of antibiotic-resistant bacteria and fewer leads in the pharmaceutical pipeline to fight them. As per expert reports, an increasing trend of treatment failures has been reported worldwide which may lead up to 10 million mortalities annually by 2050; an issue needs to be addressed with the utmost attention.

What are the Alternatives?

Over the years, several alternates such as probiotics, plant extracts, essential oils, immunomodulators, etc. have been tried out. Unfortunately, none have been able to match the efficacy of antibiotics in treating infections. After years of research, the only viable alternates identified are vaccines and bacteriophages.

A vaccine is a biological preparation usually made up of weakened or killed microorganisms or toxins that confer immunity to a particular disease. Bacteriophages are viruses that kill bacteria selectively without destroying the cells of humans or animals. Development of vaccines requires intensive research and a deep understanding of host-pathogen relations. Besides, their impact is not immediate and there are gaps in the protection conferred by the passive and active immune systems that enable pathogens to gain a significant foothold before they can be eliminated.

On the other hand, bacteriophages can lyse host bacteria within a few minutes of administration and release progeny phages that can migrate to sites of infection anywhere in the body and kill the pathogens.

Return of the Bacteriophage

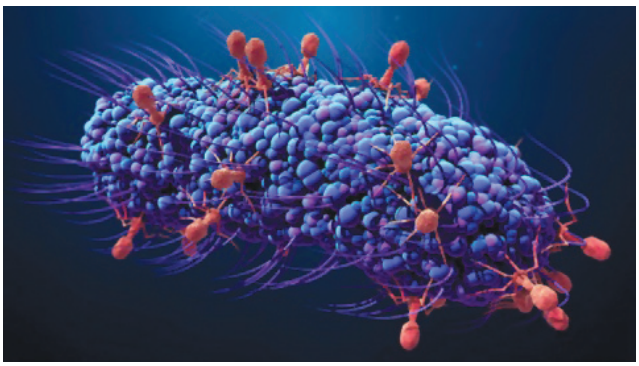
Bacteriophages are the most abundant entities on the biosphere with numbers outcompeting that of their bacterial hosts. These nanoscopic entities are found virtually in every biome on the planet like soil, water bodies, and mucous layers of animals and even in extreme environments like deserts and hot springs. We encounter billions of phages while performing our daily activities like eating, breathing, bathing, drinking and also shed a large number as we live on.

Interest in bacteriophages as anti-infective agents began a century ago, with the discovery of an active lytic agent of bacterial cells in 1921 by Felix d'Herelle a French-Canadian microbiologist. However, the rising popularity of the antibiotics and limited knowledge about the biological nature of phages led to the marginalization of phage research for several decades. With the concerning spike in antibiotic-resistant bacteria, researchers have diverted their attention to phage research again.

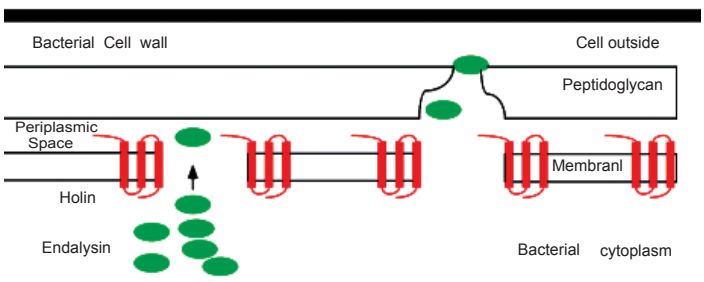
Current bacteriophage research is not only limited to phages but is also based on phage lytic enzymes called "lysins". Popularly called "enzybiotics" or enzyme-based antibacterials, bacteriophage encoded 'endolysins' have shown promising results in fighting bacteria in multiple studies and are considered now as a promising alternative to antibiotics.

Endolysin – Ray of Hope

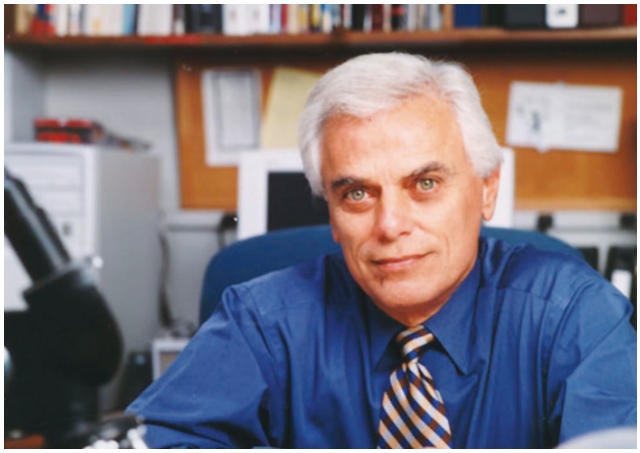
The cell membranes of some bacteria are enveloped by a thick cell wall made up of peptidoglycan, a polymer of sugars and amino acids. The bacterial cell explodes when this layer is compromised. When bacteriophages infect the host bacterium they start replicating. Towards the end of its replication cycle, the bacteriophages secrete lytic enzymes called endolysins which degrade the peptidoglycan and burst the bacterial cell like a balloon to release hundreds of newly formed progeny phages. Small proteins called 'holins' perforate the inner cell membrane of the bacterium, allowing the lysins to reach the cell wall and degrade the peptidoglycan layer.



Bacteriophages preying on a bacterium (*Picture source: Google*)



Mode of Action of Bacteriophage endolysins (Fig. by Francisco Torrens Zaragozá in NEREIS 6 [Marzo 2014], 27-37)



Vincent Fischetti (*Source: Google*)

The term 'endolysin' was coined by Jacob and Fuerst in 1958. They demonstrated that these lytic enzymes formed a part of the lytic machinery of the phage. Endolysins regained popularity in 2001, thanks to the work of Vincent A. Fischetti and his team who were successful in demonstrating the bactericidal effect of the purified endolysin when applied exogenously to a Streptococcal culture.

These enzymes are called "endo" lysins because they induce "lysis from within" the bacterial cell. The lysins are also capable of chewing up the bacteria and destroying the cell wall from outside even in the absence of phages and holins. This is called "lysis from without" meaning the cell lysis is brought about even in the absence of an infecting phage.

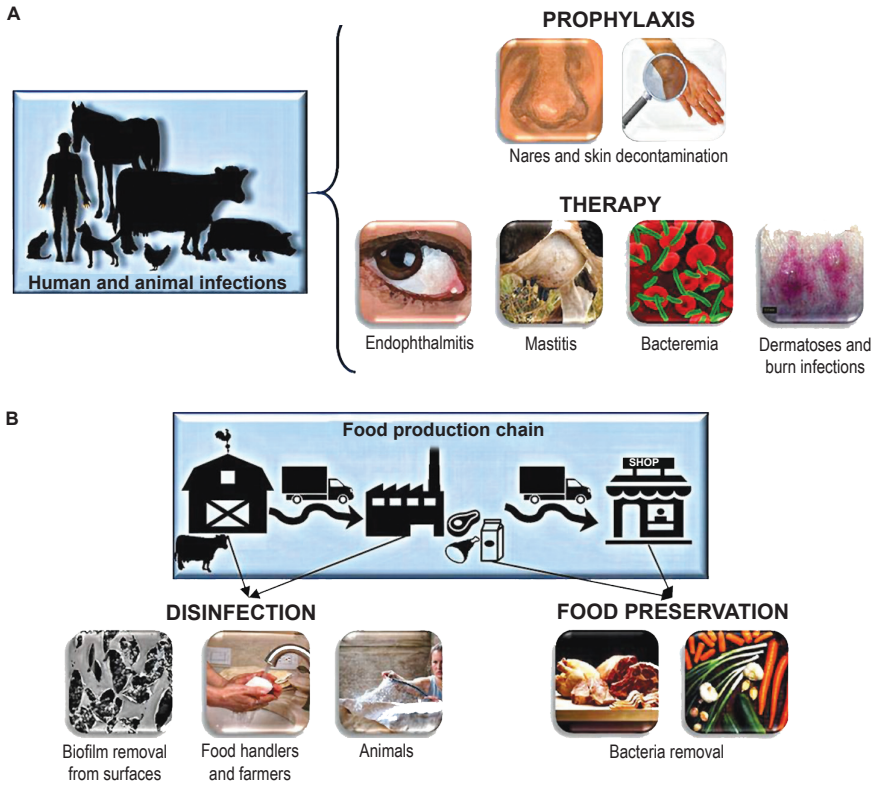
Endolysins are classified into three major types: amidases, peptidases, and lysozymes. Peptidases digest proteins, amidases break amide bonds, and lysozymes break down peptidoglycans.

The lysins have a wider range of action than the phages and therefore can be used to remove infections easily without the risk of developing resistance. These enzymes are specific to the pathogens and have little or no effect on the surrounding microflora as compared to the antibiotics which wipe out the normal flora as well.

Many pathogenic bacteria tend to form biofilms (a microbial assembly on a surface contained within a matrix of primary polysaccharides) which is extremely difficult to eradicate. Due to the impermeability of the matrix, the treatment with standard antibiotics usually fails. Endolysins, however, often result in rapid clearance of bacterial biofilms. Besides, endolysins could also be engineered to possess improved or new properties that provide an opportunity to create even more powerful tools to fight bacteria that are resistant to antibiotics.

Applications of Endolysins

Phage derived endolysins are being used as alternative therapeutic agents in the treatment of bacterial infections with proven benefits such as in the treatment of *Staphylococcal* mastitis (inflammation of mammary gland) in cow, fatal anthrax bacilli *Bacillus anthracis*, equine strangles associated with *Streptococcus equi*, Vancomycin-resistant *Enterococci*, *Clostridium difficile* associated diarrhoea and even the bee pathogen *Paenibacillus larvae*.



Current applications of endolysin in A) Human and animal therapy; B) Food industry. (Infographic by Diana Gutiérrez, Lucía Fernández, Ana Rodríguez, Pilar García in mBio. 2018; 23; 9(1) pii: e01923-17)

Therapeutic efficacy of endolysins against human pathogens like *Streptococcus*, *Staphylococcus*, *Pneumococcus*, and *Bacillus* has been proven in several animal models. Besides, endolysins are very effective as surface disinfectants in medical devices such as operative instruments, prostheses and catheters to prevent bacterial colonization and secondary infections.

Processed foods are vulnerable to contamination by a variety of microbial pathogens such as *Salmonella, Campylobacter, E. coli* and *Listeria* posing a serious threat to consumers. Chemical preservatives used are often associated with long term health risks. A food antimicrobial should be selective in action, should not affect the organoleptic properties or texture of the food and must be safe for human consumption. Phage endolysins satisfy all these criteria and have shown promising results in the control of these pathogens.

Cronobacter sakazakii is a popular contaminant in infant formulas. It can live in desiccated conditions and is immune to most antibiotics. It is a causative agent of the brain and intestinal defects in infected infants. For controlling this pathogen, the use of endolysin has shown promise as an alternative.

Fouling by *Lactobacillus* is a common problem for the brewing industries. Such contaminations alter the organoleptic properties of beverages making them turbid and unpleasant. Expression of lysin in yeasts significantly minimized bacterial fouling, without affecting the physical and sensory properties of the product. Furthermore, endolysin can be used as a preservative for storage of dairy products like yoghurt and cheese.

Phytopathogenic bacteria are a major threat to global food security, resulting in enormous economic losses. Due to the operational challenges of applying enzyme formulations to large agricultural fields, they are not effective in the control of large-scale infections. Suitably altered transgenic plant expressing these lytic enzymes may be more effective in fighting off these infections.

Commercially Available Endolysins

The first 'designer' endolysin was developed by Fritz Eicheseher and Martin Loessner at ETH university (Eidgenössische Technische Hochschule) Zurich (Switzerland) and sold under the tradename Staphefekt™ SA.100™ by Micreos, Bilthoven, The Netherlands. It is used in the treatment of methicillin-resistant *Staphylococcus aureus*.

Staphefekt solution with endolysin as the active component.
(*Photo source: Google*)

GangaGen Biotechnologies Pvt. Ltd, an Indian company founded by Dr J. Ramachandran in 2002, is dedicated to the development of new therapeutic proteins against multidrug-resistant bacteria. GangaGen developed a proprietary lysine called P128 which specifically kills drug-resistant strains such as methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Staphylococcus aureus* (VRSA) and coagulase-negative *Staphylococci* (CoNS).

Exebacase (CF-301), a lysin manufactured by ContraFect, a clinical biotechnology company based in the United States has displayed potent activity against the bacteria *Staphylococcus aureus*. Clinical trials with Exebacase in patients suffering from endocarditis and *S. aureus* infection have demonstrated effectiveness and tolerability.

The Austrian pharmaceutical firm PhagoMed Biopharma GmbH patented a new type of phage endolysin that is highly effective against *Gardnerella* bacteria, a causative agent of bacterial vaginosis.

Current Challenges

Several issues need to be addressed before endolysin application can be fully implemented as a treatment option in the medical field or as a protectant/decontaminant in the food industry. Currently, the use of endolysin in the treatment of gram-negative pathogens is limited. This is because, in the case of gram-negative bacteria, the peptidoglycan layer is sandwiched between the outer membrane and inner membrane, thus denying access to an exogenously added lysin. Nonetheless, combining endolysin treatment with cationic peptides, detergents, and chelators that permeabilize the outer membrane has shown some promising results.

Lysins are non replicating molecules that have a short half-life in the blood plasma. Half-life is the time taken for half of the substance to be removed by the body's natural cleansing actions. Hence, methods to increase their half-life need to be studied.

Endolysins being proteinaceous, can generate an antibody response leading to inactivity. Hence, the efficacy, tolerance and safety of the endolysins at various doses need to be studied both in the laboratory as well as in human clinical trials.

Antibiotic resistance is a complex, multifaceted problem that endangers human and animal health and even threatens the global economy. Endolysins are ideal substitutes for antibiotics. These have also found extensive applications in medical, veterinary, food and farming. Work-based on optimizing parameters to improve endolysin lytic performance, stability and *in vivo* efficiency will hold great promise.

Dr Pallavi Baliga is a Post Doctoral Fellow at the Department of Aquatic Animal Health Management, College of Fisheries, Mangalore-575002, Karnataka. She is working on characterization and cloning of Aeromonas phage endolysins against multidrug-resistant *Aeromonas hydrophila*. Email: Pallavibaliga1@gmail.com

Dr Malathi Shekar is an Assistant Professor at the DBT Bioinformatics Centre, College of Fisheries, Mangalore.

Dr Girisha Shivani Kallappa is an Assistant Professor at the Department of Aquatic Animal Health Management, College of Fisheries, Mangalore.

FEATURE ARTICLE

Hidden Roles of Carbohydrates

Shipra Nagar

CARBOHYDRATES are a source of energy for all living organisms. Glucose is the simplest carbohydrate, produced during photosynthesis by converting sun's light energy into a readily usable product.

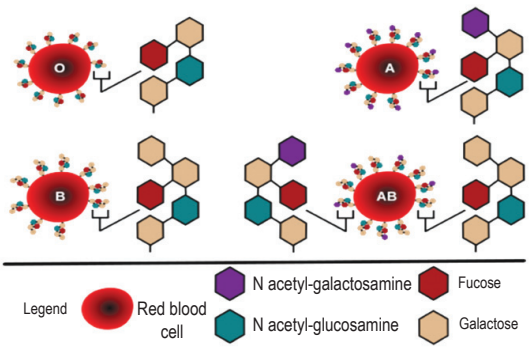
In plants, glucose is stored in the form of starch, cellulose and hemicelluloses, which is then consumed by heterotrophs and stored as glycogen. In animal body, glucose breaks down during cellular respiration to give water, CO_2 and energy in the form of adenosine triphosphate molecules. Intriguingly, apart from their consumption as energy reservoirs, carbohydrates have extended applications in clothing, medicines, vaccines, cosmetics, stabilizers, paint, etc.

There are many roles that Carbohydrates play.

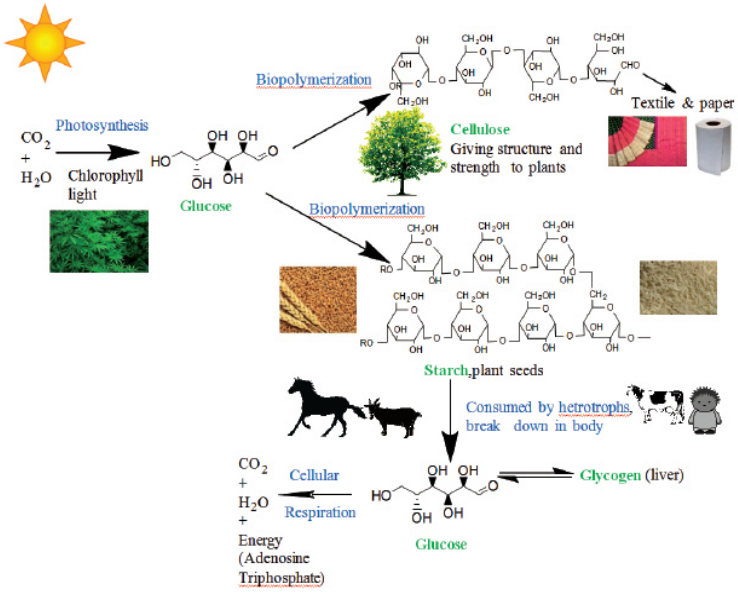
Biological and Pharmaceutical Roles

Determining blood groups

In the human body, the blood group is determined by the type of oligosaccharide chains present on red blood cells (RBC). The RBC surface has budding chains of oligosaccharides all over. This chain starts with glucose attached to the cell surface followed by four sugars in order – galactose, N-acetyl glucosamine, galactose and fucose. When RBC has such oligosaccharide chains, the blood group is called O type. If another monosaccharide N-acetyl galactosamine is attached to this chain, the blood group is A. If monosaccharide is galactose, blood group is B. In case of AB group, RBC contains both the chains.



ABO Blood Group
(*Source: Wikimedia*)



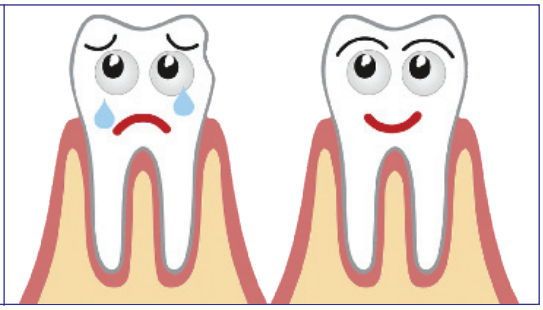
Carbohydrates: Production and utilization

Wide scope of Polysaccharide applications

Carbohydrate Fact 1

How about having sweets without fear of tooth decay?

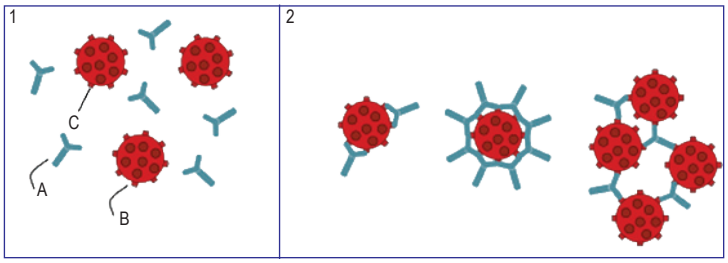
Erythritol, a monosaccharide, found in grapes, pears and watermelon is as sweet as sugar but it neither causes diabetes, nor tooth decay



How do vaccines work?

Carbohydrates are an important component of vaccines against influenza, pneumonia and meningitis, caused by bacteria and virus. These bacteria have a polysaccharide-based capsule around their cell, protecting them against the surrounding environment and inside the host. This capsular polysaccharide segment is called an antigen. Vaccines are nothing but purified form of these capsular polysaccharides.

When these antigens are administered to a person, they are treated as foreign bodies by his or her immune system inducing the development of antibodies against it. Later, when bacteria with the same capsule attack the host, the antibodies already present in the body kill them.



(1) A are antibodies, B are bacteria and C are antigens;
(2) Antibodies A bind with antigens C to capture and kill bacteria
(*Source: Wikimedia*)

Chitin

Another bioactive polysaccharide is Chitin, present in crustaceans, insects and fungal cell wall. It is composed of N-acetyl glucosamine units and has higher strength than starch and cellulose. The acetyl groups of chitin are removed to give another polymer Chitosan, comprised of glucosamine units. Chitosan is used to treat obesity, anaemia, insomnia and high cholesterol levels. It is used in making medical suture (thread in wound stitching), wound dressing, artificial skin and blood vessels. Several polysaccharide-based drugs and formulations are widely employed in Allopathy, Homeopathy and Ayurvedic medicinal systems.

Polysaccharides as artificial sweeteners

Diabetes is becoming a real menace worldwide. And so, more people are opting for artificial sweeteners to reduce the sugar consumption in their diet. Saccharin, aspartame, sucralose and acesulfame potassium are some of the most commonly used artificial sweeteners.

However, although they have been approved as safe by the FDA, their prolonged use may trigger malignancy, gastrointestinal symptoms, hyper-triglyceridaemia, bloating and weight gain. As an alternative, monosaccharides such as erythritol, mannitol and xylitol have emerged as new artificial sweeteners that are far more effective and innocuous.

Erythritol has 65-70% sweetness as sugar. Since it is not absorbed in our body, erythritol acts as a non-caloric food additive and does not affect blood sugar. Further, the oral bacteria *Streptococcus mutans* that decomposes sucrose in our mouth and causes tooth decay, cannot consume erythritol due to structural differences between the two sugars. Hence consumption of erythritol neither raises blood sugar levels nor causes tooth decay. Similarly, xylitol is digested independent of insulin and hence does not alter blood sugar levels.

Carbohydrates as drug carriers

Carbohydrates are also employed as drug carriers or drug delivery systems in our body. Sometimes, the medicines we take have non-polar molecules i.e. they do not dissolve in water or polar media. Since our body has ~65% water content, non-polar medicines inside our body may not solubilize and break down to treat the disease or infection. In such cases, carbohydrates act as drug carriers due to their high water solubility. They carry the drugs with poor water solubility to the targeted body part (e.g. liver, brain, any tumour site), get dissolved in the body fluid and release the drug in the system.

Nutraceutical Role

Nutraceuticals are functional foods with higher nutritional value that are taken as supplements to augment health, for example, anti-oxidants, prebiotics, probiotics, dietary fibres, vitamins, minerals, fortified dairy products, etc.

Prebiotics are a class of non-digestible oligosaccharides that improve digestion in two ways. Firstly, it doesn't get absorbed and hence adds to the bulk in bowel movement. Secondly, the undigested oligosaccharides move to the

Carbohydrate Fact 2

Carboxymethyl cellulose, a product of cellulose gives a smooth and soft texture to ice cream, fondant, margarine, jellies, pie fillings, puddings, confectioneries, etc.

Carbohydrate Fact 3

Common Ayurvedic formulations viz. Aloe vera gel, Giloy satva, Tulsi capsules, Jamun seed powder, Amla Berry, Marichadigutika (Black pepper) contain plant polysaccharides of medicinal significance.

colon where they are degraded by friendly anaerobic gut bacteria (*Bifidobacteria and Lactobacilli*) and thus enhance gastrointestinal health.

The growth of these bacteria also reduces the risk of intestinal infections by suppressing the growth of pathogenic bacteria such as *Clostridium perfringens* and *Escherichia coli*. Commonly used prebiotics are galacto-oligosaccharides, fructo-oligosaccharides, gluco-oligosaccharides, xylo-oligosaccharides, chitosan-oligosaccharides and β-glucan oligosaccharides, obtained from soybean, oatmeal starch, gram husk, barley hulls, wheat bran, almond shells, etc.

Carbohydrate Fact 4

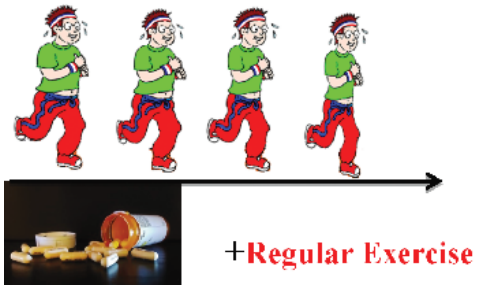
Cellulose and Chitosan are used in fabricating biodegradable plastics, e.g., Cellophane

Carbohydrate Fact 5

Chitosan is added to deodorants and perfumes to make the fragrance last longer

Carbohydrate Fact 6

Chitosan capsules are taken as dietary supplement and also for weight loss.



Carbohydrate Fact 7

Chitin is a polysaccharide that constitutes the hard shells of crabs, exoskeletons and wings of insects.

Role in Food Industry

Carbohydrates are used in food industries not just as calorie reservoirs, but as additives to enhance the quality and shelf life of packaged food products. Polysaccharides are used for thickening, stabilization and preservation of food items. For instance, starch is soluble only in hot water but swells up in cold water. This property of starch enables its application as thickener, water retaining and colloidal gelling ingredient (e.g. corn starch) in soups, sauces, custard, gravies and for producing pasta, noodles and mayonnaise.

Do you know why frozen food (and their dressings) not turn brittle or break out even after long storage periods? While processing frozen foods, modified starch is added to get higher solubility and homogenized texture, which prevents the dressings from weeping and keeps the ingredients bound and intact. Modified starch exhibits high heat resistance and is used as bulking agent, preservative, stabilizer and quality enhancer in baked products, confectioneries and snacks.

Another major carbohydrate is cellulose. Cellulose is the most abundant polysaccharide found in plant cell wall, but it lacks direct applications due to its insolubility in water. However, one of its magic derivatives – Carboxy-methyl-cellulose (CMC) is an excellent additive in the food industry. It is used as thickening and binding agent and enhances the shelf life of a variety of food items viz. cakes, gelatinous desserts, cottage cheese, dressings and toppings, dough, etc. Since CMC is neither digested nor absorbed by the body, it also acts as a laxative.

Other polysaccharides used in food industry as thickening, binding and gelling agents are xanthan gum, guar gum, pullulan, maltodextrin, carrageenan and other cellulose derivatives.

Textile and Paper Industry

One cannot think of cotton clothing and paper without trees. It is the principal structural polysaccharide in plants – Cellulose and its magic derivative CMC – which constitute the backbone of textile and paper industries. For instance, sodium CMC forms a water-soluble film or coating, used for sizing wool, yarn, and laminating fabrics and paper. This coating is also used in making greaseproof paper, commonly known as butter paper, for packaging oily foodstuffs.

Cellophane is another profusely used packing material. It is a thin, transparent sheet of regenerated cellulose with low porosity to water, air and grease, thereby keeping the material intact. Moreover, CMC, when treated with epichlorohydrin, gives a highly viscous product that is used in lubricants, printing inks and fabric colours for dying denim, cotton, cellulose wool, linen cotton, artificial silk and mixed fabrics.

In paper industry, sodium CMC is added to pulp to increase the tensile strength, flexibility, tear-resistance and ink penetration properties of paper.

Chitosan is another carbohydrate candidate that is becoming popular in textile and paper industries. It is used as binder and thickener in printing inks and its derivatives (chitosan–guanidine, chitosan-cellulose) extend their

application as paper coating and providing a paper of higher wet strength, antibacterial and grease barrier properties.

Chitosan is also used in producing textile fibre, sizing and desizing yarn and dyeing cotton, polyester, rayon, nylon, wool and silk.

In Chemical Laboratories

Cellulose plays a vital role in separation techniques. Filter papers used in laboratories (e.g. Whatmanfilter papers) are 98% cellulose. Depending upon the polarity (hydrophilic or hydrophobic) of solution and nature of solute, different varieties of filter papers like cellulose acetate, cellulose nitrate, mixed cellulose ester, regenerated cellulose, cellulose-EDTA (Ethylene Diamine Tetra Acetic acid) can be used. Cellulose-based filter papers are biodegradable, biocompatible and non-toxic and hence are permitted in food (e.g. tea bags and coffee filters) and pharmaceutical industries.

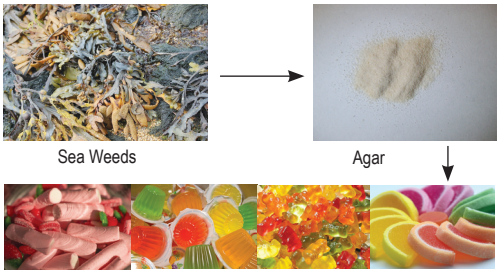
Apart from filtration, cellulose-based labwares include absorbent papers, blotting papers, chromatography papers, extraction thimbles, extraction cartridges, cellulose crucibles, ion exchange resin paper etc. employed for particle separation, spectrophotometry, chromatography, microbiological analyses, heavy metal remediation, etc.

Carbohydrate Fact 8

Polysaccharides obtained from red, brown and green algae are used in sunscreen lotions, skincare gels, fairness cream and anti-ageing serums.

Carbohydrate Fact 9

Agar-agar, extracted from seaweeds, is very popular for its gelling abilities and widely used in making jellies, candies, marshmallows, etc. It is a 100% vegetarian substitute to gelatin, derived from collagen protein extracted from animal body parts.



Carbohydrate Fact 10

Agar-agar, extracted from seaweeds, is very popular for its gelling abilities and widely used in making jellies, candies, marshmallows, etc. It is a 100% vegetarian substitute to gelatin, derived from collagen protein extracted from animal body parts.

Cosmetics and Household Items

Most of the household products we use are colloidal solutions, broadly oil-water emulsions (e.g. cream, shampoo, toothpaste, paints, ointments, handwash, etc.). Since oil and water are immiscible liquids, the two layers separate out when the mixture is kept undisturbed. The main role of polysaccharides is to stabilize this emulsion and prevent suspension of the two layers, thereby enhancing the durability and shelf life of the products.

Gum arabic, corn fibre gum and beet pectin are used as emulsifying agents in skin hydrating moisturizers. CMC is used as binder, emulsifier and viscosity controlling agent in toothpaste, laundry detergents, water-based paints, hand cream, moisturizers, shampoo, soaps, hand lotions, face wash etc. Similarly, chitosan owing to its humectant, emulsifying and cationic properties, is used in hair conditioners, hydrating and anti-ageing face masks, hair tonic, deodorants, mouthwash, perfumes, etc.

Polysaccharides obtained from red, brown and green algae exhibit anti-wrinkle, skin-whitening, UV protective, anti-inflammatory, and anti-allergic properties and are used in skincare cosmetics.

The huge spectrum of diverse applications of carbohydrates from food additives, vaccines, paper to clothing and cosmetics is enough to convince us that carbohydrates are playing an indispensable role in our daily lives rather than being just energy reservoirs. Though numerous bioactive and functional polysaccharides have been identified from various sources (plants, animals, microbes) and their products with diversified applications have been commercialized, there is still a vast pool of biotic sources from distinct environments (Antarctica, Arctic, marine algae and phytoplankton, hydrothermal vents, benthic flora and fauna, etc.) which is still unexplored and can be investigated further for the benefit of mankind.

Acknowledgments

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Email: shipranagar@ncpor.res.in, shhipranagar@gmail.com

FEATURE ARTICLE

Behind the Label

Aditi Ghose

Food labels, even with hundreds of regulated stipulations, can be misleading. On the occasion of the World Food Day on October 16th and also 200 years of official detection of food adulteration, here's an article that prods you to read behind the labels.

ARE you nuts? A chicken, broccoli or simply a vegetable perhaps? After all, you really are what you eat. Sixty per cent of you is plain water. Then comes protein – 19%, concentrated in your muscles. Fats of your adipose tissue, hidden under your skin – that's 17% of you. Next the sweet stuff – carbohydrates, 3% – as glycogen in liver and glucose in the blood. About a kilogram of minerals – mostly calcium and potassium, some iron, among few others.

Not finished yet. Leave out the vitamins and you are a dead person – they are essential to your survival, yet you cannot make them on your own. On top of that, you are never the same person that you were last year – quite literally. You shed about two and a half kilogram of skin every year. Every four or six weeks, the outer layer of your skin is completely renewed – all the dust floating around in your house, most of it used to be you.

Your gut lining gets replaced every two days, the chemicals making up the brain cells get replaced about once a year. Where do you think the raw-material for this daily upgradation comes from? You guessed it right – it comes off your spoons, glasses, bowls and plates – food. Makes sense to look behind the labels of items you purchase off the supermarket shelves.

The practice goes long back and you may have chemist Frederick Accum and medic Arthur Hill Hassall, among others, to thank for introducing quality control of the food and drinks industry today. Until 1875, you could have been served alum and chalk to whiten your bread, mashed potatoes, plaster of Paris, pipe clay and sawdust to increase the weight of your loaf, rye flour and powdered beans in place of wheat. Think you would have tasted the sour taste of stale flour?

The food adulteration business would have been one step ahead – they would have added ammonium carbonate to disguise the tell-tale signs. In fact, having been served loads of such adulterants, by the beginning of the 19th century, people had started preferring their tastes over the original ones! It took the chemical analyst, consultant and teacher of chemistry, Frederick Accum, to raise the alarm.

Mineral or natural, 200 years ago, before the 1820s, there were no reliable tests for identifying food impurities and hence the rampant business of malice. But Accum developed methods to analyse and identify commonly mixed adulterants in food – much like you would use to identify unknown samples in the laboratory today.

In his 1820 release, '*A Treatise on Adulterations of Food and Culinary Poisons*' Accum exposed the nature, extent and dangers of food adulteration. The cover used the dramatic imagery of a spider's web surrounded by intertwined snakes. A spider lurks in mid-web over its prey, while a skull crowns the collection – imagery repeated again on the title page,

Table 1: Some adulterants identified by Accum (1820)

Food	Adulterant
Red cheese	Coloured with red lead (Pb3O4), and vermilion (mercury sulphide, HgS)
Cayenne pepper	Coloured with red lead
Pickles	Coloured green by copper salts
Vinegar	'Sharpened' with sulphuric acid; often contained tin and lead dissolved when boiled in pewter vessels
Confectionery	White comfits often included Cornish clay
	Red sweets were coloured with vermilion and red lead
	Green sweets often contained copper salts (eg verdigris: basic copper acetate) and Scheele's or emerald green (copper arsenite)
Olive oil	Often contained lead from the presses

Table 2: Analysis of common adulterants

Observation	Presence indicated
Black precipitate with hydrogen sulphide	Lead and copper salts
Deep blue colour with ammonium hydroxide solution	Copper
White precipitate upon reaction with barium chloride solution	Sulphates
Blue colour in dilute iodine solution in aqueous potassium iodide	Starch, used to thicken cream
Deep blue precipitate with lead acetate	Juice of bilberries or elderberries, used to adulterate red wine

captioned 'There is death in the pot', quoted from the Old Testament (II Kings chap 4, verse 40).

Accum was determined: "The man who robs a fellow subject of a few shillings on the highway is sentenced to death," he wrote in the Preface, but "he who distributes a slow poison to the whole community escapes unpunished". With the first edition being sold out within a month in the UK, a US edition was published the same year with a German translation in 1822.

Arthur Hill Hassall, a London-based physician first observed samples under the microscope – thus quantifying the adulterant and later analyzing them with chemical tests as necessary. Ignored as analytical tools before, microscopes now were the probes of choice, helping identify foreign vegetable matter, living or dead insects, minute traces of adulterants, and crystals of foreign organic matter for which no chemical tests were available. Hassall's investigations showed that adulteration was the rule, rather than the exception and eventually led up to the governmental control of adulteration and appointment of public analysts ensuring labelling standards.

Today, we depend on high-performance liquid chromatography, solid-phase microextraction gas chromatography, mass spectrometry, time of flight mass spectrometry, Raman spectroscopy near-infrared spectroscopy, fluorescence, nuclear magnetic resonance, and inductively coupled plasma optical emission spectroscopy to detect the food adulterants present in common food items. To speed up matters we even resort to electronic sensors, a combination of voltammetric e-tongue and e-nose based on metal oxide semiconductor sensors and pattern recognition techniques to detect adulteration. Manufacturers have to comply with international food labelling standards such as the Codex Alimentarius Commission, which empower the consumer to make healthy food choices.

Treating food labels as effective instruments against the prevalence of diet-related non-communicable diseases, the Codex standards stipulate Nutrient Declaration, Nutrient Reference Values, Quantitative Declaration on Ingredients (QUID), Nutrition Claims and Health Claims on food labels.

Front cover and title page of Frederick Accum's '*A Treatise on Adulterations of Food and Culinary Poisons*', 1820

As we continue to move away from traditional face-to-face food producer and buyer relationships, food labels help to convey the necessary information about the product's identity and contents, and on how to handle, prepare and consume it safely.

But labels, even with hundreds of regulated stipulations, can be misleading. An ingredient list on a food product breaks down the food into the macronutrients in terms of energy and the micronutrients in terms of quantity. Processing operations and preservation methods require additional aids, that add up to the ingredient list. Overall, it can leave the consumer frazzled, ultimately deciding to ditch the 'processed food' all together.

Have a go at the following 'mystery' label. See if you can infer the exact item that carries this label from its nutrient information. Which aisle do you expect it to be sitting at in the super-market? Do you think it is a vegetarian or non-vegetarian product? Would you have preferred it over a product that lists maybe five ingredients only in its list?

Table 3: Other adulterants found by Hassall (1851-54)

Product	Adulterants for bulk and weight	Adulterants for colour, taste and smell
Custard powders	Wheat, potato and rice flour	Lead chromate, turmeric to enhance the yellow colour
Coffee	Chicory, roasted wheat, rye and potato flour, roasted beans, acorns etc	Burnt sugar (blackjack) as a darkener
Tea	Used tea leaves, dried leaves of other plants, starch, sand china clay, French chalk	Plumbago, gum, indigo, Prussian blue for black tea, turmeric, Chinese yellow, copper salts for green tea
Cocoa and chocolate	Arrowroot, wheat, Indian corn, sago, potato, tapioca flour, chicory	Venetian red, red ochre, iron compounds
Cayenne pepper	Ground rice, mustard seed husks, sawdust, salt	Red lead, vermilion, Venetian red, turmeric
Pickles		Copper salts for greening
Gin	Water	Cayenne, cassia, cinnamon, sugar, alum, salt of tartar (potassium tartrate)
Porter & stout	Water	Brown sugar, Cocculus indicus, copperas, salt, capsicum, ginger, wormwood, coriander and caraway seeds, liquorice, honey, Nux vomica, cream of tartar, hartshorn shavings,

Table 4: Sugar with its 61 Aliases

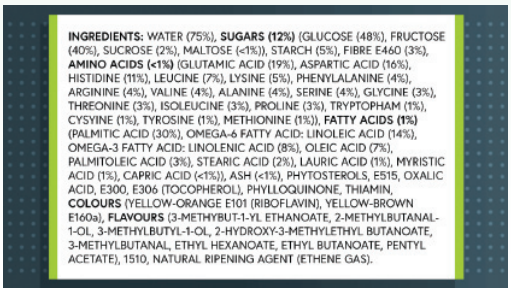
Agave nectar Barbados sugar Barley malt Barley malt syrup Beet sugar Brown sugar Buttered syrup Cane juice Cane juice crystals Cane sugar Caramel Carob syrup Castor sugar	Coconut palm sugar Coconut sugar Confectioner's sugar Corn sweetener Corn syrup Corn syrup solids Date sugar Dehydrated cane juice Demerara sugar Dextrin Dextrose	Evaporated cane juice Free-flowing brown sugars Fructose Fruit juice Fruit juice concentrate Glucose Glucose solids Golden sugar Golden syrup Grape sugar	HFCS (High-Fructose Corn Syrup) Honey Icing sugar Invert sugar Malt syrup Maltodextrin Maltol Maltose Mannose Maple syrup Molasses Muscovado Palm sugar Panocha Powdered sugar	Raw sugar Refiner's syrup Rice syrup Saccharose Sorghum Syrup Sucrose Sugar (granulated) Sweet Sorghum Syrup Treacle Turbinado sugar Yellow sugar

Table 5: Looking out for Allergens on Food Labels

Allergen	Terms to look out for		Foods to look out for	
Egg	Albumin, Binder, Coagulant, Emulsifer, Globulin/ovaglobulin, Lecithin, Livetin	Lysozyme, Ovalbumin, Ovomucin Ovomucoid, Ovovitellin, Vitellin, Simplesse	Baked goods and packaged mixes, Creamy fillings and sauces Breakfast cereals, Malted drinks and mixes, Pancakes and waffles, Marzipan, Custard	Marshmallows, Processed meat products, Pastas/egg noodles, Salad, dressings/mayonnaise, Soups, Meringue, Pudding
Milk	Caramel colour or flavoring, High protein flavor, Lactalbumin/lactalbumin phosphate, Lactoglobulin	Lactose, Natural flavouring, Solids, Simplesse	Battered foods, Baked goods and mixes, Breakfast cereals, Chocolate, Cream sauces, soups and mixes, Gravies and mixes, Ghee	Custard, puddings, sherbet, Imitation sour cream, Instant mashed potatoes, Margarine Sausages, Sweets/candies
Wheat	Flour: bleached, unbleached, white, whole wheat, all-purpose, enriched, graham, durum, high gluten, high protein, Cornstarch, Farina, Semolina, Hydrolyzed vegetable protein, Modified food starch Miso,	MSG (monosodium glutamate), Vegetable starch/gum, Gelatinized starch, Spelt, Kamut, Triticale, Malt,	Ale/beer/wine/bourbon/whiskey, Baked goods and mixes—including barley products, Battered or breaded foods, Breakfast cereals, Candy/chocolate, Processed meats, Coffee substitutes	Gravy, Ice cream and cones, Malts and flavorings, Pasta/egg noodles, Soup and soup mixes, Soy sauce, Pretzels, chips, crackers
Soy	Bulking agent, Carob, Hydrolyzed vegetable protein, (HVP)/ Hydrolyzed soy protein, Lecithin, Artificial and natural, flavoring, Bulking agent,	Miso, Monosodium glutamate (MSG), Protein, Starch, Textured vegetable protein (TVP), Vegetable broth/gum/starch	Baked goods, Some breakfast cereals, Hamburger patties, Butter substitutes/shortening, Chocolates/candy, Canned meat/fish in sauces, Canned/packaged soups, Canned tuna, Crackers, Gravies/mixes,	Asian foods, Processed meats Ice cream, Liquid/powdered meal replacers, Seasoning sauces, Seasoned salt, Snack bars, Bouillon cubes, TV dinners, Tamari
Tree	Peanut,	Groundnut	Baked goods/mixes,	Chili, Soups, Marzipan,
Nuts	Peanut butter, Groundnut	flavouring, Groundnut extract, Oriental sauce	Battered foods, Some breakfast cereals, Cereal-based products, Candy/candy bars/sweets (read label), Ice cream, Margarine/vegetable oil/vegetable fat, Some grain breads, Snack foods, Barbecue/Worcestershire sauce, Sunflower seed	Satay sauce, Milk formula, Chinese dishes/egg roll Asian dishes (e.g., Thai/ Indonesian), African dishes, Energy bars, Meat substitutes

Table 6: Allergens in seafood and shellfish

Allergen	Foods to look out for	
Fish/Seafood proteins	Worcestershire/steak sauce, Caesar salad dressing, Hot dogs/ bologna/ham, Pizza toppings, Fish sauce, Fish stock	Surimi, Caponata, Marinara sauce, Vitamin supplements (read label), Curry paste
Shellfish	Worcestershire/steak sauce, Caesar salad dressing, Hot dogs/ bologna/ham, Pizza toppings, Fish sauce, Shrimp paste, Fermented oyster sauce	Surimi, Caponata, Marinara sauce, Vitamin supplements (read label), Curry paste, Chitin or chitosan, Fermented fish stomach Fish stock,



The product listed here is a humble banana. Look closer and you will find that all the listed ingredients are naturally occurring. Water and carbohydrates make up 95% of the product – but you already knew it because you add it to your healthy smoothies and ice-creams. The fibre slows down sugar absorption – the main one being glucose here and the starch adds bulk and texture. The remaining 5% consists of protein-building amino acids, fatty acids for energy storage and cell-structure and essential fatty acids like linolenic and linoleic acids that we do not produce on our own. The rest of the ingredients are there more for the banana plant's benefit than your own. The colours from riboflavin, the aroma from the ester molecules help the plant attract insects for pollination. The ethane or ethylene gas is produced by the banana itself to ripen the fruit. Bananas are rich sources of potassium, magnesium, vitamin B6 and vitamin B12 micronutrients – but those are not revealed here.

Talking about revealing – did you know that over three-quarters of items in a typical grocery store are hiding sugar in plain sight? Added to savoury foods like sauces, breads, salad and pasta dressings or 'healthy' items like yoghurt and energy bars, sugar is known by many aliases – 61 to be precise. So, sans any 'added sugars', the diet-cola label may be made to look like the next best thing to plain water. Combining several different types of sugar in a single product makes their individual contributions look small.

Packaging apparently non-sweet foods like breakfast cereals is too easy because you will hardly be expecting to find them there. Replacing processed sugar with unrefined sugars hardly makes them healthier, but more often than not, are tagged 'diet', 'natural' and even 'healthy'. Lowering portion sizes, adding a 'low sugar variant' or lumping natural and added sugars of food items together are some other tips of the trade. Clearly, looking behind the label is your safest bet.

Aliases are particularly dangerous if you suffer food intolerances, allergies or sensitivities. Most people's bodies consider eggs, milk, wheat, soy, nuts, shellfish or seafood as offending and react adversely. What adds to the trouble is that they can easily get lost in the list of ingredients, particularly more if you are looking specifically for them. Looking for the aliases or avoiding foods with the highest probability of containing the items is thus the safest way out.

So, with a little practice, you might be able to read behind the ingredient list. But you still need to interpret it. Your body is a living record of not only all the food you eat but also all the exercises you do. You see, all our bodies have evolved to absorb and store excess fat and sugar – perhaps because they used to be scarce and yet essential for energy generation. We had to be capable of extracting and storing nutrients efficiently from food.

So, pound for pound, a large cabbage contains as much energy as a few chips – but given the choice, we tend to be drawn to the fatty, sugary, energy-rich foods and that leaves its mark on our bodies. Look behind a chips packet and the label specifies 544 kcal (2276.1 kjoules) per 100 grams of the product. Your body combines oxygen with the chips to release that much amount of energy. Is that too much?

Sitting idle, you keep spending energy on running your digestive system, breathing, keeping your brain active and keeping yourself warm. You spend as much energy as used in lighting a 60W light bulb – 60 joules per second. So, while sitting down, it would take you more than 10 hours to burn off the energy you get from a large packet of chips. Exercising – light, moderate or strenuous – helps you burn off more. As a captain of the rowing team, rowing as hard as you can, you would have burned off 16 times more energy than by sitting idle. Even then, it would have taken you about 38 minutes to have expended your precious chips pack energy stock. Here lies the importance of the delicate balance between dietary intake and energy usage – interpretation of the ingredients label could play a key factor here.

Today, on average, we are 10 centimetres taller than we would have been a century ago. That's a lot. The mean height of soldiers in the Boer War, about 150 years ago was 163 centimetres. This 5 feet 4 inches tall fully grown man would be shorter than an average teenage boy today. Childhood illness, parasite, the contributing factors can be many, but they mainly attribute to better nutrition – in quality and quantity.

Food is so important, we officially celebrate it on 16 October every year as World Food Day, mainly commemorating the founding of the Food & Agriculture Organization of the United Nations in 1945. But something that is so ubiquitous in each of our lives deserves everyday attention. So, the next time you pick up products from the shelves, remember to read behind the label – it could make you 'nuts' or even prevent you from becoming a 'vegetable'!

Dr Aditi Ghose is an Education Officer at Birla Industrial & Technological Museum, Kolkata and enjoys communicating science in all its forms. Address: 74/C, S.N. Banerjee Road, Floor-2, Flat-7, Kolkata-700014. Email: aditincsm@gmail.com

In Search of Wealth from Waste

Subrato Ghosh

THE openly-flowing sheet of stinky black water in Kolkata city in West Bengal is a matter of extreme dislike for people. But the dirty water is the lifeline of two communities – the fish farmers beyond the eastern fringes of Kolkata who depend upon domestic sewage of Dry Weather Flow channel as a source of nutrients to sustain plankton production in fish ponds/wetlands and the semi-poor city people or slum dwellers, who harvest the Oligochaeta worms *Tubifex tubifex* as a means of livelihood from a stretch of foul and derelict waterway termed the Adi Ganga.

The Adi Ganga is a course of river Hooghly/Bhagirathi in Kolkata city. It is a 15.5 km stretch of canal from Hastings to Rajpur on the outskirts of Kolkata and appears for much of its length like a flowing sheet of wastewater. Several settlements of mostly poor people and cowsheds are established on both banks of its entire stretch; temporary toilets open directly into the water of Adi Ganga. Sewage-fed Adi Ganga water becomes enriched with organic matter, favouring the natural production of tubifex worms on the stretch of quiet muddy land on both banks left uncovered during the ebb tide and in the bottom sediment. The tubifex worms provide a livelihood opportunity to poorer local people.

Apart from being one of the most favourite foods of aquarium fishes, tubifex is also crucial as live food for early stages of hatchery-produced economically-important catfishes. In the production of fry stages of *Pangasianodon hypophthalmus*, minced tubifex worms are used as feed every day @ 3kg/1320 sq m pond in addition to powdered milk suspension and liquefied mixture of groundnut oilcake, dust shrimp feed and Agri-Min feed supplement from 1st till 10th day after stocking *P. hypophthalmus* spawn in earthen nurseries (as per fish breeder Shri Babul Majumdar: personal communication).

In hatchery conditions, finely-chopped tubifex is supplied from the 7th day onwards to the young ones of *Ompak pabda*, twice in a day about 25% of the bodyweight of spawn up to 15 days (Chakrabarti *et al.*, 2012). In addition to zooplankton, chopped tubifex filtered through nylon net, adequately washed in freshwater and disinfected with Didecyl dimethyl NH_4Cl has been fed to larvae of *Clarias batrachus*; the fry stages (during 15th-45th day) strongly prefer whole tubifex worm and showed best growth and survivability among other feeds used. Better growth from tubifex may be attributed to higher crude protein content (65%) in comparison to other feeds (Sinha *et al.*, 2014).

Md Dastagir Alam (aged 48) and his nephew Mr Sonu Ahmed, residents of No. 3 Canal Road, have been involved in this profession of collecting, gathering and selling tubifex worms on a commercial basis since 2003-2004. Everyday Alam works for 3.5-4 hours normally from 10.00 am till 2.00 pm during ebb tide covering a distance of 150-200 m, walking uneasily through foul muddy conditions and collecting palm-full of thick soft mud from undisturbed exposed banks of Adi Ganga by scratching over it with fingers. Sediment material lying at 15-18 cm depth beneath water column is also collected in the right palm.

Mud collection

Sample of tubifex worms at Shri Alam's home

After collecting 12-15 kg each time in fine-meshed nylon net, the entire material is sieved in the Adi Ganga water at 0.45-0.60 m depth. Clay particles and muck are cleaned and filtered out and tubifex worms in association with silt particles (or detritus) retained inside the net. This semi-solid detritus-type material, weighing 1.0-1.5 kg is kept in large durable translucent plastic packets. The practice of mud collection and sieving is continued many times at different locations and 60-70 kg of material is accumulated in plastic containers. The process of cleaning several kilograms of muck and working in dirty water in the hope of finding tubifex worms is tedious.

After collection, the entire wet semi-solid silt material is brought home and evenly spread in a 1.2 m x 0.9 m chamber (temporarily constructed with bricks) over a plastic sheet laid

Sieving the material

Tubifex meant to be minced

Tubifex worms in ornamental fish farm

at the bottom. Tubewell water is added to it and water level maintained up to 12-15 cm. A large squarish floating frame made of mosquito net cloth is placed over the spread mass and finally, the entire structure is covered with two sheets of old flex material such that the inner surface of flex does not come in contact with the net frame. Within the next one hour, in the complete absence of light and when the temperature at the bottom starts rising, tubifex worms leave the silt/sediment material, start surfacing and reach the surface.

Shri Alam then collects the mass of tubifex, washes 2-3 times with clean water to remove residual mud and packs it in 500 gm glass bottles; each such bottle-full of tubifex is sold to aquarium shops for Rs 16-18/-. Tubifex is also transported to buyers in plastic containers; 3 lit clean water is added to every 6 kg tubifex. Some professional ornamental fish farmers in Amtala region of South 24 Pgs procure tubifex worms of Adi Ganga @ Rs 25/tea-cup full mass, says ornamental fish farmer Shri Tapan Mondal.

The practice of tubifex collection from Adi Ganga has suffered a setback. Initially, 30-40 slum inhabitants in the region between Hastings and Alipore (700-750 m) were involved in it but today it has come down to 5-6 persons. The demand for tubifex in aquarium shops has reduced because the ornamental fish food and market price has reduced. Protein-rich dry granule-type feed brought into the market by Chinese ornamental fish food manufacturers are preferred by aquarium shop owners over tubifex worms. Tiny dough balls made of wheat flour heated in frying pan, dry wheat flour in baked/heated form or pieces of half-cooked chapati roti (flat round bread comprising wheat flour, salt and water cooked on griddle) are also being fed to red molly and other live bearers and goldfish under culture, Shri Alam stated.

Collection of tubifex worms from sewage-laden waters of Adi Ganga involves high risk of skin infection. Broken small pieces of glass, shaving blades, tin sheet, discarded injection syringe, stitching needles, fountain pen nibs are components of rubbish dumped on the banks of Adi Ganga, which may inflict painful bruises and wounds while walking barefoot through the foul muddy waters.

Scientists of ICAR-CIFA have developed production systems of cultured tubifex in captivity (Chakrabarti *et al.*, 2012; Mandal *et al.*, 2018), which will serve as its source of supply in addition to that exploited by skilled persons from the natural repository, namely, Adi Ganga.

Dr Subrato Ghosh, 122/1V, Monohar Pukur Road, P.O. Kalighat, Kolkata-700026, West Bengal. Email: subratoffa@gmail.com; subratoghosh2007@rediffmail.com

Improve Sleep Quality – Pick the Right Pillow!

Shuborno Das

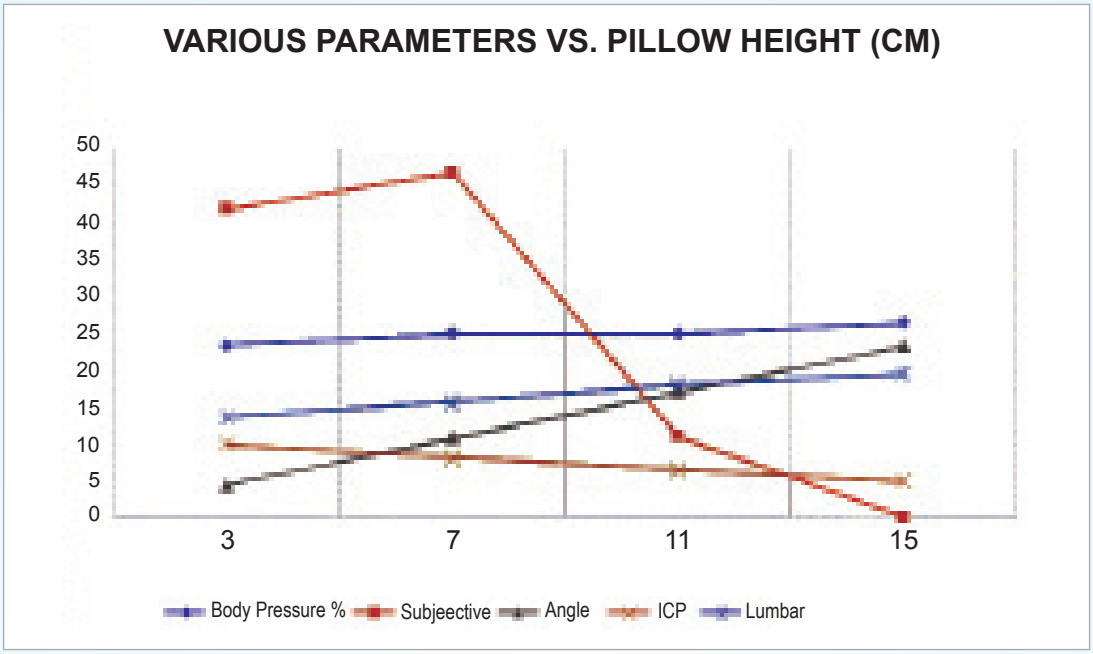


Fig. 1. Body Pressure, Subjective, Cervical Angle, CSF as a function of the Pillow Height

We can see that lumbar pressure increases while intracranial pressure decreases as the height of pillow increases. Subjective experience is poor at low and high pillow heights, being optimal around 7 cm. Body pressure does not change significantly with a change in pillow height. Keeping all these factors in consideration, I concluded that a pillow height between 3 to 7 cm would be best for sleep.

MOST of us think that the main function of sleep is to relax our tired body. But there is one very important process which is often not discussed. Our brain can clear out all the harmful accumulated toxins through secretion, absorption and flow of a fluid called Cerebrospinal Fluid (CSF) during sleep. This is the same fluid that surrounds and cushions the brain and the spinal cord.

Though this cleansing process occurs all the time, yet during the day it is observed to be almost negligible. This is because the brain cannot simultaneously clean itself and be aware of the surroundings during the daytime. So, it is only during sleep, that our brain can cleanse itself properly. If we can think of making this cleaning process more efficient, we can improve the quality of sleep. But how do we ensure that?

For the cerebrospinal fluid to be more efficient in cleaning the accumulated toxins, it is extremely important to maintain optimal pressure. Various studies have shown that the absorption of toxins slows down drastically if CSF pressure goes below 6.8 cm of water. In fact, for an adult, the optimal value of CSF pressure is between 9 cm of water and 18 cm of water. But how do we control this pressure through external means?

High school physics has taught us fluid pressure and how its flow varies with height. Can there be any external height gradient that can similarly affect the CSF pressure inside our brain and lumbar (spinal) regions? Could it be our sleeping pillow?

Pillow height can impact the pressure exerted on the various body parts like head, neck, chest, waist and the hip while at sleep. CSF pressure varies with the inclination of our body to the horizontal. This gave me an idea to connect all these previous studies to get a relationship between CSF pressures as a function of pillow height.

I used the data obtained from earlier studies and extrapolated it using Lagrange Interpolation Polynomial. I found that the angle of body inclination must lie between 0^{o} to 7.6^{o} for CSF pressure of an adult to lie between 9 cm to 18 cm of water.

To determine the optimal pillow height, I then plotted body pressure, subjective experience, cervical angle, intracranial (brain) pressure of CSF and lumbar pressure of CSF as a function of pillow height (Fig. 1).

So, buy a proper pillow! You may just be surprised to see your performance go up a notch as a result.

Contributed by Shuborno Das, 11th Std student at Ryan Global, Kundalahalli, Bangalore. Address: 202 Dream Meadows, Brookefields, Kundalahalli, Bangalore-560037.
Email: shuborno2107@gmail.com

A New Device — Error-correcting Cat

PHYSICISTS at Yale University, New Haven, Connecticut, have developed a new device called an error-correcting cat. This newly developed device combines the Schrödinger's cat concept of superposition capable of fixing the fiddliest errors in quantum computation. The device can correct an array of errors that come up among fragile bits of quantum information, called qubits while performing a task. The study appears in the journal *Nature*.

Source: https://news.yale.edu/

(Image credit: Michael S. Helfenbein)

Wearable Sweat Sensor

RESEARCHERS from Brazil have created a wearable sweat sensor which is a skin-adherent biosensor based on pure nanocellulose fibre substrate. The natural polymer offers a breathable interface with the skin and permits sweat to travel through for further electrochemical analysis with the help of printed electrodes. It can measure a range of metabolites and biomarkers present in sweat and monitor problems like diabetes. This wearable sensor overcomes various drawbacks caused by plastic sensors including sweat to build up, irritation etc. It can measure various biomarkers like glucose, lactic acid, potassium, and sodium. The related study is published in the journal *Talanta*.

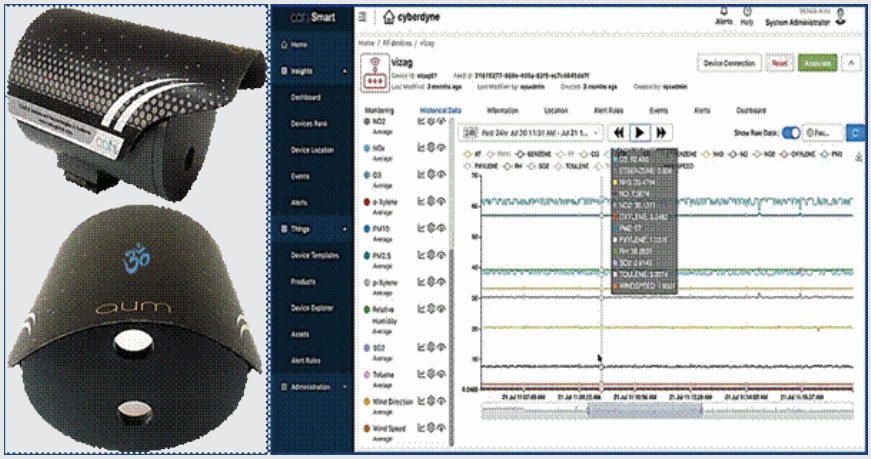
Source: medgadget.com

Colonoscopy-like Bacteria Grabber

PURDUE University researchers have built a way to swallow a tool that acts like a colonoscopy, except that instead of looking at the colon with a camera, the technology takes samples of bacteria. The tool is a drug-like capsule that passively weasels through the gut without needing a battery. The technology could also move throughout the whole GI tract, not just the colon. This tract, in addition to the colon, includes the mouth, esophagus, stomach, pancreas, liver, gallbladder, small intestine and rectum. Essentially, this tool would make it possible to conduct a "gut-oscopy." An initial demonstration of the prototype is published in *RSC Advances*, a journal by the Royal Society of Chemistry.

Source: https://www.purdue.edu/

Image credit: Jialun Zhu, Shuyu Lin, and Yichao Zhao (I²BL/UCLA)



Air Unique-quality Monitoring (AUM)

WITH support from Department of Science and Technology's Clean Air Research Initiative, Prof. Rao Tatavarti, Director of Gayatri Vidya Parishad-Scientific and Industrial Research Centre (GVP-SIRC) & GVP College of Engineering, Visakhapatnam, has developed an indigenous photonic system for real-time remote monitoring of air quality parameters. The AUM system (patent pending) is an innovative application of the principles of laser backscattering, statistical mechanics, optoelectronics, artificial intelligence, machine/deep learning, and Internet of Things. It can identify, classify, and quantify various pollutants simultaneously (of orders of less than one part per billion) and meteorological parameters, with very high precision, sensitivity and accuracy.

Source: https://dst.gov.in/

Smartwatch Tracks Medication Levels

RESEARCHERS of UCLA Samueli School of Engineering, Los Angeles, California along with Stanford School of Medicine have developed a smartwatch that can trace drug levels inside the body. The smartwatch analyses the chemicals present in sweat. This wearable technology can be used to design an ideal drug and decide its dosages as per the requirements of an individual. According to the researchers, existing efforts to personalize the drug dosage rely profoundly on repeated blood draws at the hospital. These solutions are inconvenient, time-consuming, invasive and expensive. The related research is published in *Proceedings of the National Academy of Sciences*.

Source: https://samueli.ucla.edu/

Pioneering Innovations in

Disinfection & Sanitization

Preeti Lata

The Vehicle Disinfectant Bay deployed at Rangpo Checkposts, East Sikkim
Image Credits: PIB

Foot-operated Height Adjustable Hands-free Sanitizer Dispenser Stand
Image Credits:PIB

WHILE COVID-19 has resulted in shutting down many things, the doors of innovation are still open. Everyone is trying their bit and coming up with innovative solutions.

Lately, two such innovative disinfection solutions by common people received in response to Challenge COVID-19 Competition (C3) organised by the National Innovation Foundation-India (NIF), have been supported by the foundation. NIF is an autonomous body of the Department of Science and Technology (DST), Govt of India. The two innovations are Vehicle Disinfectant Bay and a Foot-operated Height Adjustable Hands-Free Sanitizer Dispenser Stand.

Vehicle Disinfectant Bay

It is a device that can disinfect vehicles in an automated manner. It saves time and energy by finishing the disinfection process of a vehicle in less time with minimal efforts. It comprises of various components like a frame, tank, motor, MCB Board, agronet, nozzles, valves, pipes, and fittings. It sprays disinfectant liquid by means of an AC motor technology. It can be installed easily at State Borders/Checkposts. It is already deployed at two checkposts in the State of Sikkim – Rangpo Checkpost, East Sikkim, and Melli checkpost, South Sikkim.

Foot-operated Height Adjustable Hands-free Sanitizer Dispenser

It is a perfect hygiene solution suited for residential, commercial, as well as industrial applications. It is simple in operation, as one just needs to press a pedal with the foot and the sanitizer is dispensed from the dispenser. Its height can be adjusted according to the sanitizer bottle size. It can be installed at various public places. It is being commercialised by Vissco Rehabilitation Aids Pvt. Ltd, which is a leading manufacturer of orthopaedic products and mobility aids.

According to *PIB* press release, Prof. Ashutosh Sharma, Secretary, DST says, "NIF is not only scouting for relevant and frugal innovations from a large number of citizens but also helping with end-to-end solutions to see the best ideas take wings. A topical competition of this kind satisfies the creative, social service, and entrepreneurship urges all at the same time from people from all walks of life."

NIF is providing incubation, financial support and mentoring for further dissemination to the creators of these ideas.

Contributed by Ms Preeti Lata, *Science Reporter,* CSIR-NISCAIR, New Delhi

Kitti's Hog-nosed Bat

WORLD'S SMALLEST MAMMAL

Khushboo Shrivastava & Sakshi Shrivastava

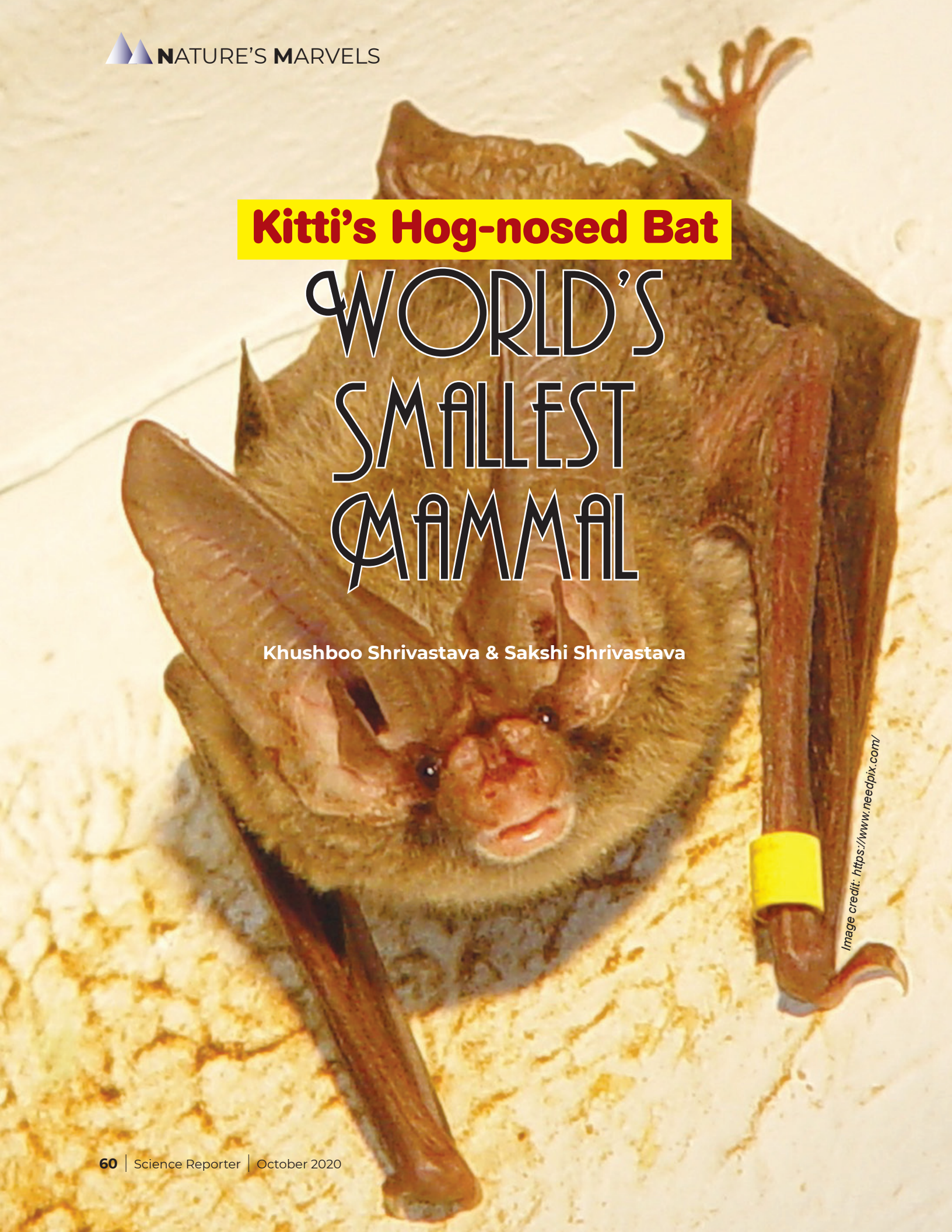


Image credit: https://www.needpix.com/

Image credit: Wikimedia commons

Image credit: nps.gov

KITTI'S Hog Nosed bat, also known as bumblebee bat (*Craseonycteris thonglongyai*) is the smallest mammal in the world with only 29-33 mm (1.14-1.29 in) head-body length, weighing 1.7-2 g (0.05-0.07 oz) and possessing a wingspan of approximately 130-145 mm (5.1-5.7 in). This unique creature is the only extant species in Craseonycteridae family and is native to Thailand and Myanmar where it roosts deep inside remote limestone caves near rivers.

The tiny creature has many astonishing features including its facial appearance with its thickened pig-like snout having two crescent-shaped nostrils, relatively large ears, small eyes. The colour of its body is buffy brown to reddish above whereas paler at the belly. They comprise uropatagium which is a big network of skin extending between back legs and help them in flying. There is a swelling at the base of the throat in the males to distinguish them from females. Kitti's Hog-Nosed bats are active in dawn and dusk both but most active during evening and morning hours and use the technique of echolocation to catch their prey that includes insects like beetles, spiders, small flies, etc.

The history of their evolution is still unclear. Mostly, other species of bats form large colonies but the Bumblebee bat doesn't do so as they include 100-500 members in their colonies and in some cases there are only about 10 of them. Unlike other bats, bumblebee bats do not come close to each other but spread out substantially.

They are listed as threatened by IUCN (International Union for Conservation of Nature) with a decreasing population trend. The main reason for the declining population is human disturbance. Fertiliser collection and extraction of limestone from their settlements are among some of the potential threats to their population.

Contributed by Khushboo Shrivastava (khushbooshrivastava2020@gmail.com) and Sakshi Shrivastava (sakshishrivastava0003@gmail.com), MSc II Year Students, Jiwaji University, Gwalior

FOOD HYGIENE

1. ..... is the appropriate temperature to keep frozen food.
a) 0° C b) 15° C or lower
c) -18° C or lower d) 20° C or lower

2. Where should raw meat be placed in a refrigerator?
a) At the top b) In the middle
c) At the bottom d) Anywhere

3. GMP labelling on products stands for
a) Good Manufacturing Practice
b) Genetically Modified Product
c) Genuine Manufacturing Practices
d) Great Manufacturing Performance

4. At what temperature mesophilic pathogens grow best?
a) 10° C b) 20 - 45° C
c) 55° C d) 90° C

5. Food Handlers should have their fingernails.....
a) Smooth b) Long
c) Sharp d) Short

6. .....therefore it is recommended to cover hair while handling or preparing food.
a) Long hair gets in your eyes
b) Hats keep your hair clean
c) Hats look smarter
d) Hair and dandruff can fall into food

7. To keep food safe from microbial contamination, the cooked food served hot should be kept at a temperature of at least .....
a) 10° C b) 60° C
c) 20° C d) 78° C

8. Which one of the following is an offence under the Food Safety Act 1990?
a) Putting rubbish outside the premises
b) Selling cold food
c) Selling food that is hot
d) Selling food unfit for consumption

9. To prevent microbial growth, cooked food to be served cold should be kept below.....
a) 50° C b) 68° C
c) 20° C d) 78° C

10. According to the US FDA, what is the ideal refrigerator temperature?
a) 4 – 10° C
b) at or below 4° C
c) 1.7 to 3.3° C
d) -2 to 0° C

11. Receiving and storage temperature of potentially high-risk food should be at or below.....
a) 5° C b) 60° C
c) 25° C d) 78° C

12. In food preparation environment, the finest way to dry hands after washing them is:
a) Using paper towels
b) Damp towels
c) Just let then dry naturally
d) Using automated dryers

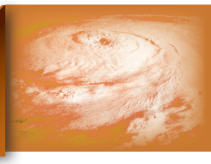
13. The appropriate concentration for a chlorine solution used to sanitize food contact surfaces is
a) One capful of chlorine for every gallon of water
b) Any Concentration of Chlorine
c) Concentration between 50 and 100 ppm, which can be measured with a chlorine paper test strip
d) Concentration must be at 200 ppm, which can be measured with a Chlorine paper test strip

14. What is the minimum temperature to which raw fish must be cooked?
a) 145° F b) 155° F
c) 165° F d) 180° F

15. "Danger Zone" is the range of temperature between.....during which the bacteria grow most rapidly.
a) 50° F to 100° F
b) 40° F to 140° F
c) 80° F to 100° F
d) 100° F to 200° F

Answers

1. (c) 2. (c) 3. (a) 4. (b) 5. (d) 6. (d) 7. (b) 8. (d)
9. (a) 10. (b) 11. (a) 12. (a) 13. (c) 14. (a) 15. (b)



CYCLONES

1. Any large system of winds circulating about a centre of low atmospheric pressure in a counterclockwise direction north of the equator and a clockwise direction to the south is known as
a. Anticyclone
b.Tsunami
c. Cyclone
d. Hailstorm

2. In which region cyclonic rainfalls occur largely?
a. Mexico b. Egypt
c. India d. UK

3. In the year 2019, cyclones emerging from the Arabian sea were Vayu, Hikka, Maha and _____.
a. Fani b. Kyarr
c. Bulbul d. Amphan

4. The principal agency responsible for weather forecasting, meteorological observations and seismology is
a. Indian Meteorological Department
b. Geological Survey of India
c. Indian Space Research Organisation
d. None of these

5. The Headquarter of the India Meteorological Department is in
a. Chennai b. New Delhi
c. Kolkata d. Odisha

6. The first pre-monsoon cyclone in a century, observed this year was
a. Nisarga b. Amphan
c. Bulbul d. Fani

7. Cyclone Amphan destroyed lives and property in which of the following states?
a. Goa b. Odisha
c. West Bengal d. Both b and c

8. _____ was the second pre-monsoon cyclone hitting India in 2020.
a. Amphan b. Nisarga
c. Kyarr d. Vayu

9. Cyclone Amphan got its name from
a. Thailand b. Japan
c. Japan d. Australia

10. The name of cyclone Nisarga was suggested by
a. Yemen b. Sri Lanka
c. Bangladesh d. Iran

11. Cyclones around the world are named by
a. Regional Specialised Meteorological Centers
b. Tropical Cyclone Warning Centers
c. Both a and b
d. None of these

12. Which of the following factors contribute to the development of cyclones?
a. Wind speed
b. Temperature
c. Humidity
d. All of these

13. Cyclones are known as _____ in USA.
a. Typhoons
b. Hurricanes
c. Tropical cyclones
d. Tornadoes

14. Recently, IMD has released new names for the tropical cyclones in the Indian Ocean, the list included _____ names.
a. 169 b. 150
c. 300 d. 24

15. The prime reason for the intensification of cyclone Amphan into a super cyclone is
a. High sea temperature in Pacific Ocean
b. Low vertical shear winds in Arabian Sea
c. Rapid warming up of Bay of Bengal
d. None of these.

16. Which of the following is a satellite for weather forecasting cyclone detection and tracking?
a. SCATSAT-1
b. Astrosat
c. Cartosat-2
d. Megha-Tropique

Answers
1. (c) 2. (c) 3. (b) 4. (a) 5. (b) 6. (b) 7. (d)
8. (b) 9. (a) 10. (c) 11. (c) 12. (d) 13. (d) 14. (a)
15. (c) 16. (a)

Online Drawing Competition 2020

"ART CARO NA"

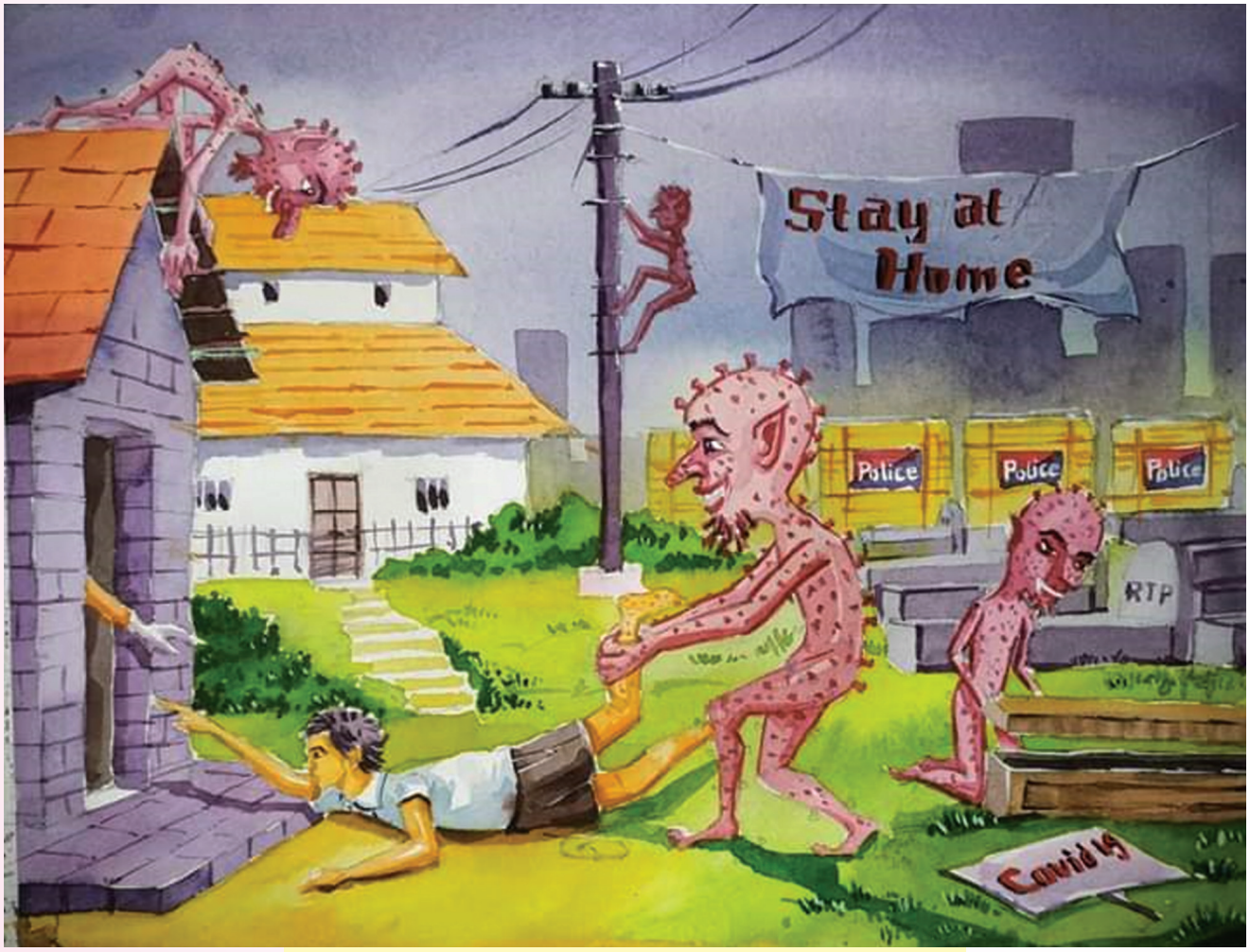
Theme — "Coronavirus: An Invisible Enemy"

Winners

Here are the best three entries from Group II (Class IX-XII) on the topic

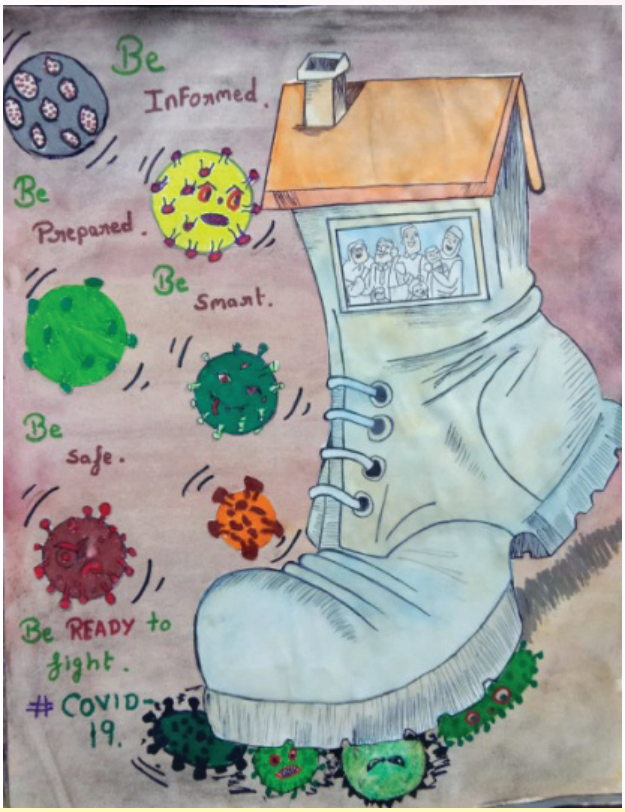
"Coronavirus Pandemic — Changing Lives"

First Best Entry



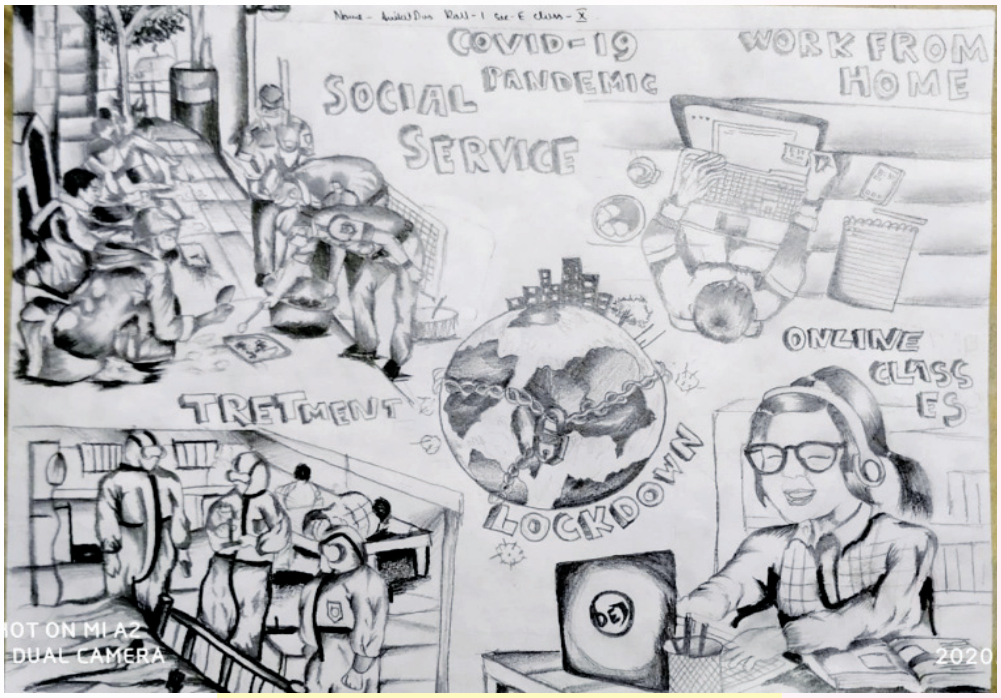
Alok Kumar Ray
Email: alokray509@gmail.com

Second Best Entry



Palakjoot Kaur Punraj
Email: palakjootkaur2005@gmail.com

Third Best Entry



Aniket Das
Email: aniketdas2005x@gmail.com