• After COVID-19, What? • Race for a Magic Bullet to Beat COVID-19 • ICMR Leads Fight Against COVID-19 • CSIR’s Five-Pronged Strategy to Fight COVID-19 • Evolution of Coronaviruses; History of Pandemics • Interviews: Dr. Shekhar C. Mande, DG, CSIR; Prof. R.K. Dhamija, Lady Hardinge Medical College; and Dr. H. Purushotham, CMD, NRDC
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KNOWING ABOUT COVID-19

The year 2020 started with the COVID-19 global pandemic. We are in the middle of the current year, but even now it cannot be said with certainty when the deadly march of the SARS-CoV-2 will be halted and how long we will have to face the fury of this pandemic. So far, the pandemic has infiltrated into 215 countries of the world leading to over 10 million infections and 0.50 million deaths.

We are living in unprecedented troubled times and our almost every activity is affected. The COVID-19-induced lockdown also halted the printing and mailing process of magazines, necessitating publication of this March-June 2020 combined issue of *Invention Intelligence*. This issue is focused on COVID-19 in which we have tried to cover various aspects of this topic.

At present, we do not have any specific drug or vaccine in hand to fight COVID-19. So, no one should take it casually. There should be no relaxation in hand washing, wearing a mask, social distancing and other preventive measures. Looking at the developments till now, we can get assured that the day will come when we will celebrate the victory over this pandemic. But by then many things in our society will have changed forever or at least for very long periods. How this pandemic will change the global scenario in terms of interpersonal relations, social relations, habits, trade, and economy is difficult to guess, but some possible postulates are presented here.

The unfolding ‘new normal’ and many other related points are elaborated in the articles ‘After COVID-19, What’, and ‘The World after COVID-19 Crisis’. The intensified efforts across the world on development of drugs and vaccines to beat COVID-19 are covered in the article ‘The Global Race for a Magic Bullet to Beat COVID-19’ with a report on the press meet of Professor K. VijayRaghavan, Principal Scientific Advisor to Govt. of India and Dr. V. K. Paul, Member NITI Aayog at the National Media Centre on 28 May 2020, on the development of indigenous COVID-19 vaccines.

On 29 June 2020, Hyderabad-based Bharat Biotech had announced that their vaccine candidate for COVID-19, COVAXIN, which they have developed in association with the ICMR (Indian Council for Medical Research), has been given approval by CDSCO (Central Drugs Standard Control Organisation) for Phase I and II human clinical trials that are scheduled to start across the country in July. This new Indian development also features in this issue.

An article, ‘ICMR Leads Fight Against COVID-19’, highlights the role of ICMR — the apex body in India for the formulation, coordination and promotion of biomedical research — and its response to implement scientific interventions to combat the pandemic. Five technology verticals set up by the Council of Scientific and Industrial Research (CSIR) for addressing the emerging situation are described in the article ‘CSIR’s Five-Pronged Strategy to Fight COVID-19’. The article, ‘Unlocking the Code of COVID-19: Health & Risk Communication Hold the Key’, gives details of the National Health & Risk Communication Programme — Year of Awareness on Science & Health (YASH), which has been initiated by the National Council for Science & Technology Communication (NCSTC), Dept. of Science & Technology, Govt. of India to combat such risks and mitigate the crises with the help of public awareness and preparedness.

The Indian Government has launched an AI portal (https://indiaai.in/), where all the recent AI-related developments will be shared among the citizens of the country. This development has given a boost to AI enthusiasts, which will eventually help in strengthening the research activity in this field. The importance
of AI in healthcare, especially during the COVID-19 pandemic, is described in the article 'COVID-19 and Artificial Intelligence: The Path Forward'.

Viruses and almost all the important aspects of SARS-CoV-2, including the natural origin of SARS-CoV-2, are discussed in the articles 'Viruses and Their Invisible World: Some Glimpses'; 'Evolution of Coronaviruses'; and 'Epidemiology, Basic Reproduction Number, and Herd Immunity of SARS-CoV-2'. The article 'History of Pandemics' chronicles the progress in the study of pandemics, the mechanism of their occurrence, the application of molecular genetics leading to better understanding of immunology, microbiology and genomics-accelerated vaccinology.

In conversation with *Invention Intelligence*, Dr. Shekhar C. Mande, DG, CSIR, speaks about the multifarious ways in which CSIR is contributing to the fight against the SARS-CoV-2; Dr. Purushotham, CMD, NRDC, talks about his initiative to bring out the *Compendium of Indian Technologies for Combating COVID-19*, a compilation of COVID-19 related technologies, and other issues related with the current pandemic; and Prof. Rajinder Kumar Dhamija, a prominent neurologist, currently heading the Department of Neurology at Lady Hardinge Medical College, New Delhi, talks about the neurological and various other health aspects related to COVID-19.

The year 2020 will also go down in the history of world sports as a year of the unprecedented. The COVID-19 pandemic has led to either cancellation or postponement of domestic and international championships as well as training sessions all over the world, including the biggest sporting extravaganza — the Tokyo Olympics 2020. In this issue, an article, titled ‘A New Scenario in Sports’, gives a glimpse of the world of sports in the new scenario. In the ‘Cross-Section’ column, we discuss gains of lockdowns and common hygiene products, which have become important tools to fight SARS-CoV-2, as also the stories behind these products, and how to cope with the abnormal times.

In the ‘IPR Corner’, patent issues related with the COVID-19 technologies are discussed. Recently, a patent application has been filed for the NavRakshak PPE by the inventors through NRDC. The manufacturing know-how of NavRakshak PPE has been developed at the Innovation Cell of the Institute of Naval Medicine, INHS Asvini Hospital (Mumbai) of the Indian Navy, and is assigned to NRDC for commercialisation. It is cost-effective as it does not require any major capital investment and can be adopted even by gown manufacturing units using basic stitching expertise. So far, NRDC has licensed the manufacturing know-how of NavRakshak PPE Suit to six MSME clients to meet the ongoing countrywide demand of quality PPE kits. These six manufacturers put together are planning to mass produce more than 10 million PPEs per year. In ‘NRDC News’ this indigenous development is discussed in detail.

We will continue to cover different dimensions of our fight against COVID-19. In the forthcoming issue, we will highlight the various indigenous technological solutions to combat the COVID-19 pandemic provided by NITI Aayog; CSIR; DST; DBT; DRDO; and some other organisations.

— RADHA KANT ANTHWAL
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After COVID-19, What?

Dr. ARVIND DUBEY

COVID-19 is upon us. Now it is irrelevant to ponder over where it came from, how it was started, whose fault it was, or if it was a natural virus or created in the laboratory. We have to think over what mistakes we have made in combating this unprecedented pandemic. Whether it was prudent to allow relaxations in a desperate attempt to save the economy and to avoid recession, hunger, looming poverty and sufferings of daily-wage workers and the middle class. Whether it will change our societies and our ways of living radically or everything will eventually return to the normal after the pandemic passes. Whether the virus will ever go away, or we have to learn living with it at least for some years. Let us evaluate what lessons we have learnt from this pandemic.

Nobody knew that a time would come when mankind has to fight a global war against a tiny invisible enemy, in which they would be helpless and miserable. They have to fight it with soap and sanitiser, despite having ferocious killer atomic weapons at their disposal. Three layers of a cloth, not the super advanced missile system, would be the most effective defence shield and staying home the most effective defence strategy. The tiny enemy would keep on its killing spree, making us only keep count of the dead. It would bring the so-called superpowers on their knees. Most stable economies would nosedive and an unprecedented recession would loom everywhere, leaving behind millions of jobless and hungry people.

But it is happening. The world is suffering endless agony, unrest, and loss of lives by the infection of SARS-CoV-2, a disease called COVID-19. Till date (28th June 2020), there are 10,182,580 people infected with SARS-CoV-2 (4,165,991 active cases) with 502,995 deaths in 215 countries. The most severely affected countries are USA, Brazil, Russia, India, the UK, Spain, Peru, Chile, Italy and Iran. India is at number four with 549,196 cases (210,935 active cases) and 16,487 deaths while it is registering around 20,000 new cases per day. On 8th June, New Zealand declared itself free of COVID-19 active cases. However, new cases started appearing in that country from 16th June, and till date there are 22 active cases. China is also facing a new surge of infections in Beijing after declaring that it has effectively controlled the infection in Wuhan. These two examples have raised a pertinent question mark. Even if once a country is free from infections caused by coronavirus, has it really won the battle?
SARS-CoV-2-positive cases Vs COVID-19

The two are not the same. The difference is same as it is in HIV and AIDS. Being SARS-CoV-2-positive means that the virus has entered your body. Later, you may be sick with it or remain asymptomatic, having no problem at all. There is merely 20 per cent chance that it may proceed to the COVID-19 stage, which is the disease caused by the virus. Out of these 20 per cent, only 3 per cent may go to ICU or need ventilators. Usually, the latter 3 per cent are those who are susceptible because of their other chronic illnesses. So, if you find that you have got the infection, don’t take it as a death warrant. It is time to be alert, active and watchful, not to get panicky. It is time to boost up your immunity. There are various means to do it from food to meditation and yoga.

Questions which still remain unanswered

1. How long does the virus survive/remain infective outside the body?

In a new research published in The New England Journal of Medicine, researchers used a nebuliser to imitate a human cough or sneeze droplets propelling virus-carrying particles into the air. They discovered that the virus is detectable for up to three hours in aerosols, up to four hours on copper, up to 24 hours on cardboard and up to two to three days on plastic and stainless steel. The study primarily investigated the virus’ rate of decay across various environmental conditions. This rate is known as a half-life, and it records the amount of time it takes for 50 per cent of virus particles to die.

Looking at stainless steel as an example, the study notes the median half-life of SARS-CoV-2 on that surface is about 13 hours. However, the virus did not drop below the threshold of detection for nearly three days. But it does not mean it was infectious on the second or third day. One has to get a certain number of viruses to be infected. This means a large enough volume of virus particles need to land on a surface initially for the surface to remain infectious for a significant period of time. The results indicate that aerosol and fomite transmission of SARS-CoV-2 is plausible till day three, since the virus can remain viable and detectable in aerosols for three days. However, plausible does not mean it happens.

2. What makes the coronavirus so good at spreading?

Whether the SARS-CoV-2 has something special in its surface proteins which enables it to stick to host cell in an especially strong latch, nobody knows.

3. What actually drives mortality in people infected by the coronavirus?

It is not just people with different risk factors like smoking and chronic illnesses who get ill after getting infected by SARS-CoV-2. It is not known why in many healthy and young people, the virus replicates quickly enough to trigger the immune system very suddenly instead of gradually, causing it to go berserk. In addition to damage caused by the virus, inflammation may further open up lung capillaries and cause them to leak more, causing fluid to quickly build up in the lungs, cut oxygen flow, and strain most organs in the body, including the heart, and even result in deaths from pneumonia.

4. How is it possible for a healthy person to get very sick from COVID-19?

Usually, COVID-19 is most dangerous for people with chronic health problems or advanced age. Yet, we have seen the virus causes serious illnesses and even death in young and healthy people. When, how, and under what circumstances, does the SARS-CoV-2 manage to disrupt an otherwise healthy organism?

5. Can one get re-infected, after full recovery from SARS-CoV-2?

No one is certain about the prospects of long-term immunity as the infection is only few months old. But scientists are sure that COVID-19 patients will have the immunity. However, this immunity may be short-lasting as it happens in other coronaviruses causing mild common cold. Coronaviruses exist in bats as persistent infections. Will this property carry over to the human-infecting strain of coronavirus?
China and South Korea, cases of reinfection have been reported. People who suffered from the disease, and then tested negative, ended up relapsing with fever and other symptoms. Scientists do not know how to account for such cases. These cases seem to be exceptions rather than the rule. Are these actual reinfections or results of testing errors?

6. How is it possible to infect others, when one doesn’t have any symptoms?

Usually, viral diseases are contagious only from the moment they manifest themselves in our bodies through symptoms like fever and cough. With COVID-19 this does not seem to be the case, which makes the virus all the more dangerous.

7. Will there be a safe and effective vaccine for the SARS-CoV-2 and when?

Many clinical trials for the SARS-CoV-2 vaccine are underway. They each take different approaches. There is a good chance at least one should work

Types of COVID-19 Tests

**Antibody Test For COVID-19**

It uses a few drops of blood to determine whether the human body has antibodies for coronavirus. It costs ₹500 and gives result in 20-30 minutes. Antibodies take eight days to develop and actually appear. So in the first week of infection an individual may start showing the symptoms of COVID-19 and start infecting others as well but there is a possibility antibody test will give a false negative.

**NAT and RT-PCR Tests For COVID-19**

For testing the virus, two kinds of tests are available — NAT (Nucleic Acid Test) and RT-PCR (Reverse transcription-polymerase chain reaction) test. Both tests require a nasal and throat swab. While NAT costs ₹2,800 and takes about an hour, RT-PCR costs ₹4,500 and requires five to six hours to test the samples thoroughly. Both tests give positive results from Day one. Though NAT test has been approved by FDA (Food and Drug Administration), currently, in India, RT-PCR is being followed for the diagnosis of COVID-19.

**What Is Pooled Testing?**

It is screening of a pool comprising multiple individual patient samples. If a pool turns out to be negative, all individual samples involved in that particular pool are regarded as negatives. On the other hand, if a pool tests positive, individual testing of samples is done.
safely and effectively. But all of the vaccine candidates are in an early experimental phase. It may take more than a year to prove that they work and another 6 months after that to manufacture and distribute them. There is also no guarantee that any of them will work at all.

8. What will be the long-term consequences for those who survive COVID-19?

Some of the first people who got the SARS-CoV-2 and recovered have only been well for a few months. So, it is not yet clear what the long-term consequences of weathering a severe bout of COVID-19 might be. Few of the early cases in China show reduced lung function. They gasp if they walk a bit more quickly. Only time will tell what else, if anything, may affect people who recover from SARS-CoV-2 infection.

9. Can we go back to our usual way of life?

Whether we can ever pick up our lives the way we used to live them before the pandemic struck, will depend entirely on whether we find a vaccine. Science has yet to unravel the full complexity of this novel coronavirus. Beyond the scientific calculations, it seems to many that our lives and the organisation of societies have already changed forever.

Vaccine for SARS-CoV-2

How does a vaccine work: Vaccine is an active way of preventing infection. When the immune system is exposed to a virus, it responds by producing highly specific antibodies that bind with great strength to viral proteins (‘S’ proteins in SARS-CoV-2) that the virus needs to infect cells and inactivate them. They also help clear the virus from the body. A second part of the immune response is the stimulation of lymphocytes, a type of white blood cells which help to produce antibodies. Some cells (macrophages) also can recognise and kill the cells that are infected with virus. Once someone has recovered from a viral infection, the cells of the immune system ‘remember’ the virus, and this results in resistance to a second infection by the same virus, known as ‘immunity’. However, the strength and length of immunological memory varies between different virus infections and generally wanes as people age. The purpose of vaccines is to stimulate an immune response to infection by a virus such as SARS-CoV-2, which then builds up specific resistance to the infection. This is done by exposing people to harmless subcomponents of the virus, typically by injection. These stimulate the immune system to develop the antibodies and lymphocytes that provide resistance to infection.

Problems in development of vaccine: Understanding more about the biology of the new coronavirus is essential for the design of an effective vaccine. Till now our knowledge about virus for vaccine is based on coronaviruses other than SARS-CoV-2, especially the SARS coronavirus, MERS virus, flu viruses, etc. For a virus to multiply, it first needs to break
into human body cells. SARS coronavirus, which caused an outbreak of disease in 2003, does this by hijacking docking bays (receptors) on the outside of lung and gut cells. These receptors are normally used by an enzyme called ACE2 (angiotensin-converting enzyme 2) which helps regulate blood flow through vessels. SARS-CoV-2 uses the same receptor but binds to it with even greater strength. It does this using one of its four main structural proteins — the spike or ‘S’ protein which sticks out all over its surface. So, the spike protein is the main target for vaccine development for SARS-CoV-2.

**Lack of good animal models for testing:** Good animal models for vaccine development are not available for the new coronavirus. Following the SARS outbreak in 2003, scientists studied mice. But mice do not naturally develop pneumonia with SARS coronavirus infection. So, it is impossible to test whether a vaccine protects against pneumonia. Hamsters develop lung changes on SARS infection but do not appear to get sick. Ferrets, and several monkey species, develop lung disease with SARS coronavirus but not consistently. So, in tests of early SARS vaccines in ferrets and monkeys, several vaccines stimulated antibodies against the spike protein, but they only protected partially against lung disease. The problem can be theoretically partially overcome by using older or genetically modified mice or by modifying the virus, which can further delay the development of a vaccine.

**Human immune system is very delicately balanced:** As part of normal immune responses, lymphocytes and other cells produce immune signalling chemicals called cytokines. These coordinate and stimulate immune responses. But if these responses are excessive, they can cause inflammation, which in extreme cases can result in the shutdown of vital organs, including the lungs, heart, and kidneys. In a small percentage of those infected with SARS-CoV-2, an overactive immune response may make an important contribution to the late complications of COVID-19. However, this is not known yet for certain and is an important area for research. It is, therefore, essential that vaccines against SARS-CoV-2 stimulate the right balance of immune response. For this reason, it will be necessary

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**Indian COVID-19 Vaccine is Ready for Human Trial**

Period of uncertainty is finally over. On 29 June 2020, Hyderabad-based Bharat Biotech had announced that their vaccine candidate for COVID-19, COVAXIN, which they have developed in association with ICMR (Indian Council for Medical Research), has been given CDSCO (Central Drugs Standard Control Organisation) approval for Phase I and II human clinical trials that are scheduled to start across the country in July 2020. The novel coronavirus strain was isolated and characterised at the Indian Council of Medical Research’s National Institute of Virology, Pune, and had been transferred to Bharat Biotech International Limited to develop a fully indigenous vaccine for COVID-19. Zydus Cadila is working on two vaccines, Serum Institute, Biological Evans, Bharat Biotech, Indian Immunologicals, and Mynvax are developing one vaccine each. India has pledged $15 million to the Global Alliance for Vaccines and Immunisation (GAVI).
to undertake careful clinical trials to ensure that new vaccines are extremely safe as well as effective. Activating the wrong pathway can increase the amount of inflammation and worsen the disease.

But these are typical findings on the route to developing vaccines and there is no reason to think that it will not be possible to develop an effective vaccine against SARS-CoV-2.

**Finding a vaccine**

By mid-June, 194 vaccine candidates were in development, with 13 in human testing: two in Phase II efficacy and dose-testing studies in human subjects; five in Phase I-II safety and efficacy trials; and six in Phase I trials. Five vaccine candidates had entered the second stage of human safety, dosing, and efficacy evaluation, Phase II. If proven effective, any of these vaccines would likely become widely available by the second half of 2021. To confirm that a vaccine is safe and effective, we need to run large, controlled trials across different populations of patients. This means any new vaccine will have to go through three clinical phases before being licensed. Once we have a working vaccine in hand, companies will need to start producing millions — perhaps billions — of doses, in addition to the millions of vaccine doses that are already made each year for mumps, measles and other illnesses. We will need to find new ways to rapidly scale up manufacturing around the world. This is why most estimates suggest that mass immunisation is unlikely for at least a year to 18 months.

<table>
<thead>
<tr>
<th>COVID-19 vaccine: Substances which are being tried till June 2020*</th>
<th>Total number of vaccine candidates (194)</th>
<th>Number of vaccines in the human trials stage (in phase II)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-replicating viral vector</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>RNA-based</td>
<td>23</td>
<td>1</td>
</tr>
<tr>
<td>DNA-based</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>Inactivated virus</td>
<td>9</td>
<td>3</td>
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<tr>
<td>Undefined substances</td>
<td>41</td>
<td>5</td>
</tr>
<tr>
<td>Protein subunit</td>
<td>59</td>
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</tr>
<tr>
<td>Replicating viral vector</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Virus-like particle</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Live attenuated virus</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Replicating bacterial vector</td>
<td>1</td>
<td>0</td>
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</tbody>
</table>

*Adapted from Data obtained from WHO, Vaccine centre-London Institute of Hygiene and Tropical Medicine and Milkene Institute
## COVID-19 Vaccine Clinical trials started in 2020

<table>
<thead>
<tr>
<th>Vaccine candidate (developer/sponsor)</th>
<th>Technology</th>
<th>Phase of trial (participants)</th>
<th>Adverse effects</th>
<th>Location</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ad5-nCoV</strong>&lt;br&gt;Camino, Institute of Biotechnology of the Academy of Military Medical Sciences)</td>
<td>recombinant adenovirus type 5 vector</td>
<td>Phase II interventional trial for dosing and side effects (500)</td>
<td>Moderate over 7 days; 81% had fever, pain, fatigue</td>
<td>China</td>
<td>March 2020 to December 2020</td>
</tr>
<tr>
<td><strong>mRNA-1273</strong> (Moderna, US National Institute of Allergy and Infectious Diseases, BARDA)</td>
<td>messenger RNA</td>
<td>Phase II dose-confirmation to evaluate safety, toxicity, and immunogenicity (600)</td>
<td>pending Phase I report</td>
<td>United States</td>
<td>May 2020 to August 2021</td>
</tr>
<tr>
<td><strong>AZD1222</strong> (University of Oxford, AstraZeneca)</td>
<td>adenovirus vector</td>
<td>Phase I–II randomized, placebo-controlled, multiple sites (1000)</td>
<td>pending Phase I report</td>
<td>United Kingdom</td>
<td>April 2020 to May 2021</td>
</tr>
<tr>
<td><strong>BNT162 (a1, b1, b2, c2)</strong> (BioNTech, Fosun Pharma, Pfizer)</td>
<td>RNA</td>
<td>Phase I–II of four vaccines, randomized, placebo-controlled, dose-finding, vaccine candidate-selection (7600)</td>
<td>pending Phase I report</td>
<td>Germany United States</td>
<td>April 2020 to May 2021</td>
</tr>
<tr>
<td><strong>CoronaVac</strong> (Sinovac Biotech)</td>
<td>inactivated SARS-CoV-2 virus</td>
<td>Phase I–II randomized, double-blinded, single-center, placebo-controlled in Xuzhou (744); Phase I–II in Renqiu (422)</td>
<td>pending Phase I report</td>
<td>China</td>
<td>April 2020 to December 2020 in Xuzhou; May to July 2020 in Renqiu</td>
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<tr>
<td><strong>INO-4800</strong> (Inovio Pharmaceuticals, CEPI, Korea National Institute of Health, International Vaccine Institute)</td>
<td>DNA plasmid</td>
<td>Phase I–II (40)</td>
<td>pending Phase I report</td>
<td>United States South Korea</td>
<td>April 2020 to November 2020</td>
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<td><strong>unnamed</strong> (Chinese Academy of Medical Sciences)</td>
<td>inactivated SARS-CoV-2 virus</td>
<td>Phase I–II randomized, double-blinded, single-center, placebo-controlled in Sichuan (942)</td>
<td>China</td>
<td>June 2020 to September 2021</td>
<td></td>
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<tr>
<td><strong>COVID-19/aAPC</strong> (Shenzhen Geno-Immune Medical Institute)</td>
<td>lentiviral vector, pathogen-specific artificial antigen presenting dendritic cells</td>
<td>Phase I (100)</td>
<td>China</td>
<td>March 2020 to 2023</td>
<td></td>
</tr>
<tr>
<td><strong>LV-SMENP-DC</strong> (Shenzhen Geno-Immune Medical Institute)</td>
<td>lentiviral minigene vaccine, dendritic cells modified with lentiviral vector</td>
<td>Phase I (100)</td>
<td>China</td>
<td>March 2020 to 2023</td>
<td></td>
</tr>
<tr>
<td>Vaccine candidate (developer/sponsor)</td>
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</tr>
<tr>
<td><strong>unnamed</strong> (Beijing Institute of Biological Products, Wuhan Institute of Biological Products)</td>
<td>inactivated COVID-19 virus (vero cells)</td>
<td>Phase I (288)</td>
<td></td>
<td>China</td>
<td>April 2020 to November 2021</td>
</tr>
<tr>
<td><strong>LNP-nCoVsRNA</strong> (Medical Research Council Clinical Trials Unit at Imperial College)</td>
<td>messenger RNA</td>
<td>Phase I randomized trial (105), with dose escalation study (15) and expanded safety study (at least 200)</td>
<td></td>
<td>United Kingdom</td>
<td>June 2020 to July 2021</td>
</tr>
<tr>
<td><strong>NVX-CoV2373</strong> (Novavax)</td>
<td>SARS-CoV-2 recombinant spike protein nanoparticle with adjuvant</td>
<td>Phase I (131)</td>
<td></td>
<td>Australia</td>
<td>May 2020 to July 2021</td>
</tr>
<tr>
<td><strong>Gam-COVID-Vac Lyo</strong> (Gamaleya Research Institute)</td>
<td>non-replicating viral vector</td>
<td>Phase I (38)</td>
<td></td>
<td>Russia</td>
<td>June 2020 to August 2020</td>
</tr>
</tbody>
</table>

*Trials highlighted in green are in Phase II, in yellow are either in phase I/II

**Substances which are tried to produce COVID-19 vaccine**

Researchers and vaccine developers are trying various viral components, viral proteins, subunits, inactivated viruses, live attenuated viruses, and different types of virus vectors.

**Vaccine testing**

After an initial vaccine has been proposed and animal safety tests conducted, there are three phases of human testing to move through before mass manufacturing and distribution can commence.

**Phase I:** Vaccine is introduced in a small number of healthy subjects. Researchers monitor each volunteer’s antibody production to get an initial understanding of the vaccine’s efficacy.

**Phase II:** The vaccine is introduced in a large number of healthy subjects. During this stage efficacy of the vaccine along with the best dose is determined, and the ideal administration protocol is established.

**Phase III:** The toxicity, immunogenicity, and serious side effects are monitored on a larger number of subjects. Vaccine recipients are randomly divided in two groups. One group receives a placebo (substance exactly looks like vaccine but does not contain vaccine contents) while the other group receives the vaccine candidate. Generally, this last phase alone can take between 6 and 12 months because researchers must recruit a large number of subjects deemed to be at a high risk of contracting the disease, and then follow those subjects for some time living in the real world. The vaccine must be shown to be safe and effective in natural disease conditions before being submitted for approval and then general production.

**Phase IV:** Phase 4 trials are typically monitor stages that collect information continuously on vaccine usage, adverse effects, and long-term immunity.

**Compressing the timeline and taking the risk**

Safety concerns for vulnerable populations, and manufacturing challenges for producing billions of doses are compressing schedules to shorten the standard vaccine development timeline, to months, for a process typically conducted sequentially over years. For this developers and governments are accepting a high risk of “short-circuiting” the vaccine development
process. These include the level of acceptable toxicity of the vaccine (its safety), the duration of vaccination protection, special delivery systems (such as oral or nasal, rather than by injection), and emergency use authorization before formal licensing of "Human challenge trial". A vaccine efficacy up to 70 per cent will be acceptable as it is enough to stop the pandemic.

**Human challenge trials**

This is one risk which looks quite unethical and directly out of *Robin Cook’s* medical thrillers. In this, healthy volunteers would receive either the vaccine or a placebo, and then would be exposed to the deadly virus to determine the efficacy of the vaccine. Participants would then be followed for two weeks to determine if rates of COVID-19 disease are lower

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**Drugs for COVID-19: Indian Scenario**

On 16 June the trial group released a statement that Dexamethasone (a steroid drug) had been shown to reduce mortality in patients receiving respiratory support. For patients on ventilators, it cut the risk of death from 40 per cent to 28 per cent (1 in 8). For patients needing oxygen, it cut the risk of death from 25 per cent to 20 per cent (1 in 5). Indian Council of Medical Research (ICMR) has taken a cautious approach towards the use of Dexamethasone because giving a steroid to hypertensive and diabetic patients can be challenging. India is the biggest manufacturer of Dexamethasone, which is available as a tablet as well as an injection and is very low priced.

Ministry of Health and Family Welfare has approved the use of two antiviral drugs Ramdesivir and Favipiravir for the treatment of COVID-19 patients. Ramdesivir is approved for restricted emergency use in serious patients while Favipiravir is approved for use in mild to moderately sick patients and also in those COVID-19 patients who are having other diseases, such as chronic kidney, heart or lung diseases and/or diabetes (co-morbidities), which can affect the outcome of COVID-19 treatment.

Drug Controller General of India has given permission to manufacture these drugs. Cipla Pharmaceutical Company and Hetero Labs have obtained the licence for manufacturing Ramdesivir while Glenmark Pharmaceuticals has been allowed to manufacture Favipiravir. Cipla and Hetero Lab have started manufacturing Ramdesivir in the name of Cipremi and Covifor, respectively. The drug comes in 100 milligram per 20 ml injections.

The cost of one injection of Hetero Labs’ Covifor will be around ₹5,000 to ₹6,000. Cipla is planning to launch generic version of the drug, which will be far cheaper. However, the company has not disclosed its price. The required dose of Ramdesivir is one injection twice a Day 1 and one injection twice a day from Day 2 to 10. Glenmark Pharmaceuticals has launched the drug Favipiravir with the name Faviflu. The drug will be available only on a doctor’s prescription. The recommended dose of this drug is 1,800 milligram (9 tablets) per dose, twice a day, for Day 1, then 800 milligram (4 tablets) per dose, twice a day from Day 2 to 14. The price for 200 milligram tablets at maximum retail price is ₹3,500 for a strip of 34 tablets.
COVID-19: candidate drug treatments in Phase III-IV trials

<table>
<thead>
<tr>
<th>Drug candidate</th>
<th>Description</th>
<th>Trial sponsor(s)</th>
<th>Expected results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remdesivir</td>
<td>Antiviral, inhibiting RNA synthesis</td>
<td>Gilead, WHO***, China, Japan</td>
<td>mid-2020</td>
</tr>
<tr>
<td>Hydroxychloroquine</td>
<td>Antimalarial and Antirheumatic</td>
<td>CEPI*, WHO, INSERM** China</td>
<td>mid-2020</td>
</tr>
<tr>
<td>or chloroquine</td>
<td>(trial stopped due to multiple side effects)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Favipiravir</td>
<td>Antiviral against influenza</td>
<td>Fujifilm China</td>
<td>April 2020</td>
</tr>
<tr>
<td>Lopinavir/ritonavir</td>
<td>Antiviral</td>
<td>CEPI, WHO, UK Government, Univ. of Oxford,</td>
<td>mid-2020</td>
</tr>
<tr>
<td>(Kaletra)</td>
<td></td>
<td>INSERM multiple countries</td>
<td></td>
</tr>
<tr>
<td>ASC-09 + ritonavir</td>
<td>Antiviral</td>
<td>Asclepis Pharma China</td>
<td>Spring 2020</td>
</tr>
<tr>
<td>Dapagliflozin</td>
<td>Hypoglycemia agent</td>
<td>Saint Luke's Mid America Heart Institute,</td>
<td>December</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AstraZeneca Multiple countries</td>
<td>2020</td>
</tr>
<tr>
<td>CD24Fc</td>
<td>antiviral new drug</td>
<td>OncoImmune, Inc. USA</td>
<td>Anytime in 2021</td>
</tr>
</tbody>
</table>

*International Coalition for Epidemic Preparedness Innovations, **Institut national de la santé et de la recherche médicale (French National Institute of Health and Medical Research), ***World Health Organisation

Ivermectin and Doxycycline

Ivermectin and Doxycycline, an anti-scabies drug, were tested by Bangladeshi doctors in Bangladesh Medical College Hospital. They claim 100 per cent cure, complete recovery within 4 days, 50 per cent reduction in sign and symptoms within three days and no side effects. But the study sample size is very small (only 19 patients). However, it needs to undergo systemic trial protocol, before considering it as a successful treatment for COVID-19. Ivermectin inhibits replication of SARS-CoV-2 in monkey kidney cell culture. On 8 May 2020, the Health Department of the Republic of Peru approved Ivermectin for treatment of COVID-19 in humans. On 12 May 2020, a similar approval was made by the Health Department of Bolivia.

in the vaccinated group than in the placebo group. Thus, vaccine evaluation could be conducted in weeks rather than many months and efficacious vaccines could be made available considerably more quickly. Regardless of the risks of getting COVID-19, so far, over 1,200 people from 44 countries have volunteered to expose themselves to SARS-CoV-2 as part of a vaccine trial on “1 Day Sooner”, a recently launched website.

Drugs for COVID-19

As of mid-May 2020, developing COVID-19 therapeutic candidates included:

- Antibodies (61 candidates)
- Antivirals (22 candidates)
- Cell-based compounds (15 candidates)
- RNA-based compounds (6 candidates)
- Scanning compounds to be repurposed (18 candidates)
- Various other therapy categories, such as anti-inflammatory, antimalarial, interferon, protein-based, antibiotics, and receptor-
modulating compounds, among numerous others (86 candidates) for a total of 293 compounds under development in May 2020.

By now several potential post-infection therapies, including Favipiravir, Remdesivir, and Lopinavir used in the International Solidarity Trial, are in the final stage of human testing — Phase III-IV clinical trials.

Monoclonal antibodies/interferon

More realistically, antibodies will provide the most value for those at the highest risk, like healthcare workers or people who are old or immunocompromised. Monoclonal antibodies provide what is known as ‘passive immunisation.’ Vir Biotechnology, San Francisco, has isolated antibodies from people who survived SARS. The company is working with Chinese firm WuXi Biologics to test them as a treatment for COVID-19. Vancouver biotech firm AbCellera has isolated 500 unique antibodies from a person who recovered from COVID-19 and is set to start testing them. After screening 300 antibodies, Celltrion of South Korea has identified the 14 most powerful antibodies that could potentially combat the SARS-CoV-2. Though these antibodies are very effective, their protection is short-lasting and these are very costly.

### Blood plasma transfers

Our blood has two main parts — cells and a liquid part in which these cells float and are transported throughout the body. This clear straw-coloured liquid, which makes up largest component (55 per cent) of human blood is called plasma. When a pathogen enters our

<table>
<thead>
<tr>
<th>Immunomodulator/Organisation</th>
<th>Mechanism</th>
<th>Stage of development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anakinra/Swedish Orphan Biovitrum</td>
<td>IL-1 receptor antagonist</td>
<td>Phase 3</td>
</tr>
<tr>
<td>Baricitinib/Lisa Barrett/Hospital of Prato</td>
<td>TNF inhibitor</td>
<td>Phase 3</td>
</tr>
<tr>
<td>Lenzilumab/Humanigen</td>
<td>GM-CSF monoclonal antibody</td>
<td>Phase 3</td>
</tr>
<tr>
<td>Leronlimab/CytoDyn</td>
<td>Monoclonal antibody</td>
<td>Phase 3</td>
</tr>
<tr>
<td>Gimsilumab monoclonal antibody</td>
<td>Roivant Sciences</td>
<td>Phase 1</td>
</tr>
<tr>
<td>Otilimab/MorphoSys</td>
<td>Monoclonal antibody</td>
<td>Yet to start</td>
</tr>
<tr>
<td>Mavrilimumab/ Kiniksa Pharmaceuticals</td>
<td>Monoclonal antibody</td>
<td>Phase 2</td>
</tr>
<tr>
<td>TJ003234/ I-Mab Biopharma Co. Ltd.</td>
<td>Monoclonal antibody</td>
<td>Phase 2</td>
</tr>
<tr>
<td>Bevacizumab/Qiu Hospital of Shandong University</td>
<td>Endothelial growth factor</td>
<td>Phase 3</td>
</tr>
<tr>
<td>CD24Fc/Oncolimmune, Inc.</td>
<td>Recombinant fusion protein</td>
<td>Phase 3</td>
</tr>
<tr>
<td>Eculizumab (Soliris)/Hudson Medical</td>
<td>Whole antibody</td>
<td>Yet to start</td>
</tr>
<tr>
<td>Emapalumab/Swedish Orphan Biovitrum</td>
<td>Anti-interferon-gamma (IFNy) antibody</td>
<td>Phase 2</td>
</tr>
<tr>
<td>Meplazumab/Tang-Du Hospital</td>
<td>Monoclonal antibody</td>
<td>Phase 2</td>
</tr>
<tr>
<td>Siluximab/University Hospital, Ghent</td>
<td>Monoclonal antibody</td>
<td>Phase 3</td>
</tr>
<tr>
<td>Tocilizumab/Hoffmann-La Roche</td>
<td>Monoclonal antibody</td>
<td>Phase 3</td>
</tr>
<tr>
<td>Interferon β1a/Institut National de la Santé et de la Recherche Médicale, France</td>
<td>Interferon</td>
<td>Phase 3</td>
</tr>
<tr>
<td>Recombinant human interferon α2β/Tongji Hospital</td>
<td>Interferon</td>
<td>Early Phase 1</td>
</tr>
<tr>
<td>Sarilumab/Regeneron-Sanofi</td>
<td>Human monoclonal antibody</td>
<td>Phase 3</td>
</tr>
<tr>
<td>Tocilizumab/Genentech-Hoffmann-La Roche</td>
<td>Human monoclonal antibody</td>
<td>Phase 3</td>
</tr>
<tr>
<td>Lenzilumab/ Humanigen, Inc. USA</td>
<td>Monoclonal antibody for pneumonia</td>
<td>Phase 3</td>
</tr>
</tbody>
</table>
body, our immune system starts producing antibodies. The first type of antibodies produced are IgM (immunoglobulin M) type. Usually IgM type of antibodies start appearing in the blood by the end of first week and they remain active in the body till the pathogen remains in the blood. At the end of second week, another type of antibody called IgG (immunoglobulin G) starts appearing. IgG antibodies are tailor-made to attack a specific disease-causing agent against which they are formed. These antibodies last long, sometimes lifelong. The recovered patient’s antibodies, when given to another patient, will begin targeting and fighting the invading pathogen in the second patient.

**Pros and cons:** Blood plasma is easily available and is cheap and safe. The antibodies are highly specific against the virus. However, a few risks are also there. The administration of antibody may end up suppressing the body's natural immune response, leaving a COVID-19 patient vulnerable to subsequent re-infection. There is a risk that an inadvertent infection might get transferred to the patient. The most common reactions are generalised itching and rash, which develops in 1-3 per cent of patients. A fever-like reaction can occur in 0.1-1 per cent of patients. Transfusion-related acute lung injury (TRALI) occurs in less than 0.01 per cent of patients.

**Status of convalescent plasma therapy in India:** On 26th April, Max Hospital in Saket, New Delhi announced that a COVID-19 patient had shown “progressive improvement” after being administered convalescent plasma therapy. However, on 28th April, the Union Health Ministry
warned against its use and called it one of the many therapies being explored. However, some state governments, including Rajasthan, Punjab, Maharashtra, and Delhi, have shown keenness for plasma therapy treatment, and the Centre has permitted a few states to perform plasma therapy on a limited number of COVID-19 patients. On 13 March, the Indian Council of Medical Research (ICMR) submitted a list of 99 institutes/hospitals to India’s Central Drugs Standard Control Organisation (CDSCO) where plasma therapy trials can be conducted. CDSCO has subsequently permitted ICMR to conduct clinical trials of convalescent plasma for the treatment of COVID-19 disease. ICMR has made a protocol for this therapy. The Government Medical College and Hospital Nagpur is all geared up to lead ‘Platina Trial,’ the world’s largest plasma therapy trial. In this state-level clinical trial, 500 critically ill COVID-19 patients will be treated with convalescent plasma.

**Stem cell therapy**

Athersys Inc. in the US began a phase II/III clinical trial that will examine whether stem cell treatment could potentially benefit people with acute

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**Organisations that have formed international alliances to expedite vaccine development**

- The World Health Organisation (will raise US$8 billion)
- The Coalition for Epidemic Preparedness Innovations (CEPI) will raise US$8 billion. The United Kingdom, Canada, Belgium, Norway, Switzerland, Germany, and the Netherlands had already donated US$915 million by early May.
- The Gates Foundation is donating US$250 million
- The Global Alliance for Vaccines and Immunization (GAVI)
- India pledged $15 million to GAVI
- The Global Research Collaboration for Infectious Disease Preparedness (GLoPID-R)
- The International Severe Acute Respiratory and Emerging Infection Consortium
- Pharmaceutical companies with experience in making vaccines, including Johnson & Johnson, AstraZeneca, GlaxoSmithKline (GSK), Sanofi, and among others, are forming alliances with biotechnology companies, national governments, and universities to accelerate progression to an effective vaccine.
respiratory distress which occurs in some people with severe COVID-19. Mesoblast has also developed a potential stem cell treatment for Acute Respiratory Distress Syndrome (ARDS), which is a part of COVID-19. The company is enrolling people with moderate to severe ARDS into a phase II/III clinical trial in the United States.

How and when will COVID-19 end?

Scenario 1: Stringent and drastic measures will be effective to curb the spread. With these in place, we could bring the pandemic under control and gradually resume economic activity by the end of the year. Looking at the situation, this scenario looks quite unlikely for us. Besides, this infection is lagging behind in its course in our country. We can expect that the worst is yet to come.

Scenario 2: The second, which appears to be the most likely scenario, could follow the trajectory most countries are following: enforcing lockdowns and reducing social contact while tracking those infected. However, many countries adopted such measures late or even downplayed the severity of the virus. We have seen how overwhelmed healthcare facilities are getting, with lack of proper equipment and jam-packed wards due to the uncontrolled spread of the contagion in those countries. Even those countries that contained the spread could face a second wave of infections as restrictions are lifting too early. This eventually will lead to even more severe lockdowns and have us battle with COVID-19 the majority of the year 2020. It means that travel restrictions, masks and an overwhelmed healthcare system will remain with us throughout 2020. Thereafter its intensity will rapidly decrease with the advent of safe and protective vaccine and effective drugs. However, coronavirus infection may continue sporadically for few more years.

Scenario 3: This least likely scenario is really bad. In this version, most countries would fold under the pressure, the virus would not just survive the summer, but could start a second wave during the cold months and perhaps even the herd immunity is out the window. That would mean hundreds of millions of people getting infected, and with collapsing healthcare systems, the mortality rate would skyrocket, leaving tens of millions of dead, as it is happening in Brazil. In this scenario we would probably suffer the consequences until a vaccine could stop its spread till the end of 2022. COVID-19 may continue to occur sporadically, surely not as an epidemic or pandemic.

Life after COVID-19: What will change?

An unprecedented toll on healthcare workers: Healthcare professionals on the frontlines are working under extreme work conditions and making sacrifices in order to help the infected. Despite a shortage of personal protective equipment (PPE), they show up to work with a high risk of being infected. It is physically and mentally draining. This will
lead to an inevitable spike in burnouts among the healthcare staff. Even before the SARS-CoV-2 outbreak, it was estimated that nearly half of the world’s 10 million physicians had symptoms of burnout. Now, after COVID-19, we may see greater number of frontliners with symptoms of post-traumatic stress disorder. After this pandemic subsides, we will have to brace ourselves for the aftermath on medical professionals on the frontlines.

_Diminishing trust in the globalised world:_ We will not be able to travel that freely or enjoy the supply chains of the world so easily as we did before the pandemic. We will think twice before going somewhere or to meet someone. The pandemic is already exacerbating signs of social anxiety and agoraphobia. Agoraphobia is an anxiety disorder that manifests as a fear of situations where escape could be difficult, or in which help would not be available if something bad were to happen. These situations can include open spaces, public transit, shopping centres, or simply being outside the home. Being in these situations may result in a panic attack. Regaining trust takes time and these trends will take place for months after lockdowns are lifted.

**More focus on the healthcare system:** We can expect to see many governments put more focus on healthcare. They can adopt similar strategies employed by other countries that better managed the crisis.

**Surveillance as an ongoing public health measure:** Countries from Germany through Israel to Singapore are using phone tracking data to locate and alert those who might be infected. South Korea went the extra mile by using CCTV footage and bank transactions in addition to phone use in its tracing process. This could lead to certain governments to erase a layer of privacy from citizens’ life. It brings a whole new dimension to privacy and ethics issues. But under the guise of another major public health crisis such measures could become the norm.

**A shift in the medical care:** Option will develop to bring healthcare to patients, rather than the other way round. Telemedicine will be used more efficiently and more often. Devices like digital stethoscopes, portable ECG monitors and digital otoscopes may be used at home and the results shared remotely with doctors. These eliminate doctor-patient visits whenever it is avoidable and also help reduce the risk of cross-contamination.

**Digital solutions:** As we have been doing during the pandemic, we will continue to experiment with digital solutions, be it virtual meetings for work, digital education for students or virtual events instead of in-person conferences. These proved not
only to be effective but also an environmentally friendly way to operate in a connected world. We are not saying everything is going to be digital, but it makes sense to make digital anything that is not more efficient in real life, if possible.

**Work places and offices will change**

- **Work from home**: When the pandemic subsides, work from home will remain popular with professionals, and that will force companies, even those that were not the biggest proponents of having a virtual workforce, to become more flexible. Yet we won’t see a wholesale move to remote working. People will be given more freedom to choose working from home.

- **Work-ready homes**: Many professionals found working from home a challenge not because of isolation, but because they did not have the ideal space or a dedicated home office. They did not have a Zoom-ready spot for video meetings. One of the biggest challenges people experienced, while working from home, was internet performance. So, the internet in homes will improve, drastically and quickly. Home offices and even home video studios will become a priority.

- **E-learning for everyone**: Many corporate learning programmes involved in-person workshops and seminars. But post-COVID-19, e-learning will become a bigger part of ongoing learning. In-person learning programmes won’t go away, but they’ll be reserved for certain functions and certain populations within the company.

- **Business attire is retiring**: Working from home, it is unlikely that you put on a suit or heels.

- **Video virtuosos**: Video is at the heart of many of the changes above. The developers behind Zoom, WebEx, Hangouts, Skype, and other video communications tools made the grand work from home experiment possible.

- **Fading lines**: As supervisors and staffers have gotten used to seeing each other in their natural habitats, the line that separates work life and personal life will fade.

**Lessons learnt**

COVID-19 has emerged as an unforgettable public health threat around the world. It adds to the list of previous epidemic infectious disease outbreaks, including Bovine Spongiform Encephalitis in 1986, the Avian flu in 1997, the SARS in 2002, the Swine Flu in 2009, and the Ebola in 2014. All these outbreaks remind us that we live in a habitat where it is necessary to respect the relationship between animal, social life, and the environment to survive and thrive. Rapid urbanisation and our incursion into forest lands have created a new interface between humans and wildlife and exposed humans to unfamiliar organisms often involving the consumption of exotic wildlife. With COVID-19, nature is sending us a message that we need to recognise the interrelationship between animals, including pets, livestock, and wildlife. The transdisciplinary ‘OneHealth’ approach involving professionals from many disciplines such as medicine, veterinary, environmental health, and social sciences has been advocated to limit new infectious outbreaks. The global experience is teaching us that containment measures and aggressive contract tracing are mandatory to keep the infection under control until an approved treatment or a vaccine is available to the global community. The implementation and development of the OneHealth collaborations on a global scale are critical in reducing the threat of emerging viruses.

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The Global Race for a Magic Bullet to Beat COVID-19

M. SOMASEKHAR

The search for the ‘Holy Grail’ to halt the pandemic in its tracks has intensified across the world, with big pharmaceutical companies, vaccine makers, research institutes, universities and even some startups throwing in their hat. The winner, or the first to find an effective vaccine/drug or a ‘cocktail of drugs’, will not just make billions but also perhaps etch its name into history. More than 120 focused efforts have been termed as promising in this pursuit. Will the preventive weapon (vaccine) be ready by end of 2020 or 2021, or never? Meanwhile, drugs like Remdesivir, Hydroxychloroquine, Dexamethasone, etc., have been showing exciting results in some trials. Any which way, as the coronavirus reaches every nation and the cases head to 10 million, the excitement and fear continue. The whole world waits with ‘hope and bated breath’ for a desperate relief.

The race to develop an effective vaccine/drug to prevent/cure people from COVID-19 is perhaps the hottest and most challenging in modern medical history. The rewards are not just a blockbuster but history in the making for saving a great majority of human population. COVID-19 has in less than 6 months affected virtually every nation in the world and the pandemic shows no signs of slowing down.

Beginning January 2020, the world economy has come to a virtual grinding halt. Country after country has gone into lockdown. The novel coronavirus is not showing signs of slowing down, but menacingly advancing in some counties with the virus mutating into multiple different and distinctive strains.

Perhaps never in recent history has the human race been engaged in only one topic — coronavirus, its varied impact on human life and different facets of the economy. In some ways, the pandemic will shape the future of the world post 2020.

The 1918 Flu Pandemic that ravaged the human population for about two years, killed an estimated 50 million, predominantly in Europe and the developed nations of those times. The toll was far more than the First World War (1914-18).

The coronavirus outbreak in the Chinese city of Wuhan sometime in December 2019, now known as COVID-19, and its rapid spread to the entire world, poses risk to millions of lives. The response and desperation to fight the pandemic has led to consorted global efforts across the biotech industry, both by pharmaceutical companies and research organisations, to facilitate development of a vaccine against COVID-19. At least 194 potential candidates are under various stages of development.

A striking feature of the vaccine development landscape for
COVID-19 is the range of technology platforms being evaluated, including nucleic acid (DNA and RNA), virus-like particle, live weakened virus, and inactivated virus approaches.

The Coalition for Epidemic Preparedness Innovations (CEPI) formed by World Economic Forum 2017 in Davos noted that many of these platforms are not currently the basis for licensed vaccines, but experience in the fields such as oncology is encouraging developers to exploit the opportunities that next-generation approaches offer for increased speed of development.

While global corporates and research teams are upbeat about coming up with a definitive vaccine by the end of 2020, the mood is not all that very rosy from virologists and those who have long experience in working in the field. They cite the example of HIV/AIDS, which has eluded a vaccine for decades and SARS, where it took a long time to come close to making one real but was never realised. According to Dr. Peter Piot, the co-discoverer of the Ebola virus in 1976, “A vaccine or a drug, at the best of rapid progress is more than a year away and it needs validation too, a tough calling”.

Where do we stand in our search for the ‘magic potion’ that will stop the virus in its track even after billions of dollars go into the race and stocks and valuations of some companies fluctuate on the bourses? As on date at least a dozen companies or collaborative ventures between university and industry have claimed to have taken potential vaccine/drug to the human trials state, while over 194 potential candidates have been identified so far. The strong buzz in the air is that by September at least one will be in the market. Among the front-runners are Gilead Inc. with its promising Remdesivir; the Oxford University Consortia of 7, which includes Serum Institute of India; Pfizer Inc and BioNTech, the German pharmaceutical company, Moderna Inc. and Lonza, the Swiss major; CasIno, Inovio and the Chinese Institute. The Oxford University candidate has been fast tracked to human trials. India’s vaccine major Serum Institute of India (SII) plans to start production of the
COVID-19 vaccine and bring it to the market by the end of 2020 if the human clinical trials are successful.

According to the Chief Executive Officer, A. Poonawala, the institute is working closely with Dr. Hill from Oxford University. Plans are to produce 5 million doses per month for the first six months, after which, it is to be scaled up to 10 million doses per month. The Jenner Institute and Oxford Vaccine Group have developed the candidate vaccine, which they call ChAdOx1 nCoV-19. The researchers utilised weakened version of chimpanzee adenovirus as vector and injected it with the genetic material of SARS-CoV-2 spike protein. According to the scientific literature, adenovirus causes common cold. After vaccination, the SARS-CoV-2 surface spike protein is produced in the body, which alerts the immune system to attack the virus, the researchers explain.

Vaccines made from the ChAdOx1 virus have been given to more than 320 people to date and have been shown to be safe and well tolerated, although they can cause temporary side effects, such as a temperature, headache, or sore arm.

University of Oxford has been working for over a decade on vaccines on MERS (Middle East Respiratory Syndrome) and Severe Acute Respiratory Syndrome (SARS) — diseases which are caused by the same class of coronaviruses.

The antiviral drug Remdesivir developed by Gilead Sciences, Inc. is considered the front-runner in the race toward developing a treatment for the novel coronavirus. The US company has recently claimed success in curing some coronavirus patients. Going by these reports, the US Food & Drug Administration granted an emergency use authorisation to Remdesivir for COVID-19 treatment in early May 2020.

Remdesivir is not a new drug and it has had its share of setbacks too. It was originally designed to treat Ebola, but studies in the lab showed it also acted against coronaviruses like SARS and MERS, so researchers began exploring its potential for treating COVID-19 when the pandemic began. It works by interfering with the ability of the virus to replicate quickly. The company has stated that it will be used in treating adults and children with severe novel coronavirus disease, especially those with low blood oxygen levels or the ones who require mechanical breathing support like ventilators.

Though the drug has shown significant results in shortening the time of recovery in some COVID-19 patients, the safety and effectiveness is still questionable, argue some scientists. However, unavailability of adequate, approved, or alternative treatments, gives the FDA reasons to believe that Remdesivir may be effective, others argue.

Gilead is constantly running clinical trials to generate more data on the safety and efficacy of Remdesivir. So far, the company has donated 1.5 million individual doses for treating more than 140,000 COVID-19 patients in a 10-day administered treatment course.

The Beijing Advaccine
Biotechnology is collaborating with the US based Inovio Pharmaceuticals — to accelerate the development of the former’s vaccine, INO-4800 as a novel coronavirus vaccine. The company has started pre-clinical testing for clinical product manufacturing.

Inovio has also prepared 3,000 doses for human clinical trials planned to be conducted across the US, China, and South Korea. Plans for large-scale manufacturing have also been developed.

Human clinical trials in 30 healthy volunteers will be started in the US, followed by China, and South Korea. A phase-I clinical trial is planned to be conducted in parallel in China, by Beijing Advaccine. Results from the clinical trials are expected to be available in September 2020.

The Chinese biopharmaceutical company, Sinovac, is also doing phase-I and phase-II trials of its COVID-19 vaccine. The company said it is in discussion with regulators in other countries and the World Health Organisation (WHO) to launch phase-3 clinical trials in regions where the SARS-CoV-2 is still spreading rapidly.

**mRNA based vaccines**

New York-based pharma giant Pfizer Inc. and German pharmaceutical company BioNTech announced that their potential candidate vaccine is into human trials in the United States since early May 2020. If the tests are successful, it could be ready for emergency use as early as September 2020. The vaccine is based on genetic material known as messenger RNA, which carries the instructions for cells to make proteins. By injecting a specially designed messenger RNA into the body, the vaccine could potentially tell cells how to make the spike protein of the SARS-CoV-2 without actually making a person sick.

Because the virus typically uses its spike protein as a key to unlock and take over lung cells, the vaccine could train a healthy immune system to produce antibodies to fight off an infection. The technology also has the advantage of being faster to produce, and tends to be more stable than traditional vaccines, which use weakened virus strains. The duo has stated that the first batch of 12 human volunteers were injected with their vaccine candidate, called BNT162, in Germany in April 2020. The trial will eventually expand to 200 participants.

The US-based Moderna is perhaps leading the pack in tapping RNA to come up with a vaccine. In partnership with the Vaccine Research Centre, a unit of the National Institute of Allergy and Infectious Diseases (NIAID), it has developed a vaccine that targets the spike (S) protein using the mRNA route. The first batch of vaccines is now cleared by FDA for Phase-II study.

Moderna, the clinical stage biotechnology company, is working in the largely experimental domain of mRNA-based vaccines. In theory, mRNA-based treatments work faster and show greater efficacy than their DNA-based counterparts. While DNA is found only in the nucleus of the cell, mRNA can be found more or less everywhere, making it easier to access and target.
Moderna has a pretty large pipeline of early stage mRNA vaccines, but its coronavirus vaccine, mRNA-1273, hit headlines for just how quickly it was completed after the virus’s genetic sequence was released. In less than two months, Moderna researchers came up with an initial vaccine, a creditable achievement by modern drug development standards.

To fast-track the trial phase and gear up for commercial market, Moderna has raised funds, including the grant of $483 million from the Biomedical Advanced Research and Development Authority (BARDA) of the US government, the company CEO, Stephane Bancel, said. The company has also entered into a strategic collaboration with Lonza Ltd., the Swiss major to manufacture up to one billion doses of mRNA-1273 per year. "We are accelerating manufacturing scale-up and our partnership with Lonza puts us in a position to make and distribute as many vaccine doses of mRNA-1273 as possible, should it prove to be safe and effective”, the CEO stated.

**Hope from repurposing of drugs**

In the wake of the looming medical emergency, repurposing of existing drugs, which has been one area of research in recent past, is getting a booster dose. The main advantage is that developers can get a lead time in accelerated development of potential cures explains, Sunit K. Singh, a virologist with the Banaras Hindu University (BHU). Repurposing existing medicines focussed on known drug targets is likely to offer a more rapid hope of tackling COVID-19 than developing and manufacturing a vaccine, argues an international team of scientists in a recent article in the *British Journal of Pharmacology*.

A team of researchers representing the International Union of Basic and Clinical Pharmacology say there will be no ‘magic bullet’ to treat COVID-19 and they argue that a multi-pronged approach is needed to find new drugs. They caution that an effective and scalable vaccine is likely to take over a year before it can be used to tackle the global pandemic.

"Any drug to treat COVID-19 will need to focus on the three key stages of infection: preventing the virus entering our cells in the first place, stopping it replicating if it gets inside the cells, and reducing the damage that occurs to our tissues, in this case, the lungs and heart,” said Professor Anthony Davenport of the University of Cambridge, one of the authors of the review.

"While we're waiting for a vaccine, drugs currently being used to treat other illnesses can be investigated as treatments for COVID-19 — in other words repurposed”, said Dr. Steve Alexander from the University of Nottingham.

"There's unlikely to be a single magic bullet — we will probably need several drugs in our armoury, some that will need be used in combination with others. The important thing is that these drugs are cheaper to produce and easier to manufacture. That way, we can ensure access to affordable drugs across the globe, not just for wealthier nations".

The team estimates there are currently more than 300 clinical trials taking place worldwide, though many of these
India is fighting hard on all fronts against the COVID-19 pandemic with big industries and academic individuals trying to develop vaccines, drugs, and testing technologies to deal with this unprecedented health menace. This was stated by Professor K. VijayRaghavan, Principal Scientific Advisor to Govt. of India, and Dr. V. K. Paul, Member, NITI Aayog, at a press meet on 28 May 2020 at the National Media Centre, New Delhi.

Elaborating on the four types of vaccines under development, Prof. VijayRaghavan said the first kind of vaccine, which is known as mRNA, a component of genetic material of the virus, is injected into the body. Our body translates it into viral protein and develops immunity against the virus. Another is a standard vaccine, in which a weakened version of the virus is used. The third one uses a protein coding region of the virus attached to the backbone of another virus. In the fourth kind of vaccine, a virus protein is developed in the lab and is used with another stimulant. Work is in progress to develop all the four kinds of vaccines.

“India has played a very important role in providing vaccines and generic medicines to the world. Out of the three vaccines used to inoculate children globally, two are manufactured in India,” he added. Whoever succeeds in making COVID-19 vaccines, India is going to play a vital role in providing logistics to make it available globally. Over the last few years, Indian vaccine manufacturers have been involved in their own R&D work and collaborating with other foreign companies.

Prof. VijayRaghavan also specified that the vaccine being evolved by way of virus protein development on the backbone of flu vaccine, is in late pre-clinical trial stage and quite likely the trials would be over by the month of October. A protein-based vaccine possibly will be ready by February 2021. Similarly, some of the startups associated with Indian Institute of Science, Bengaluru have started vaccine development working in collaboration with several scientific institutions and outside agencies.
He reiterated that normally, vaccine development work takes nearly 10-15 years and costs around 20 million dollars or more, but in the current situation, every country in the world is aiming to find a vaccine for COVID-19 in a year’s time. So, parallel processing is needed to achieve the goal, and that is why, instead of working only on one COVID-19 vaccine, the world is working on over 100 vaccines at the same time. It was also pointed out by him that once developed the worldwide distribution of an effective vaccine will be a major logistical challenge.

Deliberating upon the matter of drug development, he said it is equally challenging as vaccine development. The drug attacks the virus chemically inside the infected body. As the virus uses our body machinery to replicate, the drug has to be designed very cautiously in such a way that it attacks the virus only and does not harm any of the human organs. And it is even a more challenging task to make a drug which is effective against the virus in the initial stage of infection as lesser doses of medicine are needed to control the virus in the early stages.

There are three approaches in drug discovery that are being followed. The first is repurposing of existing drugs to see how effectively they work against the virus and in abating the implications of the infection. The second is the phytopharmaceutical approach where extracts from medicinal plants are being tested. In addition, All India Council of Technical Education (AICTE) and CSIR have embarked on a drug discovery hackathon to fight against COVID-19 where students are being trained about computational drug discovery. They get access to high end computational tools to design drugs.

Prof. VijayRaghavan was quite hopeful that any drug designed with the collective efforts would reach the human testing stage in next six months. According to him, India is currently testing the action of several drugs on COVID-19 patients as possible treatment, including Hydroxychloroquine, Avidal, and Remdesivir; in addition to plasma therapy and the BCG vaccine. According to him, a plant derivative called ACQS is also being tested by the researchers at the CSIR laboratories. Another group from the same institution is working on establishing the efficacy of Mycobacterium w. All these efforts are in various stages.

Genome sequencing of SARS-CoV-2 has been done in several Indian laboratories, but no abnormal mutation was observed except the normal ones which appear because of change of place and it has not affected the fundamental properties of the virus. Prof. VijayRaghavan also mentioned that due to joint research efforts, new techniques for testing the virus and test kits are about to roll out. ICMR and the laboratories under Department of Biotechnology have developed a new protocol for a serological test which will look for antibodies in the serum. The rapid progress became possible because of great cooperative efforts by the scientists, scientific research institutions and other agencies. Above all, the quality and regulations have not been compromised or overlooked in reaching near to the objectives in a very short time.

Earlier, initiating the address Dr. Paul emphasised that the final battle against the COVID-19 would be fought through science and technology and won with the help of vaccines, drugs and testing. If one gets infected with SARS-CoV-2, medicines will cure him or her. Treatment would be possible after early diagnosis of the disease through rapid testing. He said that “We have a solid base of scientific institutions and the country’s strong pharmacy industry is well known. We supply vaccines and medicines throughout the world, and we are quite sure that our pharmacy industry is going to play an important role in providing vaccines and medicines to the entire world.” He noted (Translated by Pramod Pande)

— MADAN MOHAN
investigational drugs are unlikely to be effective for widespread use because either it is not clear which part of the disease pathway they are targeting or whether they cause unpleasant side-effects.

**India Inc Role**

India has in the past decade emerged as a major global player in producing affordable vaccines and generic drugs for the world. According to a recent report by the Federation of Indian Chambers of Commerce & Industry (FICCI), India is the world’s third-largest producer of drugs with a pharmaceutical industry worth around $38 billion a year. It is known for producing high-quality and low-cost medicines. It fulfils 50 per cent to 60 per cent of global demand for many vaccines, and 40 per cent of generic drugs. India’s contribution, especially in low-cost vaccines for hepatitis B, typhoid, rotavirus and DPT, and as a big manufacturer for vaccines of global makers with capacity units has been significant and growing. Shantha Biotech, Bharat Biotech International, SII, Panacea Biotech are among the leading players.

Interestingly, not long ago, the country had a robust manufacturing base in the public sector and vaccine and drug makers like the Hindustan Antibiotics, Indian Drugs & Pharmaceuticals Ltd., Hindustan Latex, Bharat Immunologicals and Biologicals Corporation Ltd. (BIBCOL), etc. Sadly, currently, many of them are in a limbo.

Perhaps, the time is ripe to revive some of these PSUs which have idle manufacturing capacities. It took a public interest litigation in the Supreme Court to reopen three PSUs making vaccines — Central Research Institute, Kasauli, Pasteur Institute of India, Coonor; and the BCG Vaccines Lab, Chennai in 2012, says Y. Madhavi, Senior Principal Scientist at the Delhi-based National Institute of Science, Technology and Development Studies (NISTADS).

At present, the flourishing private companies meet nearly 75 per cent of the government need to drive its immunisation programmes. There are also imports of some vaccines. These factors have driven up the costs and budget for funding these programmes. A greater contribution or better mix between private and PSU vaccine makers might be in the larger public interest in the country.

In the global effort to control HIV/AIDS, led by the United Nations agencies and individual countries, India’s role in producing and supplying low-cost, antiretrovirals (ARVs) has been exemplary. Led by CIPLA, Aurobindo, Hetero, Mylan and many companies are doing yeomen service.

Yousuf Hamied, Chairman & Managing Director of CIPLA, which was the key player in driving down the costs of the HIV/AIDS treatment regimen with of three drug regimen for $1 in 2000-2001, has announced that his company will manufacture the drug against SARS-CoV-2 and make it very affordable in cost to the people at the earliest.

Zydus Cadila, Ahmedabad is working on two vaccines, while Serum Institute, Pune; Biological E; Bharat Biotech; and Indian Immunologicals, all from Hyderabad; and Mynvax, Bengaluru are developing one vaccine each, says Dr. Gagandeep Kang, Executive Director of the Translational Health Science and Technology and vice chair of the Coalition for Epidemic Preparedness Innovations (CEPI).

That the Indian entities are entering into challenging and risky areas is borne out by the statement of Poonawala of SII, “We have decided to initiate manufacturing at our own risk. The decision has been solely taken to have a jump-start on manufacturing, to have enough doses available, if the clinical trials prove successful”. The company plans to initiate trials in India for the vaccine with necessary regulatory approvals, which are underway presently.

Bharat Biotech, Hyderabad announced that the intranasal vaccine ‘CoroFlu’ is under development. An international collaboration of virologists at the University of Wisconsin –Madison and the vaccine company FluGen, along with Bharat Biotech, has begun the testing. CoroFlu will build on the backbone of FluGen's flu vaccine candidate known as M2SR based on an invention by UW-Madison virologists and FluGen co-founders Yoshihiro Kawaoka and Gabriele Neumann. In a statement, Bharat Biotech
said, M2SR is a self-limiting version of the influenza virus that induces an immune response against the flu. Kawaoka’s lab will insert gene sequences from SARS-CoV-2, the novel coronavirus that causes the disease COVID-19, into M2SR so that the new vaccine will also induce immunity against the coronavirus.

According to Dr Raches Ella, Head of Business Development, “Bharat Biotech will manufacture the vaccine, conduct clinical trials, and prepare to produce almost 300 million doses of vaccine for global distribution. Under the collaboration agreement, FluGen will transfer its existing manufacturing processes to Bharat Biotech to enable the company scale up production and produce the vaccine for clinical trials. Bharat Biotech has commercialised 16 vaccines, including a vaccine developed against the H1N1 flu that caused the 2009 pandemic.

Refinement of the CoroFlu vaccine concept and testing in laboratory animal models at UW-Madison is expected to take three to six months. Bharat Biotech in Hyderabad, India will then begin production scale-up for safety and efficacy testing in humans. CoroFlu could be in human clinical trials by the end of 2020.

Four Phase-I and Phase-II clinical trials involving hundreds of subjects have shown the M2SR flu vaccine to be safe and well tolerated. This safety profile, M2SR’s ability to induce a strong immune response, and the ability of influenza viruses to carry sequences of other viruses make M2SR an attractive option for rapidly developing CoroFlu as a safe and effective vaccine against SARS-CoV-2.

“We are going to modify M2SR by adding part of the coding region for the novel coronavirus spike protein that the virus uses to latch onto cells and begin infection,” says Gabriele Neumann, a senior virologist in Kawaoka’s lab and co-founder of FluGen. “CoroFlu will also express the influenza virus hemagglutinin protein, which is the major influenza virus antigen, so we should get immune responses to both coronavirus and influenza.”

Glenmark Pharmaceuticals has emerged as the first Indian drug maker to launch Phase-III clinical trials of its antiviral tablet Favipiravir. The company has received approval from the Drug Controller General of India in late April 2020 to start trials on COVID-19 patients in India. Glenmark estimates that the study would be complete by August 2020.

Favipiravir has demonstrated activity against influenza viruses and has been approved in Japan for the treatment of novel influenza virus infections. When commercialised, it will be marketed under the brand name ‘FabiFlu’ in India.

Mynvax, the Indian Institute of Science (IISc)-incubated biotech startup with a team led by Dr. Raghavan Varadarajan (one of the founders) of the Molecular Biophysics Unit of IISc, is involved in developing a vaccine based on evaluation of a set of potential candidates. Drawing upon previous studies on the 2003 SARS-CoV, these studies have shown that the antibodies against the spike glycoprotein found on the surface of the virus inhibit viral infection. IISc has been involved in designing of test variants of the spike glycoprotein as potential candidates. It has received funding from the Bill and Melinda Gates Foundation. These vaccine candidates are being tested in animal models through Mynvax.

Giving an overall picture of the country’s efforts, Dr. Renu Swarup, Secretary, Department
of Biotechnology (DBT), said about 20 research institutes are involved in vaccine development work. A research consortium has been formed with experts from the DBT, ICMR, NIV, etc. Another focus area is on researching repurposed drugs for treatment. Nearly 50 drugs have been identified and research is going on. Several DBT institutions are working to see which formulations can work effectively against COVID-19.

The DBT Secretary said the government is engaged in a broad spectrum of things — from scaling up production of low-cost COVID-19 testing kits and ventilators to expediting research for the development of vaccines.

In another collaborative effort, the Council of Scientific and Industrial Research (CSIR) under its flagship programmes, the New Millennium Indian Technology Leadership Initiative (NMITLI), has sanctioned a project to develop human monoclonal antibodies as therapy for COVID-19 infections. The project will be led by Bharat Biotech and brings together academia — National Centre for Cell Science (NCCS), Pune and Indian Institute of Technology, Indore, and industry — PredOmix Technologies, Gurugram in a collaborative mode for a public health emergency. The rationale behind the move is the premise that efforts are underway for the development of drugs and vaccines for controlling the COVID-19 pandemic, though these are slow and expensive processes with uncertainties. Therefore, an alternate therapeutic regimen for early deployment is critical.

The project aims at such an alternative therapeutic regimen by generating highly effective and specific human monoclonal antibodies that are capable of neutralising the SARS-CoV-2. Such virus-neutralising antibodies can block the spread of infection by binding to the virus and rendering it ineffective.

Monoclonal antibody therapy is a highly effective and safe method. "The question is of how to treat those individuals who are already infected. Plus, we do not yet know how effective an anti-SARS-CoV-2 vaccine will be in the elderly people and those with co-morbidities. Given the large number of Indians suffering from hypertension, diabetes, and heart diseases, this becomes an important issue, said Dr. Krishna Ella, MD.

Israel and the Netherlands have recently announced the development of virus-neutralising antibodies The Indian approach is to develop a powerful cocktail of neutralising antibodies that can also simultaneously block mutational variants of the virus. "We are fast-tracking the development process, to make the antibodies available within the next six months and thus improve the treatment efficacy", he said.

The most recent initiative is the one involving the Indian Council of Medical Research (ICMR) and Bharat Biotech. They have announced a partnership to develop a fully indigenous vaccine for COVID-19 using the virus strain isolated at ICMR's National Institute of Virology (NIV), Pune. The strain has been successfully transferred from NIV to Bharat Biotech, says Raman Gangakhedkar, Head of Epidemiology & Communicable Diseases of ICMR. Work on vaccine development has been initiated between the two partners. (See Box on page 33)

ICMR-NIV will provide continuous support to BBIL for vaccine development. Overall, the NIV has isolated 11 strains of the SARS-CoV-2. ICMR and Bharat Biotech will seek fast-track approvals to expedite vaccine development, subsequent animal studies and clinical evaluation.
Indian Immunologicals Limited (IIL), a leading vaccine maker has joined hands with Griffith University of Australia to conduct exploratory research and develop a lead vaccine candidate for coronavirus. They will use the latest codon de-optimisation technology. The technology looks promising for developing a vaccine for prophylactic, active, single dose immunisation against coronavirus in humans, with an enhanced safety profile.

Upon completion of the research, the vaccine strain will be transferred to Indian Immuno-Biologicals Limited (IIL) to further conduct clinical trials, which will be taken up in a phased manner. IIL intends to use its existing Vero cell platform technology for mass production of the virus, says Dr. K. Anand Kumar, Managing Director, IIL.

Meanwhile the IIT Kanpur, too, has joined the race to develop a vaccine. A team of researchers led by biophysicist Dibyendu Kumar Das is trying out two approaches — a subunit and a live attenuated.

The researchers have been working for the past three months. If the results are positive, they intend to test the vaccines in animal models, and hopefully reach human trials in three months.

On the drugs front, Indian companies are gearing up to take on production and ramping up capacities. Gilead Inc. has announced out-licensing of Remdevisir to three Indian firms — Jubilant Life Sciences, Hetero Drugs (which is a major player in ARVs and the manufacturer of Tamiflu for control of Swine Flu), and CIPLA, another major player in ARVs and affordable drugs.
ICMR Leads Fight Against COVID-19

Dr. RAJNI KANT AND Dr. ENNA DOGRA GUPTA

The COVID-19 pandemic has infiltrated into 215 countries of the world leading to 10 million infections and 0.50 million deaths. In the current fight against COVID-19, the Indian Council of Medical Research (ICMR), the apex body in India for the formulation, coordination and promotion of biomedical research, is working relentlessly to implement scientific interventions to combat the SARS-CoV-2 (COVID-19) pandemic. It is leading the mammoth task of testing and diagnosis of COVID-19. Reaching the copious number of per day current testing capacity in the face of a pandemic and in the shortest possible time span is a success story in itself. As on 28 June 2020, ICMR has crossed the figure of eight million in testing of samples, with a total of 83,98,362 samples tested of which 5,28,859 were found positive for SARS-CoV-2. It is interesting to note that there are only five countries that have crossed the eight million testing mark. Apart from testing, ICMR is involved in a plethora of aspects of COVID-19 research. This article summarises the response of ICMR to the COVID-19 pandemic.

ICMR has been on the forefront in the fight against Corona Virus since its beginning at Wuhan in Hubei Province of China (December, 2019) and detection of first case in Kerala in India (January, 2020). Corona Control Room was set up at ICMR Hqrs to develop appropriate strategies, strengthen ICMR-DHR Viral Diagnostic Research Laboratory Network and close monitoring of situation for preparedness. National Institute of Virology (NIV), Pune was the only lab that detected the 1st case of the Corona virus in the country in January, 2020 and developed RT-PCR diagnosis. Over the period of time ICMR escalated the testing capacity and capability from one lab to more than 1,000 labs working 24x7 for testing of COVID-19. ICMR expanded its activities from diagnosis and testing to validation and evaluation, procurement and distribution of reagents to conduct sero-prevalence and from developing guidelines/advisories to initiate research on COVID-19.

Ramping up the testing capacity

The testing capacity has been ramped up in the time-bound mission-mode with a current total of 1,047 government and private labs. To ramp up the testing capacity, ICMR has engaged with non-ICMR/MoH&FW Govt. laboratories to initiate testing facilities. This includes CSIR, DBT, DRDO, Govt. Medical Colleges, etc. ICMR has also engaged with high-quality National Accreditation Board for Testing and Calibration Laboratories (NABL) accredited private laboratories to increase access to the test while ensuring appropriate safeguards. ICMR has regular touch points with public and private labs and is resolving their issues related to logistics, approvals, reporting, etc., on a continuous basis. Fourteen institutes of national repute have been identified as mentor institutes for reviewing the requests for approving new COVID-19 testing laboratories.
Currently, more than 2 lakh samples are being tested per day. ICMR, in collaboration with NIC (National Informatics Centre) has prepared a data portal for streamlining the data collection from all the laboratories on a real-time basis.

**Formulating a National Testing Strategy**

The testing strategy is reviewed by national task force chaired by Dr. V.K. Paul, Member, NITI Aayog. The first strategy was formulated on 9 March 2020, which stated that all the symptomatic people who have travelled to countries reporting COVID-19 and symptomatic contacts of a confirmed case must be tested. The testing criteria has been revised five times as per the situation thus broadening the spectrum of people who should be tested. The current criteria include symptomatic people who have travelled abroad in last 14 days, all symptomatic contacts of laboratory confirmed cases, all symptomatic health workers, all hospitalised patients with influenza-like illness (ILI) symptoms, all symptomatic ILI patients within hotspots/containment zones, all symptomatic ILI among returnees and migrants within 7 days of illness, all patients of severe acute respiratory illness and asymptomatic direct and high-risk contacts of a confirmed case (tested once between day 5 and day 14 of coming in his/her contact). In addition, now multiple testing platforms are available to cater different needs including antigen testing. ICMR has a constant vigil on the national testing strategy in line with the current trend of the outbreak.

**Fast track mechanism for diagnostic kit validation**

In ideal situations, the validation of diagnostic kits takes much longer time. In the wake of fighting this pandemic, ICMR has instituted a fast track mechanism for validation of indigenous COVID-19 diagnostic kits (RT-PCR and antibody based). Taking risk/benefit ratio into account, the committee decided to recommend only those kits which show 100 per cent concordance with the positive as well as negative sample to mitigate any discrepancy which may lead to skewed results. Apart from validation, ICMR is also mentoring the indigenous kit manufacturers to improvise their kits and re-submit for evaluation. A total of 24 institutions are engaged in validation of diagnostic kits batch testing and supplies.

ICMR response to COVID-19 pandemic
In a short span of time, 56 RT-PCR kits and 13 antibody kits have been validated. The recommendations have been shared with the Central Drugs Standard Control Organisation (CDSCO) for taking it forward. In addition, all US-FDA/EU CE approved RT-PCR and antibody kits can be used for COVID-19 diagnosis after approval from Drug Controller General of India (DCGI) and intimation to ICMR.

In order to increase the national testing capacity, TrueNat-based indigenous point-of-care test for COVID-19 has been validated at DHR/ICMR VRDL (BMCRI, Bengaluru) and now included as a testing modality, using the equipment already deployed for diagnosis of tuberculosis. The Truenat™ beta CoV test has been recommended as a screening test. All positives through this platform will need to be reconfirmed by RT-PCR. The chip-based test is cost effective and allows for point-of-care testing due to its portability. Currently, there are over 300 Truelab™ workstations already deployed in country and these will be utilised for the testing.

**Procurement and pan-India distribution of COVID-19 testing supply**

ICMR has been entrusted with the procurement of RT-PCR kits, RNA extraction kits and virus transport medium (VTM). A number of ICMR institutes have been identified as lot testing and validation centres for the procured material. Along with procurement, ICMR is also taking a lead in pan-India distributions of testing supplies. Sixteen depots have been established across the
country for an uninterrupted supply of reagents to government testing laboratories.

**Disease prevention and management: The research aspect of the pandemic**

ICMR has isolated and sequenced the SARS-CoV-2 and its scientists are engaged in planning research studies to give insights into the virus, the disease, and its prevention and management. A national research task force in four research areas has been constituted: (i) Operational research; (ii) Epidemiology and surveillance; (iii) Clinical research; and (iv) Diagnostics. ICMR is coordinating a hospital-based clinical research collaborative, the ‘India COVID-19 Clinical Research Collaborative Network’, to enhance the clinical understanding of COVID-19 in the country to develop India specific treatment protocols, and push research and development in the field of drug development for the viral infection. Several research studies are being planned and conceptualised in collaboration with other science and research agencies (DST, DBT, CSIR, DRDO, DAE, ICAR) for developing research solutions to the COVID-19 situation.

**In-house diagnostics development**

At the time of the beginning of this pandemic, when very little was known about this novel coronavirus and there was dearth of testing facilities in the country. ICMR-NIV took
on the RT-PCR reaction. Considering the limited supply of positive controls and increasing demand for use in the national network of Viral Research and Diagnostic Laboratories (VRDLs) engaged with SARS-CoV-2 testing, in-vitro transcribed (IVT) RNA as positive controls for the screening and confirmatory assays was generated in-house at ICMR-NIV.

To conclude, the successful establishment of the RNA-based diagnostic system including the in-house positive controls has proved highly beneficial to provide a timely diagnosis to accelerate clinical management and isolate SARS-CoV-2 patients in order to control further spread.

In February, we supported 13 VRDL laboratories and today we are supporting 760 Government run laboratories throughout the country.

**Development of first indigenous human IgG ELISA kit for SARS-CoV-2 diagnosis**

ICMR-NIV has developed the first indigenous human IgG ELISA kit for SARS-CoV-2 diagnosis. Developed in a months’ time, it would help to study the presence of anti-SARS CoV-2 IgG antibodies in Indian population that would aid in future vaccine development. It is cost-effective, sensitive, and rapid. A large number of samples can be tested at a time and it can be used at any level of a clinical setting, public health centres and hospitals. The kit has been validated at three centres. The technology has been transferred to Zydus Cadila for mass production of the ELISA kits. The technology transfer was done in a record time to ensure early supply of kits.

**Undertaking a National Sero-Surveillance Initiative**

ICMR in collaboration with Department of Health and Family Welfare, Govt. of India and National Centre for Disease Control with support from State health departments and key stakeholders, including WHO India, conducted a community based sero-survey to estimate the prevalence of SARS-CoV-2 infection in Indian population. The survey was coordinated by ICMR’s National Institute of Epidemiology (NIE) and National Institute of Research in Tuberculosis (NIRT), Chennai.
This household level cross-sectional survey covered 24,000 adults distributed equally across four strata of districts categorised on the basis of reported cases of COVID-19. Overall, the survey was conducted in randomly selected 69 districts from 21 States. The results of the 1st phase of the survey indicated 0.7 per cent exposure, however, the further results of the survey will provide information about the spread of SARS-CoV-2 infection in different parts of the country and thus framing the future course of action.

**Vaccine development**

ICMR has partnered with Bharat Biotech International Limited (BBIL) to develop a fully indigenous vaccine for COVID-19 using the virus strain isolated at ICMR’s National Institute of Virology (NIV), Pune. The strain has been successfully transferred from NIV to BBIL and work on vaccine development has been initiated. ICMR and BBIL will seek fast-track approvals to expedite vaccine development, subsequent animal studies and clinical evaluation of the candidate vaccine.

Apart from the fully indigenous vaccine development initiative, ICMR has also collaborated with Serum Institute of India and Oxford University to fast-track phase I/II clinical trials of the live attenuated recombinant vaccine for COVID-19 developed by the Oxford Group.

**Drug therapy clinical studies**

In the absence of evidence of a successful clinical therapy, ICMR has taken lead in planning and participating in clinical studies for the evaluation of various drug therapy trials.

- **WHO Solidarity Trial**: ICMR has collaborated with the World Health Organisation for public health emergency Solidarity Trial — an international randomised trial of additional treatments for COVID-19 in hospitalised patients. The 5-arm trial will assess the efficacy of hydroxychloroquine, Lopinavir-Ritonavir combination therapy,

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National guidelines developed by ICMR
Interferon beta-1a and Remdesivir. The trial has been initiated on 30 April 2020.

- **Studying the side-effects of Hydroxychloroquine**: To guide evidence-based policy decisions, an observational study has been initiated to understand the benefits of using hydroxychloroquine in health-care workers. Five sites have participated in the study.

- **Plasma Therapy**: ICMR has developed generic protocols, selected sites, obtained requisite approvals and made essential preparations for roll out of phase II Randomized Controlled Trials (i) to understand the effect of convalescent sera in moderately ill COVID-19 patients (PLACID Trial); (ii) to study the effect of total plasma exchange therapy in severely ill COVID-19 patients.

### Guidelines for tackling various aspects of COVID-19

ICMR has developed guidelines ranging from preparation of network of government and private laboratories to ensure efficient validation/evaluation of new diagnostic kits. ICMR has also forecast requirements for testing equipment, kits, and manpower for the preparation in the worst-case scenario.

ICMR has issued guidelines to address the issues specific for liver transplantation, considering the impact of the outbreak of COVID-19 pandemic. These guidelines have been prepared by Liver Transplant Society of India (LTSI). The guidelines include various aspects of COVID-19 diagnostics before, during, and post liver transplant.

ICMR has also framed a guidance document for the management of pregnant women during the COVID-19 pandemic. This document guides healthcare facilities providing obstetric care for pregnant patients with confirmed COVID-19 or pregnant persons under investigation (PUI) in obstetric healthcare settings including obstetrical triage, labour and delivery, recovery and in-patient postpartum settings.

ICMR has recommended empiric use of hydroxychloroquine (HCQ) in the prophylaxis of SARS-CoV-2 infection in both asymptomatic healthcare workers involved in the care of suspected or confirmed cases of COVID-19 and asymptomatic household contacts of confirmed COVID-19 cases. Revised guidelines have been issued on 22 May 2020 which includes the findings of the effect of the use of HCQ as a prophylactic treatment in health care personnel.

In view of the increasing dangers of the COVID-19 pandemic, ICMR has appealed to the public to refrain from consuming the smokeless tobacco products and spitting in public places. Chewing smokeless tobacco products (like gutka, paan masala with tobacco, paan and other chewing tobacco products) and areca nut (supari) increases the production of saliva followed by a very strong urge to spit and spitting in public places that could increase the spread of the SARS-CoV-2.

ICMR has also prepared a guidance document for appropriate recording of COVID-19 related deaths in India. Robust data is needed from every district and state in India to measure the public health impact of COVID-19 and to plan for timely health interventions and protect communities. Apart from this, standard guidelines for the medico-legal autopsy in COVID-19 deaths in India have also been drafted.

### Conclusion

ICMR is catering to diverse national needs in these unprecedented times of COVID-19. It has played a major role in initiating and ramping up the COVID-19 testing in the country to isolating the SARS-COV-2 that lead to the development of ELISA kit and vaccine candidate. ICMR would continue to provide support in the fight against COVID-19 to the best of its capabilities. Since Covid-19 is a new and evolving disease, strategies to combat it are also being revised as per the situation. ICMR is having a close vigil on it and working accordingly with the support from Central and state Governments, various Science Agencies and other stakeholders.

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CSIR’s Five-Pronged Strategy to Fight COVID-19

UMASHANKAR MISHRA

Considering the multifarious problems created by the SARS-CoV-2, which require interventions in several areas and a multi-pronged strategy, CSIR has set up five technology verticals for addressing the emerging situation due to the pandemic.

The ongoing pandemic of COVID-19 is caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), which has proved to be a stubborn zoonotic killer. Over 10 million people have already fallen prey to this virus worldwide while more than 0.50 million people have lost their lives across the globe as on 28 June 2020. These numbers are increasing thick and fast with each passing day.

Indian Council of Medical Research (ICMR), Department of Biotechnology (DBT), Department of Science and Technology (DST), Indian Institutes of Technology (IITs), Indian Institute of Science (IISc), Defence Research and Development Organisation (DRDO), Council of Scientific and Industrial Research (CSIR) and other scientific institutions and universities are working at various levels to fight COVID-19.

CSIR is one of the largest public-funded scientific establishments of the world. Considering the multifarious problems created by coronavirus that require interventions in several areas and a multi-pronged strategy, CSIR has set up five technology verticals to address them.

In a review meeting held virtually, Dr. Shekhar C. Mande, DG, CSIR informed: “A Core Strategy Group (CSG) has been set up in CSIR and five verticals have been identified under which COVID-19-related activities are being carried out. These verticals are need-based and span multiple research labs and disciplines and draw upon the strength of scientists and students and harness it for the fight against COVID-19. These five verticals are surveillance, diagnostics, drugs, hospital-
assistive devices and supply chain.” In addition, CSIR is also working on promoting rural employment and providing ready-to-eat food to migrants. Awareness generation through outreach programmes has also been given utmost importance.

Given below is a brief account of the activities taken up by CSIR under each of the verticals. Read on.

1. Digital and molecular surveillance

Isolation and social distancing being key measures in containing COVID-19 outbreak, the goal is to be able to trace patients digitally, establish virus transmission chains and mitigate transmission. Further, identification of the strain of the virus and its sequence are critical towards understanding molecular epidemiology, which will assist in accurate diagnosis and development of suitable vaccines and drugs.

Towards this end, a digital surveillance platform has been built with the objective of integrating digital data, such as viral genome, deep patient data and disease course data, including outcomes. Integration of data, involves collection and segregation of data from multiple sources and linking them together. While Aadhaar could be used as a hidden private integrator, it is not available in most data. As such, the alternative is to have a unique ID and consented data tracing via an app downloaded at the time of initial testing, and a network of clinical and molecular partners.

The CSIR-Centre for Cellular and Molecular Biology (CCMB) and the Institute of Genomics and Integrative Biology (IGIB), along with a few other institutions, are working for the digital and molecular surveillance of the spread of COVID-19. With digital and molecular surveillance of the SARS-CoV-2, scientists are hoping to identify many of the unknowns about the virus. The surveillance centre has been established at IGIB where all the labs, research centres and hospitals will share their data through cloud sharing. The surveillance will be done at three levels: the genome sequencing of the virus, the patient, and the clinical course of the patient.

CSIR is building end-to-end capacity in this vertical and taking support from industry to come up with optimum solutions for digital surveillance. A platform for surveillance is being developed in partnership with Intel India. It is also working with the TATA Group for district-level screening in Kolar and large-scale screening centred on the TATA group employees.

CSIR-CCMB, CSIR-IGIB, and CSIR-Institute of Microbial Technology (IMTech) are doing sequencing of SARS-CoV-2 to ascertain if any genetic changes are occurring in the virus while it is spreading in the country. The information will help gauge the severity of disease in various geographical regions, in developing an ELISA (enzyme-linked immunosorbent assay) detection test, and ultimately a vaccine against SARS-CoV-2. Over 300 genome sequencing of SARS-CoV-2 have been done so far in various scientific institutions of the country, and this number is increasing continuously. Of this, 200 sequencing have been done by CSIR itself, as informed by Dr. Mande, during an interview on a national channel.

CSIR is working with the National Centre for Disease Control (NCDC) and with local hospitals also for pan-India representation for all these things. Using the testing data, to identify the asymptomatic-infected people and people who experience a mild impact, the study will also include infected people outside the hospital network. The surveillance will be
able to monitor the population in a community where the spread is virulent.

Accessibility to this data has been restricted to only government officials and on a need-to-know basis, while a part of it has been linked to the Aarogya Setu app recently launched by the government. The idea is to provide benefits to maximum number of people.

2. Diagnosis is the key to combat COVID-19

Accurate diagnosis is important for proper treatment and effective care of patients. That explains why CSIR has taken up diagnostics as another major vertical against COVID-19. CSIR labs are well-equipped with the technology and know-how of COVID-19 diagnostic tests and possess expertise in developing newer and rapid diagnostics.

CSIR is deeply involved in the testing of human samples using the RT-PCR test. Several of its laboratories are engaged in the work, which include CCMB, Indian Institute of Integrative Medicine (IIM), IMTech, IHBT, and NEERI. IGIB, IICB, NEIST, CDRI, IITR, NBRI, CIMAP, and CFTRI are a few others that are ready for testing. Laboratories, such as CLRI, NIIST and NIO, are supporting the state governments with RT-PCR machines.

When the need for testing increased in the country, CSIR came up with a new, faster, more sensitive, and cheaper diagnostic test kit called FELUDA. The FELUDA CRISPR/ Cas-based paper diagnostic test, developed by IGIB, can detect single nucleotide variants in RNA or DNA or more broadly any DNA or RNA fragment, without the need for sequencing.

CCMB and IGIB are also engaged in training of human resources for conducting SARS-CoV-2 testing. An indigenous diagnostic platform, namely Truenat, developed with the support of the New Millennium Indian Technology Leadership Initiative (NMITLI), has been approved for testing of the SARS-CoV-2 at the national level. It can capture data from the installed machines and feed the central database for surveillance purposes. About 1,000 devices are being used across the country for coronavirus testing. Some of the CSIR labs are also working as Diagnostics Validation Centres. Several Indian companies are coming up with new diagnostic kits that need to be validated by the government before accepting them and putting them to use. CCMB is the only non-ICMR designated validation centre and IGIB will soon become one.

3. Development of repurposed drugs/new drugs and vaccine

Developing new drugs against COVID-19 may take a few years despite the best efforts from the global scientific community. However, efforts are under way worldwide to fast-track and test the drugs approved or tested for non-COVID-19 diseases such as HIV or Ebola. It is this repurposing of drugs that CSIR took up as its third vertical.

India is also participating in some of the global trials and will also carry out its own clinical trials. The main focus of this vertical is on enabling quick access to drugs against COVID-19 for Indian patients as soon as they are developed in the country or globally. CSIR is exploring all possible options...
ranging from repurposed drugs to new drugs to Ayush products and biological therapeutics including vaccines.

CSIR is working on the synthesis of the top ‘potential’ repurposed drugs in case India goes for compulsory licensing so that the country can quickly launch the drugs for its patients. For this, it has tied up with top pharmaceutical companies, such as Cipla and Cadila. CSIR has established credentials in the synthesis of drugs and has worked closely with industry earlier too. It has also been the fountainhead of processes for generic drugs for which India is globally renowned.

**Clinical trials of Mw:** CSIR and Cadila have received regulatory approval for clinical trials to evaluate the efficacy of an existing gram-negative sepsis drug, called Sepisvac for COVID-19 patients. The drug contains heat-killed Mycobacterium (Mw) and is found to be extremely safe in patients. Also no systemic side effects are associated with its use. In Gram-negative sepsis and in critically ill COVID-19 patients, there is an altered immune response leading to a massive change in their cytokine profile. The drug modulates the immune system of the body and thereby inhibits the cytokine storm leading to reduced mortality and faster recovery. It can be used concurrently with any other therapies required in the management of such critically ill patients without any restriction.

**Small molecules and active pharmaceutical ingredients (APIs):** CSIR has been participating in advanced global clinical trials of repurposed drugs. The vital issues being tackled in this vertical are synthesis of key intermediates of these repurposed drugs, reducing India’s dependence on imports, hydroxychloroquine and APIs, initiating trials on indigenously repurposed drugs, and conducting clinical trials of phytopharmaceuticals and Ayush drugs. The following table gives a list of such drugs that are being developed:

<table>
<thead>
<tr>
<th>Name of drug</th>
<th>IP Status/ company</th>
<th>Status</th>
</tr>
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<tbody>
<tr>
<td>Favipiravir</td>
<td>Expired in 2019/ Fujifilm</td>
<td>Scaling up for regulatory purpose, currently with Indian regulatory authorities</td>
</tr>
<tr>
<td>Remdesivir</td>
<td>Patent valid till 2035/ Gilead</td>
<td>Gram-scale synthesis achieved, awaiting FDA approval and Gilead stance</td>
</tr>
<tr>
<td>Umifenovir (Arbidol)</td>
<td>Patent expired</td>
<td>CSIR made process development and industrial partners scaling up studies</td>
</tr>
<tr>
<td>Chloroquine/ Hydroxychloroquine (intermediate)</td>
<td>Generic</td>
<td>Gram-scale synthesis completed with starting materials available in India</td>
</tr>
<tr>
<td>Camostat Mesylate</td>
<td>Ono Pharma</td>
<td>Gram-scale synthesis completed</td>
</tr>
</tbody>
</table>

Source: [https://urdip.res.in/covid19/vertical3.jsp](https://urdip.res.in/covid19/vertical3.jsp)
Phytopharmaceutical formulation: CSIR and Sun Pharma are developing ACQH, a formulation developed for dengue being repositioned for COVID-19. The application for clinical trials has been submitted to DCGI and approval is expected soon.

Supplements: CSIR has filed an application for trademark for developing zinc gluconate and Vitamin C as nutraceuticals, which have been found beneficial in patients with SARS-CoV-2 infection.

Traditional medicines: CSIR is working with the Ministry of AYUSH to come up with prophylactic measures, symptom management, and add-on interventions to modern medicine treatments.

The following AYUSH botanicals/formulations have been taken up by CSIR and Ministry of AYUSH for clinical trials:

- *Withania somnifera* (CSIR, Pune University, Ministry of AYUSH)
- *Tinospora cordifolia* (CSIR and Medanta Hospital, Ministry of AYUSH)
- *AYUSH-64* (Ministry of AYUSH and CSIR): This is a four-herb formulation comprising *Alstonia scholaris*, *Picrorhiza kurroa*, *Swertia chirayita*, and *Caesalpinia crista*.

Inactivated corona vaccine: CCMB and Bharat Biotech are working together for inactivated COVID-19 vaccine development under the aegis of the NMITLI Programme.

Convalescent plasma therapy: The U.S. Food and Drug Administration has approved the use of convalescent plasma therapy as an experimental treatment in clinical trials, and for critically ill COVID-19 patients where there are no other treatment options left. The therapy involves taking the antibodies from the blood of a person who has recovered from SARS-CoV-2 infection and transfusing those antibodies into a person sick with that virus. This therapy has long been used to help kick-start a person’s immune system. The IICB proposal on convalescent plasma therapy was approved by the West Bengal government on 9 April 2020.

The trial has been planned involving IICB, Medical College Hospital, and ID & BG Hospital in Kolkata. Applications were submitted to the Human Ethics Committees and the approval has been received from all three institutes. The trial has been submitted for registration at the Clinical Trial Registry of India and would be submitted for regulatory approval. A dedicated ‘Epidemic Immune Monitoring Lab’ has been prepared for this programme.

SARS-CoV-2 cultures and cell lines for screening assays and testing: To take forward new drug discovery, a critical step is the establishment of viral cultures and assays for testing. CCMB has made considerable progress towards that and all the identified small molecules, natural products and phytopharmaceuticals will be tested once the platform is ready. It will also help in vaccine development.
4. Hospital-assistive devices and PPEs

A major challenge during the COVID-19 pandemic globally has been the severe shortage of ventilators and oxygen enrichment devices given that COVID-19 patients develop severe respiratory problems. Another critical requirement in this pandemic has been the need for personal protective equipment (PPEs) to the caregivers such as doctors, nurses, and paramedical staff.

CSIR has many high-quality engineering labs with the expertise of developing medical devices. NAL, CMERI, CECRI, CSIO and other labs are working actively in the development of ventilators and PPEs. For the production scale-up of these, CSIR has tied up with PSUs such as BHEL and BEL. Under this vertical, CSIR is developing ventilators, oxygen enrichment units, pedal-operated water dispensing taps, electrostatic disinfectors, PPEs, etc.

**Makeshift hospital:** CSIR is also preparing to address the unmet need of a large number of hospitals. Its constituent laboratories, namely Central Building Research Institute (CBRI), Roorkee, and Structural Engineering Research Centre (SERC), Chennai, have the desired expertise and can undertake the work of transforming existing schools into makeshift hospitals, and also set up on-site modular 2 to 4-bed transit hospital facilities as immediate measures. The laboratories also have expertise in setting up pre-engineered buildings by way of short-term measures.

CBRI, Roorkee, has made prototype make-shift hospital building. This design of the make-shift hospital is being implemented near Haridwar in Uttarakhand along with the State Government. A demonstration unit for COVID-19-related facility is also being set up by CBRI for NDRF at their 8th Bn Station in Ghaziabad.

5. Supply chain and logistics support systems

The supply chain initiative is to ensure, to the extent possible, that no user organisation (hospital, testing lab, ambulance network, health centre, mohalla clinic, police, municipality, etc.) ever runs short of what is needed to address the COVID-19 pandemic. Effectively, the platform is to assure security to any individual user who is infected with or at risk of infection from SARS-CoV-2 (doctors, nurses, hospital attendants, sanitation workers, police, etc.). This is expected to become the national benchmark for all future epidemics and a model for pre-emptive disaster relief.

The Supply Chain Vertical Team of CSIR is working with CSIR labs/unit scientists across the country, TCS, CII, and other third parties to set up information management and forecasting databases at the national level to capture demand and supply scenarios for key items that are required to address the COVID-19 emergency.

Scientists from all over the world are trying to devise effective ways to combat COVID-19. At the same time, the whole world is keeping a close watch on India as to how this country with a population of 130 crore is going to save its citizens from this deadly SARS-CoV-2. The early announcement of lockdown by the Prime Minister, when the infected count was less than 400, was well appreciated by the World Health Organisation (WHO). These efforts by Indian scientists can yield better results against the COVID-19 pandemic.

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COVID-19 and Artificial Intelligence: The Path Forward

ANKIT MANDERNA

Humankind has been hit by a disease which was mistaken for a flu but has turned out to be much worse. With hospitals jam-packed in countries which are badly hit by COVID-19, the pandemic is far from getting over. Governments across the world are advising their citizens to learn to live with the virus, till we get a vaccine in hand. As a result, Artificial Intelligence (AI) has become the focus, specifically because of the enormous possibilities it holds for the future of humanity. The role of AI has been a slightly debatable topic, but the outbreak of COVID-19 has certainly made people see this new-age technology in a different light. The coming years are going to be intriguing as the relationship between AI and healthcare is going to unfold in unexpected ways and could bring about a paradigm shift.

Artificial Intelligence (AI) is a term that we come across very often in this day and age. A concept that was a fun element in science fiction films has become a reality. Its influence is evident in various disciplines. Medical science, in particular, has benefitted immensely due to this technology. The unprecedented outbreak of COVID-19 has created a crisis throughout the world and put the health systems in a very precarious position. Despite all the technological advances that humans have made, COVID-19 has brought everything to a standstill. With our health systems, economies, the tech industry, etc., on the edge, the researchers, and scientists across all the fields are on their toes to deal with this global crisis and bring back “normalcy” again. Over 500,000 deaths and still no vaccine at hand, the COVID-19 crisis does not seem to be getting over anytime soon. This brings us to the question of how AI is helping in the present state of affairs.

Artificial Intelligence, a field which was predominantly considered to be concerning computer science, has swiftly made its way into other areas of our life, namely Sports, Agriculture, Healthcare, Defence, etc. The use of AI in different

(Credit: Hospital and Healthcare Management)
sectors has also come under fire because of the question of humans losing their jobs. The counter argument has been that AI will make completion of jobs more efficient, but the varied views make this technology a constant topic of debate. The $10 billion Joint Enterprise Defence Infrastructure (JEDI) contract between the American government and Microsoft for creating the US military’s “war cloud” exhibits that countries are willing to invest heavily in AI. The aim is to make defence operations more efficient and precise with the help of a combination of cloud computing and AI. India as a developing country has major potential in adding AI to its infrastructure.

According to the Economic Times, “The NITI Aayog has drawn up a plan for creating an institutional framework for AI in the country”. An increase of US$ 957 billion to India’s GDP by 2035 has been estimated because of the inclusion of AI. The Indian Government has launched an AI portal (https://indiaai.in/), where all the recent AI-related developments will be shared among the citizens of the country. This development has given a boost to AI enthusiasts, which will eventually help in strengthening the research activity in this field. Its use has made the diagnosis of your health much easier than before. There are several applications that help in the overall diagnosis of one’s health. The American 3D computer-animated superhero film Big Hero 6 has Baymax, an inflatable healthcare robot. But not just in films, you can download various apps from Play Store and App Store where you just have to enter symptoms and a possible cause or a certain health condition is identified.

The language barrier is something that still needs to be resolved for increasing the efficiency of such apps and to bring them at par with physical presence for diagnosis. Verily is an application that helps in predicting non-contagious and hereditary genetic diseases so that one can prevent potential threats and take precautionary steps beforehand. AI is generally used in diagnosis, drug development, and gene editing. The benefit of AI is the rapidity in the diagnosis as compared to a physical check-up. AI is also being used for genome editing in western countries. In genome editing, alterations to DNA can be done to change the characteristics of an organism. Although it has also received negative reactions, genome editing and AI are together making breakthroughs in medical sciences.

In the current COVID-19 pandemic caused by the virus SARS-CoV-2, since the virus spreads mostly through close contact via small droplets produced due to coughing, sneezing, and talking, the precautions are majorly based on maintaining physical distance and good hygiene which typically involves washing hands frequently and not touching one’s face. The Government of India and WHO both have issued strict guidelines for preventing the spread of the disease. The government has also pledged $15M to the vaccine’s alliance GAVI at the Global Vaccine Summit.

**COVID-19 and AI**

Over the years, psychologists, roboticists, and other professionals dealing with AI have predicted its powers and what all could be achieved with its help. With the outbreak of COVID-19 across the globe, the research community is trying to find patterns in the clinical trials and reports so that the nature of the virus can be predicted well.
in advance. Machine Learning, Deep Learning, and AI are the tools that are being explored by the researchers for this task and as a result some success has been achieved too.

Students at Cranfield University in the UK have designed “computer models that can identify COVID-19 in X-ray images. The models use computer vision and artificial intelligence (AI) to analyse chest X-ray imagery. It can classify information which would not normally be recognised with the naked eye and assist with the diagnosis of COVID-19”. COVID-19 open research dataset CORD-19 has been made free for researchers to work with new advances in AI and NLP (natural language processing). The data is available in abundance for AI experts to work out and develop technology that could directly help our healthcare professionals and ease the load off them.

AWS (Amazon Web Services) has launched a Machine Learning website (https://cord19.aws/) where a researcher can look for research papers related to COVID-19 and can also get answers to their queries.

A Singapore-based software and services provider, Ramco Systems, has prepared itself for this phase of COVID-19 by introducing face recognition and thermal scanning in their workspace. The first step in this new system is face identification in which after verification, the next step is thermal scanning wherein the employee is only allowed to enter when the temperature is found out to be normal. Staqu Technologies, a Gurugram-based AI startup, has developed technology to identify people who are not following social distancing norms. A French startup Clevy.io has introduced chatbots for the citizens so that they can search for government communications related to COVID-19. Chatbots are a type of Assistive Intelligence that is first in dealing and providing some user-based response which can be textual or in the form of an audio.

Chan Zuckerberg Biohub is working on a model that could estimate the number of undetected cases of COVID-19. In this model, Machine Learning is being used to quantify the number of undetected cases by analysing the mutation of the virus as it is being transmitted among the population. BenevolentAI is using an AI drug discovery platform which checks the efficiency of existing certified drugs in suppressing the spread of COVID-19. The development in the scientific studies related to COVID-19 is expanding the literature available for studying the virus and hence, researchers have more data at their disposal. While writing this article, one of the new developments is the identification of lack of smell (anosmia) as one of the symptoms of COVID-19.

BlueDot, a Canadian AI startup is amongst those tech firms which had warned about the outbreak of a flu-like disease (later identified as COVID-19) even before WHO released its notification about the same. BlueDot used an AI-based algorithm to go through various foreign-media reports along with air ticketing patterns to detect the spread of the pandemic. Johns Hopkins University and ETH Zurich together have made an interactive dashboard that tracks the COVID-19 infections across the globe. Vehant Technologies, which was conceived at IIT-Delhi is an AI startup that has developed FebriEye, a system that is equipped with thermal
temperature screening and a camera that monitors social distancing and face masks, a technique similar to Ramco Systems’. An application developed by the Government of India, called Aarogya Setu, is being used to alert people when/if they are around a COVID-19 infected person.

**Future trends**

Machine learning and deep learning are a subset of AI that can be referred to as powerful statisticians. The techniques used are a bit sophisticated and technical, therefore before introducing such systems, we have to make sure that both healthcare professionals and patients understand these techniques and are familiar with them. The learning of AI and NLP has grown exponentially in recent years, establishing a different growth from its parent branch, namely computer science. Courses in medical technology (Masters, Masters-PhD, and Ph.D.) are being offered by both AIIMS Jodhpur and IIT Jodhpur, where the two institutions can work in collaboration and develop products (devices and services) that the country can use to enhance its healthcare system.

Due to the COVID-19 outbreak, ‘Work from Home’ is on the path to becoming a mainstream mode of dispensing duties. The tech giants like Google and Facebook have declared that their employees need to work from home till 2021. Work from home has given a boost to internet services in the developing countries because the demand has increased manifold. With our homes equipped with adequate internet connectivity, the Internet of things (IoT) will make its way into society rapidly. The volume of online data will increase as more devices get connected to the internet, thus making the use of AI prominent across technological platforms.

Online education platforms have also seen a drastic increase in the user-base during this pandemic. The field of biotechnology, which was emerging slowly, has gained rapid growth lately with overnight success in some cases. Timothy A. Springer, a professor at Harvard Medical School became a billionaire when the shares of the company, Moderna Inc. skyrocketed after the COVID-19 pandemic crisis started.

**Summary and conclusion**

The use of AI in healthcare is far from perfect as it does not account for a false negative or false positive. It may lead to a treatment but will not be able to consider the unintended consequences. Since 100 per cent accuracy has not been achieved yet and is a distant target as of now, the question of responsibility remains very critical in case anomalies are found. Due to this, the use of AI in healthcare systems is still far from having a dominant or primary role. For now, it will be used as a secondary measure in dealing with healthcare issues. During the development database for AI, researchers need to have well maintained previous records because any tampering in the records will affect the course of treatment. The privacy of patients is a concern because the patient would not want their medical history to fall into the wrong hands.

One of the issues that AI encountered recently was when Facebook’s AI systems were shut down after automated chatbots stopped interacting in English and started developing their language. Later, the bots were programmed to converse only in the English language. A researcher can encounter such an unprecedented situation with AI, and this is one of the main reasons why they cannot be a dominant force in the near future.

COVID-19 has not only spotted the shortcomings in society, but it is also preparing the world for any such crisis in the near future. COVID-19 is not the first virus that humanity is faced with and it will surely not be the last. The amount of information exchanged and shared among research communities has strengthened the efforts in dealing with such problems. The future is very indecisive at the moment but how the researchers deal with the virus right now will bring about major changes in healthcare and will also determine the course of action in the field of AI.

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Unlocking the Code of COVID-19: Health & Risk Communication Hold the Key

Dr. MANOJ KUMAR PATAIRIYA

The National Council for Science & Technology Communication (NCSTC), which being the apex body of the Govt. of India as part of the Dept. of Science & Technology, has a mandate of evolving policy initiatives, implementation mechanisms and extending support for promoting science communication and scientific temper among masses in the country. In view of the COVID-19 pandemic and emerging threats to human life such as earthquakes, landslides, extreme weather events and other risks posed by different uncertainties in today’s scenario, the NCSTC has taken initiative to put together a National Health & Risk Communication Programme — Year of Awareness on Science & Health (YASH) to combat such risks and mitigate the crises with the help of public awareness and preparedness. The programme also intends to empower and enable people to take informed decisions especially when it comes to conflicting choices to reach a better solution to the crisis! A National Organising Committee has been formed to steer and implement the YASH programme at the national level.

The reports are alarming, surveys are disappointing, stories are worrisome, and the surroundings are suspicious! Each one of us looks at the other as a potential threat of virus, who knows who is a carrier! In the circumstances where there is no medicine, no vaccine, or no remedy available for COVID-19, communication, awareness and preparedness hold the key for combating the virus. However, often simple straight communication may not be sufficient unless people are made aware of the risks involved and attitudinal aspects inculcated into people’s minds so that eventually they become part of daily routines.

On the other hand, every next day we find information on various aspects on COVID-19 in abundance in the mass media, on social media, or through personal messaging. Be it a breakthrough of a miracle drug, a magic remedy, or high TRP value discovery of a vaccine, everything is presented in such a sensational manner that people often tend to believe such claims! Some may be true while some misleading. The common masses have to cope with this spurt in info-demic. Many times even the educated people are prone to confusion in the absence of correct and evidence based scientific knowledge on the subject.
The current scenario of the pandemic caused by COVID-19 has posed concerns and challenges all around. Scientific awareness and health preparedness can play a significant role to help correct the situation with translation and usage of authentic scientific information and to convey the risks involved. It can facilitate the communities to overcome the crises of knowledge deficit on the one hand and knowledge abundance on the other. It is equally important to deal with the problem of deficit of the right kind of knowledge and, at the same time, the abundance of fake and misleading information.

**COVID-19 Focused Awareness Programme**

The National Council for Science & Technology Communication, Dept. of Science & Technology, Govt. of India has come up with a comprehensive and effective science and health communication programme for promoting grass-root level appreciation and response towards saving and shaping the lives of the people at large as well as building confidence, inculcating scientific temper and promoting health consciousness amongst the masses.

In order to facilitate necessary actions and preparedness of the society to address the challenge, the strategies were worked out by involving academic, research, media and voluntary organisations. The translation and usage of authentic scientific and health information to communicate the risks and facilitate risk management, and immediate and effective science communication for promoting community-level response is necessary. A framework for a year-long campaign on science and health awareness and risk communication has been worked out. Health and risk communication in the society may eventually lead to informed decision-making by the people thereby promoting community preparedness and sustainable health hygiene culture in the country.

In view of the variety and spread of various programmes and activities on various aspects of science and technology communication and popularization across the country, especially the programmes centred on public health and hygiene, water and sanitation, hands-on science, media, and public awareness, etc., a comprehensive yearlong programme has been put together. The programme is targeted at different levels of stakeholders on health and risk communication focusing on COVID-19 for sustainable response to the health risks posed mainly by communicable diseases.

Various scientific interventions are required specially to address different areas in dealing with COVID-19 as per the NITI Aayog and role of communication interventions would be crucial, such as: new waves of infection and new transmission areas including urban-to-rural migration and potential acceleration during/after the lockdown; community-based resource mobilization in rural areas with limited public and private health system capacity including quarantine, testing and management of patients, panic and higher risks to health workers; building trust and anti-stigma atmosphere to address potential stigmatization of
returning migrants; and panic and/or fear and lack of trust amongst community vis-a-vis health workers. All these require a coordinated effort of risk and health communication involving all stakeholders in an effective manner.

The overall concept behind evolving such an initiative is not just to diffuse information among the masses and clarify public concerns but also to nurture an informed public response to reach a reasonable, thoughtful, and collaborative solution. The necessity of two-way risk communication process has also been highlighted in the context of COVID-19.

The NCSTC has been able to develop networking with several organisations and resource persons across the country through a range of high impact programmes and activities. It is to further develop the experience and implement a yearlong programme on health and risk communication on current and emerging issues covering science communication priorities related to the preparedness for disasters, crises, hazards, calamities and emergencies, health risks, climate change, Sustainable Development Goals (SDGs), occupational hazards, and lifestyle problems, risk prevention in digital technologies and cyber security, traditional and local knowledge practices for risk reduction, etc., and catering to the needs of different stakeholders.

The initiative is aimed at encouraging public participation in risk related reciprocal communication processes to open routes for better decision making and stakeholders’ involvement. This could entail incorporating explanations of risk assessment process, strategically addressing the different ways of target groups to interpret science and different notions of acceptable risks and attitudes.

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**Reaching the Unreached**

Science is interdisciplinary and the ability to communicate scientific ideas and technological solutions effectively across the disciplines fosters collaboration, creativity and innovation. Being able to communicate the relevance and impact of the technology and discoveries can enhance public participation by educating the society about the challenges being faced today and also help policymakers to chart new directions. An indicative set of objectives of science, health and risk communication programme includes, and is not limited to, the following:

1. To reach the unreached and minimize risks at all levels with the help of public communication and outreach activities at large.

2. To promote public understanding of common minimum science for community care and health safety measures like personal sanitation and hygiene, physical distancing, and maintaining desired collective behaviours, etc.

3. To develop and disseminate science communication software, enhance science coverage in mass media including illustrative interpretations specially to reduce the fear of risks and build confidence with a dose of necessary understanding.

4. To assess and rationalize community preparedness and perceptions.
5. To inculcate scientific temper for adopting sustainable healthy lifestyles, and nurturing scientific culture among the masses and societies.

**Health & Risk Communication Programme**

Risk communication by and large relates to situations where the life of the people at large is at risk. Be it an epidemic, a pandemic, risks of genetically engineered food, nuclear disaster, or extreme weather situations, these need to be addressed immediately with the right kind of approach and public awareness using interdisciplinary scientific knowledge and practices. Ongoing reciprocal communication among all beneficiaries is an integral part of the risk management process. Risk Communication is more than the dissemination of information and a major function is the process by which information and opinion essential to effective risk management is incorporated into the decisions of risk management.

Prof. Ashutosh Sharma, Secretary, Department of Science & Technology, has said, “In the absence of vaccines and cure for COVID-19, conveying the authentic best practices on cutting down on the transmission of the virus and its management are of paramount significance. For a widespread impact, our communication strategies have to be multidimensional, engaging, informative and delivered with speed and scale.

The National Health & Risk Communication programme has been planned and is being implemented in a big way with a mechanism of pan India presence and reach. State Councils of Science & Technology have been involved in the programme, which has three major ingredients: a) software/content development, b) capacity development, and c) dissemination and outreach.

Networking and training of communicators and volunteers for works related to community health would be an advantage. The activities are spread over six regions: East, West, North, South, Central and Northeast. Special communication modules may be developed depending on specially marked zones, i.e. Red, Orange, Green. Awareness software materials may be provided in regional languages including Hindi and English. Active and experienced resource persons may be roped in.

The project teams in various regions would channelize science communication activities towards translation and interpretation of authentic public health information and guidance in layman’s language. The activities undertaken to ascertain and fulfill communication needs are as follows:

1. The communicators and volunteers may be trained across the country to help spread health awareness in their respective areas and languages.
2. India is home to different faiths, customs, and belief systems. The science communication programmes need to be weaved into the cultural fabric of the nation. Science communication efforts by only refuting them and working in isolation may not penetrate well into the society and may experience a great deal of deviation. Generally, people tend to listen to the preachings of different faith leaders; this trust and belief on faith leaders can be harnessed for conveying scientific and health messages among the masses for their benefit.

3. Science cartoon (scientoon), comics-based information materials, audio-visual programmes, clips, etc.
4. Digital, e-books, pamphlets, booklets (digital/print), info-graphics, etc., may be prepared. Street plays, theatre, skits, puppetry, folklore, etc., may be developed.
5. Swasthya Yatra, Jatha, Vigyan Mela, exhibitions, gallery, etc., may be organised.
6. Webinars, Web-shops, online/offline lectures, conferences, workshops, etc., with different stakeholders are envisaged on the subject and beyond.
7. Collaborative programmes with other organisations, etc., are envisaged for current and post-crisis scenario; current and post-crisis campaigns to be worked out.
8. Handling info-demic, fake news, misinformation, etc.
9. Trust building between the people and healthcare workers to ensure fulfilling the needs of community through clarity of scientific messages.

10. Building local risk managers or opinion/learning facilitators vis-a-vis capacity of healthcare systems and access to the same.

11. Important community functionaries in rural areas: Panchayati Raj institutions—ward member, Sarpanch, Block representatives, Zilla Parishad representatives, etc., Self-help groups, Community-based organisations, community-based government functionaries, like ASHAs, anganwadi workers, Agriculture extension workers, teachers, and ANMs.

12. Important community functionaries in urban areas: Urban local bodies, Non-government organisations, Resident welfare associations, Community-based organisations.

13. Evolving and using community-based effective science communication approaches and software through virtual/digital interface (WhatsApp/SMS/ others) or traditional and creative yet non-physical contact modes for compliance with health instructions thereby reducing avoidable pressure on healthcare systems.

14. Applying local languages for risk communications with illustrative interpretations of scientific knowledge and for informing role and responsibility of people to support health emergency management.

15. Encouraging scientific evidence-based reporting by media to all stakeholders including health workers about affliction and redressal measures.

16. Encouraging personal sanitation and hygiene, locally making masks using the guidelines issued by the office of PSA, etc.

17. Developing science communication software on radio, video, films, books, booklets, science cartoons, and other science media related activities.

18. Activities under ongoing programmes to develop young change-makers for responding to natural or manmade disasters and calamities.

19. Folk media (puppetry, nukkad-natak, song, drama, etc.) based and digital science communication.

20. STEMM (it can be expanded as Science, Technology, Engineering, and Mathematics) demonstration activities, fairs and exhibitions, and target group specific outreach, etc.

21. Innovative approaches to communication would be an advantage.

In addition to utilising already available authentic materials developed by public organisations, i.e., ICMR, PIB, MoH&FW, and AYUSH, new information materials to be developed and disseminated to focus on risk and health communication.

**YASH: Year of Awareness on Science & Health**

In the current scenario of anxiety, depression and challenges, the translation and usage of common minimum science and authentic information to communicate the risks and facilitate risk management, an immediate and
effective science communication for promoting community level response was desired. In order to facilitate necessary actions and to ensure preparedness of the society to face the challenge and threat posed by the pandemic of COVID-19, the NCSTC has come out with a year-long programme “Year of Awareness on Science & Health” (YASH). The YASH programme has the various components to have a consolidated countrywide effort.

The inherent idea of the programme is to build capacities and enable communities to develop a sense of awareness, an analytical mind, and take an informed decision especially when it comes to healthcare and risk for their wellbeing. Some of the expected outcomes are summarised here:

1. Improved risk understanding amongst target groups, including working with local sensitivities, belief systems, traditions, and indigenous knowledge by way of using different channels of communication.

2. Attitudinal changes among target groups about appreciating risks, associated challenges, solutions, and coping with the situation with courage and confidence.

3. Better working relations with community leaders, influencers including faith leaders, doctors, etc.

4. Improved ability to clarify mis-perceptions, misbeliefs, and malpractices based on authentic knowledge duly verified by scientific process.

5. Trust in scientific competence of solutions/service providers.


7. Target group specific interpretations for emergency readiness and behavioural change.


9. Enhanced public participation in health and risk related reciprocal communication processes to open routes for better decision making and stakeholders’ involvement.

10. Availability of a range of science, health, and risk communication software in terms of publications, audio-visuals, digital platforms, folk performances, trained communicators, especially in regional languages to cater to various cross sections of society.

A feedback and evaluation mechanism would be incorporated into the programme. A report would be prepared and submitted at the completion of the programme to the Department. The risk communication initiative for sustainable health and future preparedness based on current and post COVID-19 approach offers a composite response to be brought in place.


As part of the programme, the National Council for Science & Technology Communication has
brought out an online multimedia resource guide on A-to-Z of COVID-19 in association with Anamika Ray Memorial Trust (ARMT), titled **COVID Katha — A Multimedia Guide for Mass Awareness**, which is extremely useful and exemplary science communication solution for the people at large in the present scenario and accessible freely on smartphone, laptop, computer, and other such devices with multiple information resources.

Dr. Harsh Vardhan, Hon’ble Minister of Science & Technology, Earth Sciences, and Health & Family Welfare, released the multimedia guide on 3 May 2020 on the occasion of the launch of the Golden Jubilee Celebrations of the Department of Science & Technology that enters 50th year of its glorious presence since it came into being in 1971.

While releasing the multimedia guide, the Hon’ble Minister said, “COVID Katha must reach out across the country and every citizen must read and watch it. It may strengthen numerous corona warriors with far reaching efforts of building mass awareness on current health and social crisis. It is designed to facilitate and update on the objective interpretation of scientific aspects, would also help build the much-needed trust between people and public health systems. The guide is an empowering measure to strengthening public understanding of science and health in the special context of COVID-19.”

COVID Katha presents different aspects from scientific to social regarding COVID-19 pandemic in a simple and lucid manner with the help of well-drawn scientoons equally interesting for children and grown-ups. The multimedia links offer updated information in text, visuals, graphics, animation and videos. As for the stress caused by the pandemic and resultant lockdown, it carries a variety of genres of communication, i.e. folk songs, puppetry, and folk arts like Kathakali to bring in infotainment and amusement. This dynamic and interactive multimedia
platform offers a completely new and innovative approach to public communication of science. Similarly, a variety of communication software is being developed including various forms, such as Science Fiction, Poetry, Drama, and Comics.

**Misinformation and Fake News**

Although it is important to ensure the proliferation of information regarding scientific breakthroughs among the masses, today new challenges have evolved in the field of science communication. One of the biggest challenges in the current digital environment is the faulty communication of scientific and technological issues including COVID-19. The major challenges among them are paid news, fake news, propaganda and several other issues with ethical dimensions due to the promotion of business interests and access to social media channels.

Prevalence and impact of paid news and fake news has become a global concern and their spread has been aided and exacerbated by social media. With media coverage being a regular activity and information being amplified across the internet, it becomes difficult to differentiate between actual news and fake news. As a result, general belief in scientific information has started breaking down which is not a good indication.

There is a need to curb the widespread dissemination of misleading and biased information to strategize the innovative initiatives in communication, especially for scientific organisations to avoid and deal with such issues of fake news, paid news and ethics particularly when it comes to reporting risks posed by epidemics or pandemics.

Certain mechanisms are being developed to address the menace of fake news by employing various methods and techniques to deal with the issues of misleading information. It is pertinent to say that an interactive platform for scientists, communicators and policymakers may offer a quick redressal of the issues of fake news and paid news by creating ethical awareness and practical wisdom to handle such issues. Fake news is a global concern and misinformation in digital age is a challenge for true science. There is need for an analytical perspective for breaking the fake news phenomenon and bringing in ethical dimensions while dealing with the issues through communication strategies and initiatives. Such efforts would help shape the way forward in effective science and health communication thereby connecting the masses to the authentic science news and foster global partnerships and innovations creating newer avenues and vistas in the field of science communication.

The Press Information Bureau (PIB), Ministry of Information & Broadcasting, has created a website and given an e-mail to verify the fake news and misinformation especially on COVID-19 issues. Similarly, the Indian Institute of Mass Communication (IIMC), Dhenkanal has brought out guidelines to address the issues of fake news in mass media. The Anamika Ray Memorial Trust (ARMT), Guwahati has launched a campaign with a newspaper...
group using mass media to curb the COVID-19 related fake news with the help of well-illustrated information and cartoons.

Health Consciousness: A Cultural Pursuit

India as a nation carries a great treasure of cultural and scientific heritage led scientific wisdom from time immemorial that is partly known as scientific temper in modern times! The important lesson that the novel coronavirus has taught to the world is Namaste! A major cultural practice to inculcate a sense of social distancing to avoid infection causing communicable diseases. Greeting each other with Namaste has been an integral part of Indian culture.

A variety of our cultural practices have scientific basis, be it food and spices with medicinal values, yoga and meditation with physical and mental rejuvenation and the festivals and rituals with seasonal and astronomical cycles, and Ayurveda, Pashu-Ayurveda and Vriksha-Ayurveda, etc., and so on. The world has now started realising the deep-rooted Indian concepts and knowledge systems of wellbeing, especially during the current outbreak of pandemic.

Communication Efforts

Reports on a number of activities on health and risk communication as part of YASH programme are pouring in. The Hindi version of COVID Katha has now come out and is available on the website dst.gov.in. The COVID Katha pages are being reproduced in alphabetical order and disseminated through Twitter and Facebook. COVID Katha has been reported to be translated in Khari, Assamese, Bengali, Tamil and other regional languages as a voluntary effort by various science communication enthusiasts.

Some 3,000 volunteers trained under different NCSTC projects across the country on health and hygiene and water and sanitation are contributing on health and risk communication in their respective areas by following social distancing measures.

NCSTC in association with Gujarat State Council of Science & Technology and Gujarat Science City has organised Citizens’ Science Webinar Series on “Science Communication & Awareness in the Time of COVID-19” during 10-16 May 2020, everyday between 10-11 am. Over 3,000 active participants joined through video conferencing from across the country and interacted with the experts from different walks of disciplines.

Preventive and proactive health and risk communication is the strategic mantra especially during public health emergencies like the current one. Much before the outbreak was declared as a public health emergency, India has been much ahead in implementing actions targeting core capacities, including augmenting healthcare systems, promoting breakthrough research, measures of social distancing and public awareness using a novel concept of ringtone messages of do’s and don’ts on cell phones and telephones, amongst others. Since the onset of pandemic, India has taken leadership and assisted neighbouring and other countries in multiple ways.

As our scientists and doctors are exploring new and innovative measures to minimize the risk, new solutions are going to be a tremendous support to our unified efforts towards mitigating COVID-19 pandemic. Effective science and health communication at mass scale with necessary health awareness will provide further reinforcement to these efforts.

Finally, COVID-19 also teaches us why investments in communication and education, research and healthcare including promotion of scientific temper are most crucial for the nations and societies!

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“CSIR fighting unitedly against SARS-CoV-2”

— Dr. SHEKHAR C. MANDE

At this point of time, all the constituent laboratories of the Council of Scientific and Industrial Research (CSIR) are fighting against the SARS-CoV-2. CSIR scientists are doing this at three levels. These involve finding ways to avoid infection and treatment protocols; coming up with techniques to detect and treat the disease; and developing medical instruments for interventions. The Director General of CSIR, Dr. Shekhar C. Mande speaks with Madan Mohan (MM) about the multifarious ways in which CSIR is contributing to the fight against the SARS-CoV-2.

MM: The entire nation is fighting the war against the SARS-CoV-2. CSIR is a premier scientific organisation of the country. How is CSIR contributing to this endeavour?

DG-CSIR: We have divided our laboratories into separate groups and given different tasks to each group. Some laboratories are working on finding medicines or vaccines; some are dedicated to developing testing protocols while others are working on making equipment such as ventilators, etc. I am happy to say that progress has been made in quite a few fields; so much so that technology transfer has also taken place.

MM: What are CSIR laboratories doing in the field of medicines and vaccines?

DG-CSIR: The CSIR laboratories involved in the field of medicines are currently working on about 10 drugs; some are totally new drugs while others are known ones that are being clinically tested for efficacy against SARS-CoV-2.

MM: Would you like to mention any such drugs?

DG-CSIR: Certainly. Indian
Institute of Chemical Technology (IICT), which is a CSIR laboratory situated in Hyderabad, is carrying out research on Favipiravir. IICT has successfully developed a synthetic process for this drug and transferred it to Cipla. This drug is recognised as a medicine for flu in China, Russia, and Japan. Thus, it may be a likely candidate to treat COVID-19 as well. It will soon be used in trials on COVID-19 patients. Similarly, the Central Drug Research Institute (CDRI), which is located in Lucknow, is carrying out research on the antiviral drug Avidol. It is used to treat flu in many countries. This will also be tried out on COVID-19 patients. Our laboratory in Jammu, the Indian Institute of Integrative Medicine (IIIM), is working on a drug named ACQH. This is a molecule that has been identified in India. It is a phyto-pharmaceutical molecule, i.e., it is derived from plants. It has been sourced from a district inhabited by the indigenous people. The molecule has been used to treat dengue, earlier. Dengue is also caused by an RNA-virus. This is the reason why a private company is repurposing it for use against SARS-CoV-2.

**MM:** Are you also working in collaboration with the Ministry of AYUSH?

**DG-CSIR:** Yes, we are carrying out research on four formulae provided by the Ministry of AYUSH. Our laboratories are testing these formulae from AYUSH to establish these in the context of modern medical science although these are recognised and used as antivirals in Ayurveda.

**MM:** What about vaccines? Is CSIR working on vaccines too?

**DG-CSIR:** Well, not on a separate vaccine *per se*. However, we do have a molecule named Mycobacterium W (Mw). This drug has been used to treat leprosy for almost two decades. Initial findings have indicated that this drug may be effective as a drug against COVID-19 too. That is why we began trials on this drug with Cadila. AIIMS at New Delhi, Bhopal, and Jodhpur along with PGIMER, Chandigarh, have initiated trials on seriously afflicted COVID-19 patients. These are blind trials, so we still do not have the full report. However, the results may be encouraging. We wish to test this drug as a prophylactic too. This is because studies indicate that it may be useful in prevention too!

**MM:** What steps has CSIR taken in the field of COVID-19 diagnostics?

**DG-CSIR:** We have developed quite a few tests. The Institute of Genomics and Integrative Biology (IGIB) in New Delhi, has developed a rapid paper test for COVID-19. It gives accurate and correct results in just half an hour. The technology has been already transferred to a private party. The test kit will be in the market shortly.

Similarly, the collaboration between CSIR and Reliance has resulted in a RT-lamp test which is a RT-PCR test, but it can give the result on the spot in just half an hour at a cost of less than Rs.100. It can be used in hospitals, clinics, railway stations, airports, ...just anywhere. This test kit will be available in the markets soon.

CSIR has been working on developing different diagnostic techniques depending on diverse needs. The Hyderabad-based Centre for Cellular and Molecular Biology (CCMB) has developed the next generation sequencing test. This test is important for large-population surveillance. You can test 50,000 samples in one go. So, if you want to test for coronavirus in a city or district, you can carry out the tests on a large scale. This test will be launched in the market in association with a private company.

**MM:** And what about the equipment for testing for COVID-19? What is CSIR doing in this field?

**DG-CSIR:** We had a dearth of ventilators in our country. We have designed ventilators and transferred the technology to BHEL. Our equipment includes affordable ventilators that cost just Rs. 10,000 each. The National Aerospace Laboratory (NAL) in Bengaluru, has designed a special BIPAP ventilator which has significant ease of operation for the not-so-seriously afflicted patients of COVID-19. It can be used just like a face mask. Developed in a record time of just 36 days, it has been named Swasthya Vayu. It is being tested at the Manipal Hospital in Bengaluru. This ventilator will be available in the markets soon.

In addition, CSIR has developed...
and transferred technology for an electrostatic spray machine. It can decontaminate an area or place of SARS-CoV-2 infection. The Central Scientific Instruments Organisation (CSIO) in Chandigarh, has designed it. It sprays droplets of 10-20 microns and easily targets the coronavirus.

**MM:** What do you think about the means being adopted to stop SARS-CoV-2? Do you think we can emerge victorious soon?

**DG-CSIR:** Scientists have joined hands to fight the virus. In our country, significant steps have been taken at different levels to fight the SARS-CoV-2. All Departments are cooperating in this fight and good results are sure to emerge as a result.

**MM:** As a scientist, how long do you think it will take for us to triumph over the SARS-CoV-2?

**DG-CSIR:** This is a new virus. Initially, we knew little about it. Our knowledge about it was limited. However, now new knowledge is coming forth regularly. Scientists are gaining in-depth knowledge about this virus. So, by the next 5-6 months scientists will be able to claim victory over it...either by means of medicines or by vaccines.

**MM:** CSIR is working on so many drug candidates. How hopeful are you of success?

**DG-CSIR:** In research, especially in the field of drugs and vaccines, you cannot predict which drug or which vaccine will be successful. However, it is clear that more the number of candidates for drugs and vaccines being vetted; the higher are the chances of success.

(Translated by Dr. Sukanya Datta)

“Combating COVID-19 requires tough regimes of care and treatment”  
— Prof. R.K. DHAMIJA

Prof. R.K. Dhamija (MD, FRACP, FRCP), a prominent neurologist, is currently heading the Department of Neurology at Lady Hardinge Medical College, New Delhi. He is Advisor of the Royal College of Physicians (London) in India. He is also the Chair of the Movement Disorders in World Federation of Neurorehabilitation. He was awarded the 33rd S. Radhakrishnan Memorial National Medical Teacher Award in 2017. Dr. Manish Mohan Gore (MMG), Scientist with CSIR-NISCAIR, spoke with him on the neurological and various other health aspects related to COVID-19.
**MMG:** Sir, thank you so much for agreeing to this interview for Invention Intelligence. The pandemic of COVID-19 has impacted the whole world. In our country, COVID cases are increasing day by day. Do you think the efforts of our hospitals are effective enough to combat the COVID-19 pandemic, especially in the context of India?

**Prof. R. K. Dhamija:** Thanks for this interview session and I appreciate this endeavour in understanding implications of the COVID-19 pandemic which is of immense public interest in present time. It is true and is expected that the number of cases will increase in coming days due to enhanced public movement. Our health system has been geared up in last three months to meet this challenge. We have augmented our hospital beds, testing capacity, ICU beds, availability of ventilators, etc. Our hospitals in most parts of the country are now well equipped to admit and treat COVID-19 patients. One of the most important things the government has done during the lockdown period is setting up more than 600 labs for testing in less than three months.

**MMG:** What do you think about the new guidelines on the hospitalisation of COVID-19 patients in our country? Patients with no symptoms or even mild symptoms are carrier of SARS-CoV-2 infection. If they are not admitted, chances of infection might be increased. How could the possibilities of such infection be reduced?

**Prof. Dhamija:** Ministry of Health and Family Welfare has come up with new guidelines for treatment of mildly positive or asymptomatic COVID-19 patients. These guidelines are evidence-based and in line with international norms. For self-isolation, there are strict protocols for these patients, like they need to have a separate room with washroom and only one specific attendant to look after; in addition to other advisories. They have to be monitored daily by surveillance teams. Patients are allowed self-isolation at home only if they meet these mandatory requirements; otherwise, they are admitted to quarantine facilities. As such, there is very little chance of spread if these requirements are met and they are isolated.

**MMG:** Studies reflect that older population and children are more vulnerable to SARS-CoV-2. Hence, they are advised to remain at home, which may cause psychological effects. You are a neurologist. So, I would like to know from you how older people and children can cope with this unforeseen situation of lockdown. In what ways, they could keep their body and mind calm as well as active?

**Prof. Dhamija:** The vulnerable groups, including elderly persons with co-morbidities, are at a higher risk and need to take extra precautions with minimal movement and contact with others. The social isolation and shielding of elderly for a long time in lockdowns can lead to mental health issues, especially when there is no support from community or family. We suggest that social cohesion rather than social isolation while maintaining physical distance is a better option. This group of individuals should be encouraged to keep in touch with their family and friends through digital communications, etc. Children, on the other hand, seem to be less affected than the
general populace from COVID-19 but peer-reviewed and reliable research is still lacking in this area.

**MMG:** Older people are frightened, and they often take this pandemic as an untimely death threat. How can they overcome this mental and psychological state of anxiety?

**Prof. Dhamija:** This is true that COVID-19 has higher mortality in the elderly as they have a weak immune system which can behave in an aberrant manner. They also tend to have multiple other illnesses like diabetes, hypertension, neurodegenerative and lung diseases, among others. The best way is to stick to basic precautions of hygiene, physical distancing, face mask and self-screening. We also need to educate them, reassure them, and encourage them to digitally connect with their family and caregivers through this crisis.

**MMG:** Research findings indicate that the novel coronavirus is highly unpredictable, and its characteristics are mysterious as well. If we focus on the Indian scenario, we need to find out the types of COVID-19 cases that are coming and the impact of this disease that is expected to happen in future. Also, how should we be prepared to meet the coming circumstances?

**Prof. Dhamija:** You are right. We are battling against a new virus about which we still do not have much reliable research. There has been a learning curve for all of us about the way the virus is behaving in terms of its infectivity, natural history, pathogenesis, and immunity in addition to testing with different treatment modalities. The disease spectrum is also changing in terms of its clinical features. Now it is well known that COVID-19 goes beyond fever, cough, and breathlessness. This virus can attack heart, kidney, brain and other systems of our body in some cases. We need to be vigilant of this aspect and suspect COVID-19 in other sick patients attending our hospitals or admitted under our care who may not show typical respiratory clinical features. We need to educate our healthcare professionals about these unusual manifestations.

**MMG:** Large sections of the population are apprehensive of a big crisis constantly attendant on their psyche. They are aware and even taking the best possible precautions whatsoever. But they feel emotionally and mentally insecure. How can they come out from this mental crisis?

**Prof. Dhamija:** COVID-19 is now emerging as a multifactorial disease with its ramifications going beyond a simple viral illness. The rising number of cases we see every day is bound to scare people in the community. However, timely and proactive government action has galvanised our response in terms of our preparedness to treat these patients. Numbers will still be a concern but the good reassuring thing is that we have a high recovery rate and low death rate. The best way to handle the anxiety and emotional imbalance is to keep away from too much exposure to COVID-19 information and misinformation through electronic and social media and adopt relaxation techniques like yoga and meditation which are best healthy practices in terms of helping us coming out of this crisis.

**MMG:** The battle against COVID-19 will be fought equally by science in tandem with technology. How can the technological innovations be utilised to combat such a pandemic?

**Prof. Dhamija:** SARS-CoV-2 is once in a century pandemic. We, in the scientific community, are collectively facing this challenge. At the same time, this is also an opportunity for us to make use of technology in terms of bringing out better methods for testing seroprevalence (cumulative exposure to infection) in the population, and diagnostic technologies in terms of genomics and proteomics. Technology can also aid in devising new methods to improve hygiene and sanitisation, PPE kits and face masks. Tele-medicine and digital health are the way to go in the post-COVID-19 era. Contact tracing apps like Aarogya Setu are another helpful method in combating the pandemic. Most of these tech-based measures have been initiated by the government in the last three months.
Vaccine development is in full swing with more than 100 candidate vaccines, including in the Indian institutes. We are seeing some significant advances in how new vaccines are prepared and trialled with the timelines being compressed 10-fold or more from previous instances of vaccine development. We have also seen really encouraging international collaborations with countries, institutes, pharmaceutical companies and international aid organisations working together to solve this challenge.

**MMG:** How effective is plasma therapy for the treatment of COVID-19 patients?

**Prof. Dhamija:** Plasma therapy has been used in some other diseases. This modality is very promising and can be effective. Clinical trials are underway in our country to evaluate its response and in the next few months we would know its utility in clinical management of COVID-19. But we have to make sure to explore all the avenues and not to limit ourselves to one type of treatment which might not be successful for all patients or be delayed in trials.

**MMG:** Do you have any innovative idea to make the common man scientifically aware about COVID-19, its infection chain, precautions to be taken, and prevention?

**Prof. Dhamija:** We need to break the chain of this virus. It is highly infective and spreads from person to person very quickly. We need to outpace the virus spread using technology. I would strongly recommend everyone to use the contact tracing app Aarogya Setu which is one of most important tools to prevent the spread of the infection. We can devise better ways of maintaining hygiene, working from home where possible, maintaining social distances in offices and using tele-medicine for consultations. Rapid and better communication strategies, data sharing amongst public health authorities and devising clinical protocols are other areas which can go a long way in tackling this pandemic.

**Prof. Dhamija:** This is a very important question in terms of healthcare delivery during the post-pandemic time. One of the time-tested areas in medical science is telemedicine, which has been in practice since the last 20 years. But it has not gained momentum because of its legal status as well as the reservations from both the medical fraternity and public. This pandemic has given a push to telemedicine and digital health. Both the Government of India and the Medical Council of India have legalised telemedicine as a clinical tool. The immediate advantages of telemedicine include providing healthcare services to people who are placed remotely via video calls, tele-consultations and many other virtual platforms. This will also reduce the hospital visits and burden on out-patient departments. Regular monitoring and follow-ups can be done while the patients are in self-isolation even when the doctors are also under quarantine. This will also increase the safety of patients and healthcare workers from the COVID-19 by avoiding hospital visits. Telemedicine has been quite useful during the lockdown period also when there was problem in transportation and it was difficult to physically reach hospital for non-COVID conditions.
“COVID-19 has improved the efficiency of National Innovation System”

— Dr. H. Purushotham, CMD, NRDC

The National Research Development Corporation (NRDC), over six decades of its existence, has developed a wide network with R&D organisations, viz., CSIR, DRDO, ICMR, ICAR, universities, industries, industry associations, NGO’s, etc. NRDC nurtures new ideas and inventions by providing support and rewards, ensuring intellectual property protection; effective transfer of know-how from laboratories to industry; providing access to new technologies from India and abroad; exporting Indian technological expertise; and offering an array of technology consultancy services. To combat COVID-19, all these organisations have risen to the occasion and come out with various innovations and technological solutions. Aligning itself with the fight against COVID-19, NRDC has brought out a widely appreciated Compendium of Indian Technologies for Combating COVID-19.

Dr. H. Purushotham, Chairman & Managing Director, NRDC, in a conversation with R.K. Anthwal (RKA), Sr. Editor, Invention Intelligence, talks about his initiative to bring out the Compendium and other issues related with the current pandemic.
RKA: Recently, NRDC has brought out a Compendium of Indian technologies for combating COVID-19, which was widely covered by the print and electronic media, and some social platforms. Please tell the readers of Invention Intelligence about this compendium.

Dr. Purushotham: India reported, first case of COVID-19 on 30th January, 2020 and since then the number of infected persons is rising. India’s proactive, preventive and productive approach to fight COVID-19 pandemic were implemented under the eminent leadership of Hon’ble Prime Minister of India, Shri Narender Modi Ji. At present there is no known specific, effective and proven treatment and vaccine for the disease available worldwide. In this critical situation, Government of India has sanctioned relief package of `20 lakh crores to help citizens most affected by the novel corona virus outbreak and `15,000 crore towards Covid-19 emergency response and many more initiatives including activating programmes like “Make in India”, “COVID-19 Task Force” etc. to fight against the pandemic. It has geared up various Science Ministries, Departments and funding organisations to battle this pandemic with all its might. Government of India aimed at screening and early detection of SARS-CoV-2 infections accurately, and rapid drug repurposing, providing training to young microbiologists on Covid-19 diagnostics and developing drugs and vaccines. Many creative, low-cost and hi-tech innovative solutions and technologies have been developed and a number of projects are at research and validation stage in record time of 2-3 months.

National Research Development Corporation (NRDC) has made an attempt to compile most relevant and emerging indigenously developed technological innovations, including those which are at advanced research stage, to fight COVID-19 for the benefit of the stakeholders. The document comprises information about 200 various COVID-19 related technologies, ongoing research activities, projects at proof-of-concept stage, technologies available for commercialisation, initiatives and efforts taken by the Government of India, categorized under 3Ts of Tracking, Testing and Treating. This Compendium of Indian Technologies for Combating COVID-19 shall serve as a ready reference for policy makers, industries, entrepreneurs, start-ups, MSMEs, research scholars, scientists and other stakeholders.

The compendium prepared by NRDC was launched by Dr. Shekhar C. Mande, Director General, CSIR and Secretary DSIR, Govt. of India, at CSIR HQs, New Delhi on 6th May, 2020. Dr. Shekhar C. Mande acclaimed Dr. H. Purushotham, CMD, NRDC and his team for this initiative for the benefit of public at large.

I complement the National Innovation System/Triple Helix. Players mainly comprises of Academic / National R&D Laboratories, Industries/Start-ups, Regulating Authorities and governments who have raised to the occasion and developed about 200 technologies in 2-3 months. I feel that the NIS / Triple Helix worked at its highest efficiency in developing innovative solutions for combating COVID-19 and implementing the containment strategy effectively.

RKA: What are some of the major technologies covered in the Compendium?

Dr. Purushotham: Some of the major technologies developed by Indian institutions such as CSIR, DRDO, IITs, DST, DBT, BIRAC, Start-ups and Corporates, etc. under the 3Ts are:

**Tracking & Surveillance:**
- Aarogya Setu
- COVID India Seva
- Digital & Molecular Surveillance
- Machine Learning Model
- Jarvis-AI based Thermal Camera

**Testing/Diagnostics:**
- Real-time PCT Test Kit
- Chip based RTPCR Test Kit
- Paper based Testing Assay
- Reverse Transcriptase Loop Detection device
- Probe Free Detection Assay

**Treatment & Preventive**
- Mist Sanitizer System
- Personal Protective Equipment
- Nasal Gel
- Disinfection Walkway
- Portable Isolation Chamber
- Fifatrol
- Drugs & Vaccines in Clinical Trials Stage: ACQH, MW, Favipiravir Chloroquine or Hydroxychloroquine (ICMR approved as preventive medicine)

Hon'ble Prime Minister Shri Narendra Modi pledged USD 15 million as Indian contribution to the Vaccine alliance GAVI at the Global Vaccine Summit hosted by UK. India has emerged as the global vaccine hub. The six Indian companies are in race to make the 1st COVID-19 vaccine are i.e. (i) Zydus Cadila (ii) Bharat Biotech (iii) Indian Immunological Ltd., (iv) Biological E Ltd. (v) Serum Institute of India and (vi) Mynvax.

**RKA:** How far has NRDC travelled in the direction spelt out in the Compendium?

**Dr. Purushotham:** Most of these technologies compiled in the compendium are proof-of-concept (POC) tested and can help the entrepreneurs to take the product to market faster as they do not have to reinvent the wheel. Several of the technologies related to PPEs, diagnostics and testing of COVID-19 compiled in the compendium are approved by ICMR.

NRDC has already transferred the technology for mass production of the first breathable, uncoated untapped using SSMMS fabric PPEs to six companies. The PPE technology was developed by Indian Navy and IPR’s protection were facilitated by IPFC-DGQA-Ministry of Defence and NRDC.

**RKA:** What role do you envisage for NRDC in the present and post COVID-19 scenario?

**Dr. Purushotham:** COVID-19 pandemic has profoundly influenced the lives of most people on the planet. It has changed daily activities and businesses. New patterns of consumer and worker behaviour and expectations have emerged during this crisis.

During the post-COVID-19, NRDC has been and shall be playing a catalytic role connecting the innovations that are being developed by various research groups to innovators, entrepreneurs, start-ups and Corporates for mass production.

During the COVID-19, NRDC has been actively engaged with stakeholders though several webinars to communicate the challenges and opportunities, the COVID-19 brought on R&D, innovation and on the overall Indian economy and the strategies to be adopted to overcome the challenges posed by COVID-19.

The Modi Government launched the ambitious “Atmanirbhar Bharat” which envisages building self-reliant India. This brings lot of opportunities for indigenous development of technologies and their subsequent transfer to industry.

Moreover, the new Science, Technology and Innovation (STI) policy which is on the anvil, also brings lot of opportunities to NRDC to implement the STI policy. Considering its vast and diverse experience of over more than six decades on innovation promotion, NRDC shall play a major role in promoting commercialisation of the indigenous innovative technologies.

In view of the emerging national and international opportunities
in the innovation space, particularly post COVID-19, NRDC is expected to play an effective role in implementing the govt. policies and leverage the market opportunities for its robust growth.

**RKA:** How can the COVID-19-induced crises by turned into an advantage in terms of technological innovations?

**Dr. Purushotham:** Coronavirus sparked a wave of innovation and rapid technological dissemination and advancements in India. Across the country, scientists, students, entrepreneurs and innovators have quickly responded to the challenge posed by COVID-19 and devised new apps, robots and ventilators to help overcome the pandemic. Even educational institutes having the wealth of trained engineering and medical young talent considered this challenge as opportunity and worked with frugal innovation mindset to find hacks to problems with limited resources.

As experts say we need to live with coronavirus until a vaccine is successfully developed. This uncertainty and crises the humanity is currently facing can only be solved through application of Science, Technology and Innovation.

The researchers and governments across the globe will be continuing their efforts to come out with effective innovation and sustainable solutions for combating the global crises caused by COVID-19 in terms of health and economic challenges.

Artificial intelligence, virtual reality, data modelling, automation and data management technologies have also played a critical role in everything from tracking the outbreak and providing scenario planning, to helping quickly build medical devices, repurposing of vaccine candidates and even support for research in finding viable treatment and applying the ICT platform technologies and innovations are going to play a major role in the time to come.

**RKA:** What are the opportunities and challenges COVID-19 brought to the National Innovation System (NIS)?

**Dr. Purushotham:** As highlighted above the COVID-19 has impacted severely on the health of the public and economy of the nations across the globe in more than 215 countries, and national R&D, innovation and startups ecosystem are no exception. Due to lockdowns, the supply chains were broken, liquidity of fund got disrupted, institutions were closed, markets were closed. Due to COVID-19, a new norm of life is being evolving. All these challenges could only be solved by leveraging Science, Technology and Innovation as was done in the past.

In my opinion, COVID-19 has improved enormously the efficiencies of national innovation system. For example, the govt. departments funding COVID-19 R&D projects have shortened the rigorous evaluation processes without losing focus on the quality of evaluation, a new class of entrepreneurs and business models have emerged to leverage the market opportunities. As Shri Amitab Khant, CEO, NITI Aayog said “Thanks to the Covid-19 pandemic a new market estimated to be worth of at least 10,000 crores has popped up from nowhere in two months in India”.

Furthermore, due to geopolitical changes and disruptions in the supply chains particularly from China, many developed economies like USA, Europe, Japan, and Australia are looking towards India as a destination for establishing global supply chains which can contribute significantly to the Make in India Mission of Govt. of India.

To overcome the ill-effects of COVID-19, the Govt. of India has launched a flagship programme “Atamnirbhar Bharat”, under which it is envisaged to build a self reliant India. In building self reliant India, R&D, innovation entrepreneurship and start-ups will have to play a major role and the future for National Innovation System (NIS) is very bright.

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Viruses and Their Invisible World: Some Glimpses

Dr. SUBODH MAHANTI

We are living in unprecedented troubled times as the global COVID-19 pandemic rages on. A virus, named SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2), has caused the COVID-19 pandemic. The pandemic has not only spread far and wide, but it continues to spread even further. There is no doubt that it will leave a huge footprint.

Viruses are responsible for many deadly diseases. The study of viruses, which are classified as non-living, began more than 100 years ago but their origins are still unclear. Viruses are parasitic in nature and they cannot reproduce on their own, yet they have persisted and diversified for billions of years. They are not part of the evolutionary tree of life. Viruses are among the smallest pathogens; they are invisible. They spread in many ways. Dealing with deadly viruses remains a major challenge for humankind. Today, in view of the ongoing pandemic, it has become important to understand what viruses are and how they work.

Viruses are by far the most abundant biological entities on Earth. So far about 5,000 different viruses have been described in detail. The concept of virus as a distinct entity dates back to the 1890s.

Viruses may be seen as the ‘dark matter’ of the biological world. They have managed to maintain their existence for billions of years without being alive. They carry genetic information from the past, reproduce in living hosts and they evolve through natural selection.

Viruses are invisible to the naked eye. They even cannot be seen with an ordinary microscope and are visible only under electron microscope. Most viruses are approximately one hundred times smaller than an average bacterium. Viruses range in size from about 20 to 300 nanometres (1 nanometre = 10⁻⁹ metre). A typical E. Coli bacterium has a diameter of 1,000 nanometres.

Some viruses may be much bigger than the usual ones. One of the largest and most complex viruses to date is the Mimivirus (Acanthamoeba polyphaga mimivirus — APMV). The virus has a total particle diameter of approximately 750 nanometer. A second strain of the Mimivirus, presently known as ‘Mamavirus’, may be even larger. Mimivirus contains more than 900 protein-coding genes. Its genome is twice as big as that any of the other known viruses. In fact, its genome is bigger than that of many bacteria. Scientists believe that studying the genes found within the Mimivirus genome will not only help them to understand the evolutionary
history of the Mimivirus but it will also help them in throwing some light on the question of evolutionary history of all viruses. The Mimivirus was first observed in 1992 by a research team headed by Bernard La Scola and Didier Raoult, but the researchers thought that they had discovered another pneumonia-causing bacterium. However, in 2003, they showed that what they had discovered in 1992 was, in fact, a giant virus and not a bacterium. The discovery of the Mimivirus, is an interesting episode of scientific inquiry. After Mimivirus, virologists have discovered much larger viruses namely, Megavirus (2011) and Pandoravirus (2013).

Tracing the origins of viruses is not an easy task. They do not leave fossils behind them. The origins of viruses are yet to be fully understood. Presently there are three main hypotheses to explain the origin of viruses:

1. **The Progressive or Escape Hypothesis**: According to this hypothesis, viruses originated from genetic elements that had acquired the ability to move from cell to cell.

2. **The Regressive or Reductive Hypothesis**: According to this hypothesis, viruses are remnants of cellular organisms and they became parasitic to persist over time.

3. **The Virus-first Hypothesis**: According to this hypothesis, viruses existed before or co-evolved with their cellular organisms, which acted as their hosts. So, viruses may be considered as relics of pre-cellular life forms.

David R. Wessner of the Department of Biology, Davidson College, North Carolina, USA, in his article entitled “The Origins of Viruses” published in *Nature Education* (2010), has argued that no single hypothesis may be correct. It might be possible that viruses originated multiple times via multiple mechanisms (https://www.nature.com). In view of above, the study of the evolution of viruses remains a fascinating subject. It may also throw some light on the very question of the origin of life itself.

The name ‘virus’ is derived from the Greek word meaning ‘slimy liquid’ or ‘poison’. In early years of their discovery, viruses were referred to as ‘filterable agents’. In those days, the term ‘filterable agent’ was used to refer to a germ, which was able to pass through a filtering device that could remove other large germs like bacteria and parasites. The term ‘virus’ was originally used to describe any infectious agent. Subsequently the term ‘virus’ was restricted to ‘filterable agents’, which required a living host for their reproduction.

A virus is a nanoparticle of biological origin. A virus particle consists of a protein shell and an inner core, which is called virion. The core contains nucleic
acid, which may be ribonucleic
acid (RNA) or deoxyribonucleic
acid (DNA). The protein shell of
a virus that protects its genetic
material from the outside is
known as capsid. The virion
core is responsible for infectivity.
The protein shell or capsid of
the virion confers its specificity.
The capsid of a virus is made
from proteins encoded by the
viral genome. A viral capsid has
regularly arranged subunits
called capsomers. Capsomers
are self-assembled to form the
capsid. Some virions may have an
additional protection in the form
of lipid membrane.

Viroids are similar to a virus but
they are not virus. Viroids are the
smallest pathogens known. They
are smaller than any of the known
viruses. Viroids cause certain
plant diseases, for example,
potato spindle tuber disease. A
viroid consists of a short strand
of a single-stranded RNA. Unlike
viruses, viroids do not have a
protein coat. So far viroids have
not been found in animal cells.

Viroids were discovered in 1971
by Theodor Otto Diener, a Swiss-
American plant pathologist.

Viruses outnumber all other
entities put together. There are
billions and billions of viruses
on Earth. To give an idea of
unbelievable number of individual
viruses present on Earth, we
quote Dirk Schulze-Makuch of
the Technical University Berlin,
Germany, from his article “There
are more viruses on Earth than
there are stars in the Universe:
And yes, they are alive” (Air &
Space Magazine, 17 March 2020):
“IT is estimated that there are
10 viruses for every bacterium
on Earth. Viruses outnumber
stars by a factor of 10 million.
To put it on a more conceivable
scale, it has been estimated
that every day, more than 700
million viruses, mainly of marine
origin, are deposited from Earth’s
atmosphere onto every square
metre of our planet’s surface.”
(https://www.airspacemag.com)

The branch of science that studies
viruses is called virology and the
scientists who study virology
are called virologists. Virology
is a branch of microbiology.
Classification of viruses is an
important branch of virology. There are many ways to classify
viruses based on:

- Host cells they infect, e.g.,
  animal virus, plant virus,
bacteriophages (viruses that
infect bacteria), and fungal
viruses.

- Geometrical shape of their
capsid e.g., Helix (rod-shaped)
or icosahedron (20-sided)
polygons.

- Virus structure, e.g., the
  presence or absence of lipid
  membrane.

- Type of nucleic acid they carry
  as genetic material, e.g., DNA
viruses, RNA viruses, and
reverse transcribing viruses.

Viruses are not included in the
evolutionary tree of life, as they
do not share characteristics with
cells. Further, there is not a single
viral gene, which is common to
all viruses or viral lineages. As
we know cellular life has a single,
common origin but viruses seem
to have multiple evolutionary
origins. The evolutionary tree of
life underlines the relationship
among various biological groups,
which does not apply in case of
viruses.

Viruses are classified into families
and genera based on their
structural considerations. The
Encyclopaedia Britannica states:
“The criteria used for classifying
viruses into families and genera
are primarily based on three
structural considerations: (1) the
type and size of their nucleic
acid, (2) the shape and size of
capsids, and (3) the presence
of a lipid envelope, derived from the
host cell surrounding the viral
nucleocapsid.” (https://www.
brannica.com)

The International Committee
on Taxonomy of Viruses, in its
2005 report, listed 5,450 viruses,
organised in over 2,000 species,
287 genera, 73 families and 3
orders. Coronaviruses belong
to the coronaviridae family in
the Nidovirales Order. The sub-
groups of coronaviruses are
called alpha, beta, gamma and
delta. Coronavirus got its name from its crown-like spikes on its outer surface. The name 'coronavirus' was derived from Latin ‘corona’ meaning ‘crown’ or ‘wreath’. The Latin term ‘corona’ in turn was borrowed from Greek ‘korone’ meaning ‘garland’ or ‘wreath’. The name ‘coronavirus’ was coined by June Almeida and David Tyrell, who were the first persons to study coronaviruses. Coronaviruses are minute in size (65-125 nm in diameter) and contain a single-stranded RNA as a nucleic material, size ranging from 26 to 32 kilobase pairs or kbs in length. (One kilobase pair is equal 1,000 base pairs of RNA or DNA).

It is often asked whether viruses are alive or not. Viruses have not been classified as being alive. Some of the common characteristics or functions of living organisms are order, metabolic activities, sensitivity to the environment, growth and development, homeostasis (self-regulating process by which living systems tend to maintain stability while adjusting to optimal survival conditions) and energy processing. Viruses do not grow; they have no metabolic activities and they cannot make their own energy. As we know, all living beings are made of cells; they may be unicellular or multicellular and cell is an essential component of our definition of life. Something to be living it must be made up of cells. Viruses have no cells.

It seems viruses exist at the border between life and non-life. One may say that viruses are 'at the edge of life'. It has also been said of viruses that they lead 'a kind of borrowed life.'

Gary Whittaker of the Cornell University, USA says of virus: "It's switching between alive and not alive in its existence". Further he says that virus is somewhere “between chemistry and biology." It has been argued that viruses should be treated as fourth domain of life, the other three domains being eukaryotes (eukarya), bacteria and archaea.

On the issue of whether viruses are alive or not-alive, Luis P. Villarreal of the Center for Virus Research at the University of California, Irvine, USA, in his article "Are Viruses Alive?" in Scientific American, wrote: "For about 100 years, the scientific community has repeatedly changed its collective mind over what viruses are. First seen as poisons, then as life forms, then biological chemicals, viruses today are thought of as being in a grey area between living and non-living; they cannot replicate on their own but can do so in truly living cells and can also affect the behaviour of their hosts.
The characterisation of viruses as non-living during much of the modern era of biological science has had an unintended consequence: it has led most researchers to ignore viruses in the study of evolution. Finally, however, scientists are beginning to appreciate viruses as fundamental players in the history of life. (https://www.scientificamerican.com, the article was originally published in December 2004 issue of the Scientific American).

Further, in the same article Villarreal wrote: “Viruses matter to life. They are constantly changing boundary between the worlds of biology and biochemistry. As we continue to unravel the genomes of more and more organisms, the contributions from this dynamic and ancient gene pool should become apparent. Nobel Laureate Salvador Luria mused about the viral influence on evolution in 1959. "May we not feel", he wrote, "that in the virus, in their merging with the cellular genome and redeeming from them, we observe the units and process which, in the course of evolution, have created the successful genetic patterns that underlie all living cells” Regardless of whether or not we consider viruses to be alive, it is time to acknowledge and study them in their natural context — within the web of life. Our young researchers should seriously ponder over the prophetic comments of Villarreal.

The first virus was discovered in 1892. It was a plant virus — tobacco mosaic virus (TMV). In 1892, the Russian botanist Dmitri Iosifovich Ivanovsky observed that the agent causing tobacco mosaic disease could pass though porcelain filters used for retaining bacteria. However, he did not realise that he had discovered the first virus. Ivanovsky called the infectious agent discovered by him ‘contagium vivium fluidum’ ('contagious living fluid’). He believed that the infectious agent was liquid in nature.

In 1898, after independently replicating Ivanovsky's experiments, the Dutch microbiologist and botanist Martinus Beijerinck came to the conclusion that the agent causing tobacco mosaic disease, which could not be retained by the porcelain filters, was a new form of infectious agent. He called it a virus; he was the first to call it ‘virus’. Beijerinck subsequently accepted Ivanovsky’s priority of the discovery.

It should be noted here that Adolf Eduard Mayer, a German agricultural chemist, studied the peculiar disease affecting the tobacco plant for the first time. His pioneering works on the tobacco mosaic disease played an important role in the discovery of viruses, including the tobacco mosaic virus.

The filtering device used by Ivanovsky had been invented by Charles Chamberland in 1884. Chamberland worked with Louis Pasteur (27 December 1822-28 September 1895), the celebrated French biologist, microbiologist and chemist. The filter developed by Chamberland, which could be used to completely remove all bacteria known at the time, was also called the Chamberland-Pasteur filter. The filter consisted of unglazed porcelain with pore size of 0.1-1 micron or 100-1000 nanometer.

It was American biochemist and virologist Wendell M. Stanley, who succeeded in crystallising TMV for electron microscopic studies. He also demonstrated that TMV maintained its infecting power even after crystallisation.
Irish scientist James Desmond Bernal and his co-worker, I. Fankuchen, obtained clear X-ray diffraction images of the crystallised TMV in 1941. The full structure of TMV was proposed in 1955 by the English chemist and crystallographer Rosalind Franklin.

The first animal virus was discovered in 1898 by the two German bacteriologists Friedrich Loeffler and Paul Frosch. The virus was Foot and Mouth Disease Virus (FMDV) of farm and other animals. Many consider that true discoverers of a virus were Loeffler and Frosch. This is because for the first time they proposed that the infectious agent was a tiny particle and not a liquid infectious agent.

The first human virus to be discovered was the yellow fever virus in 1901. It was discovered by the US Army pathologist and bacteriologist Walter Reed. The virus was found in tropical and subtropical areas of Africa and South America. It spreads to humans by mosquito. Max Theiler, a South African-American virologist, received the 1951 Nobel Prize in Physiology or Medicine for his discovery of an effective vaccine against yellow fever in 1937.

The first bacterium-infecting virus or bacteriophage was discovered in 1915 by the English bacteriologist Frederick William Twort. He discovered that a filterable infectious agent caused the bacterium *Staphylococcus* that he was growing to lyse or burst open. He named it ‘bacteriolytic agent.’ While he demonstrated that the agent could pass through porcelain filters, he did not conclusively state that it was a virus. Subsequently in 1917, Felix d’Herelle, a French-Canadian microbiologist, demonstrated that a virus lysed a bacterial agent *Shigella*, which caused human dysentery or diarrhoea. He called the virus bacteriophage (eater of bacteria).

In February 2020, the discovery of a new and enigmatic virus was announced. Jonatas Abrahao, a virologist at the Federal University of Minas Gerais, Belo Horizonte, Brazil, reported that he had discovered a virus from the Lake Pampulha that had genes never seen before. The virus has been named Yaravirus after Yara, the Water Queen, according to Brazilian mythology based on ancient Tupi-Guarani mythology.
The discovery of the enigmatic virus has demonstrated that there are many surprises waiting for scientists in the invisible world of viruses.

There is a great diversity among viruses. They exhibit extreme variations in size and shape. Reproductive pathways of different viruses vary considerably. Viruses have different levels of infectiousness and virulence. Some viruses have RNA genomes while some others have DNA genomes. Some viruses have single-stranded genomes, some have double-stranded and some others have both double-stranded and single-stranded segments.

It may be noted that despite their great diversity, viruses have some common features:

- They are usually extremely small in size.
- They carry genetic information encoded in their nucleic acid, but they can replicate only within a host cell.
- They cannot carry out metabolism.
- No known virus contains ribosome, the essential component of a cell’s protein-making machinery.

Viruses infect all living things — plants, animals, bacteria, protozoa, fungi, amoeba, and archaea (single-celled microorganisms with structure similar to bacteria, they form the third domain of life). Viruses can infect humans in several ways, for example, through air (coughing and sneezing); via carrier insects (mosquitoes); and through transmission of body fluids (saliva, blood, or semen). It has been suggested that some viruses can also infect other viruses.

If we want to know what really happens in the time between the viral infection and release of new virus particles (virions), we need to look at the life cycle of a virus.

The life cycle of a virus can be divided into five broad steps:

1. Attachment: The virus recognises and binds to a host cell. To achieve this, proteins on the surface of the virus interact with specific receptor molecules on the host cell. This specificity determines the host range, that is, the range of cell types and host species a virus can infect.

2. Entry: The genetic material or the genome of the virus enters the host cell. After a virus enters the host cell, the viral capsid is removed and degraded by viral or host enzymes to release the viral genetic material, a process called uncasing.

3. Replication and gene expression: In this step the viral genome is copied and more viral proteins are made through gene expression to make it possible to assemble new virus particles.
Most of the machinery for genome replication and gene expression are taken from the host cell.

4. **Assembly:** This step involves assembling of new virus particles. The process of assembling is also referred to as maturation.

5. **Release:** The newly made virus particles are released from the host cell. This step is also called viral shedding.

Treating viral infection has proved to be tricky as well as a challenging affair. Scientists are yet to develop an effective treatment for the ongoing COVID-19 or means to prevent it from further spreading. Antibiotics cannot be used for treating viral infections. Some antiviral medicines have been used to treat certain viral infections. To prevent diseases caused by viruses and other pathogens, vaccines are designed. A vaccine trains the immune system of human body to recognise and combat viruses (and other pathogens). Multiple strategies are adopted to produce vaccines. The human immune system is a complex network of cells and proteins that mounts a defence against any infection. The human body has some natural defence against viruses. As Molly Edmonds of HowStuffWorks articles, writes: “The human body does have some natural defences against a virus. A cell can initiate RNA interference when it detects viral infection, which works by decreasing the influence of the virus’ genetic material in relation to cell’s usual material. The immune system also kicks into gear when it identifies a virus by producing antibodies that bind to the virus and render it unable to replicate. The immune system also releases T-cells, which work to kill the virus. Antibiotics have no effect on viruses, though vaccinations will provide immunity. Unfortunately for humans, some viral infections outpace the immune system. Viruses can evolve much more quickly than the immune system can, which gives them a leg up in uninterrupted reproduction. Some viruses, such as HIV, work essentially by tricking the immune system...” (Molly Edmonds in "What is a virus, and how does it become a danger to human life?", https://science.howstuffworks.com)

There is a bright side of viruses. Sometimes they do good things. As C. Michael Holgan, writing on viruses for the Encyclopedia of Earth, of which he served as an Editor-in-Chief, wrote: “The common concept of viruses focusses on their role as pathogen. Actually, there are vast numbers of viral entities that are beneficial to individual species as well as providing ecosystem services. For example, a class of viruses known as bacteriophages can kill a spectrum of harmful bacteria, providing protection to human as well as other biota. Viruses are key in the carbon cycle, their role in ocean biochemistry includes microbiological metabolic — including decomposition — processes. It is this decomposition that stimulates carbon dioxide respiration of marine flora. That respiration annihilates effectively about three gigatons of carbon every year from the atmosphere. Significantly, viruses are being developed as tools for constructive modern medicine as well as the critical field of nanotechnology." (https://eof.org)

Mario Mietzsch and Mavis Agbandje-McKenna in their write-up entitled “The Good that Viruses Do” in Annual Review of Virology (September 2017), have reported that virotherapy (the ability to treat diseases using viruses) “has become the subject of intensive research in recent years”. Viruses may be used to cure cancer, to correct genetic disorders or to fight pathogenic viral infection. They can be used in many genetic studies to determine molecular mechanisms. It has been reported that viruses can increase drought tolerance in some plants, and they can also be used as insecticides. (https://www.annualreviews.org)

The virus named HTLV (Human T-cell lymphotropic virus) has come to our aid to study prehistoric migration patterns. This virus has coevolved with humans for thousands of years.

When a virus reaches a living host, it uses its surface proteins to enter its cells and once inside a cell it takes control of the cell's molecular machinery to produce and assemble the materials needed for its multiplication. A virus occupying a host cell can make 10,000 copies of itself.
in a matter of an hour. A virus multiplies faster than any other living organism. In the process of incredible quick multiplication, viruses make frequent mistakes (mutations) while copying their genetic information and they rapidly change their forms through these mutations. For example, scientists at the National Institute of Biomedical Genomics, Kalyani, West Bengal, have found that SARS-CoV-2 has undergone mutations to form 10 different types. (The Hindu, 30 April 2020)

The spread of SARS-CoV-2 throughout the world has demonstrated the extent of damage a virus can do. To handle a pandemic, we must be mentally prepared and for it, it is important to know what a virus can do and what it cannot do. As Tedros Adhanom, WHO Director General, in the media briefing on COVID-19 on 11 March 2020, declared: “In the past two weeks, the number of cases of COVID-19 outside China has increased 13-fold, and the number of affected countries has tripled. There are now more than 118,000 cases in 114 countries, and 4,291 people have lost their lives... WHO has been assessing this outbreak round the clock and we are deeply concerned both by the alarming levels of spread and severity, and by the alarming levels of inaction. We have therefore made the assessment that COVID-19 can be characterised as a pandemic. Pandemic is not a word to use lightly or carelessly. It is a word that, if misused, can cause unreasonable fear, or unjustified acceptance that the fight is over, leading to unnecessary suffering and death.”

The basic reproduction number ($R_0$), also called basic reproduction rate, or ratio of a virus decides how fast it will spread. Defining the $R_0$, Jeffrey K. Aronson, John Brassey and Kamal R. Mahtani of the Centre for Evidence-Based Medicine, Nuffield Department of Primary Care Health Sciences, Oxford University, UK, wrote: “The basic reproduction number is defined as the number of cases that are expected to occur on average in a homogeneous population as a result of infection by a single individual, when the population is susceptible at the start of an epidemic, before widespread immunity starts to develop and before any attempt has been made at immunization. So if one person develops the infection and passes it on to two others, $R_0$ is 2. If the average $R_0$ in the population is greater than 1, the infection will spread exponentially. If $R_0$ is less than 1, the infection will spread only slowly, and it will eventually die out. The higher the value of $R_0$, the faster an epidemic will progress.”

(“When will it be over?”: An Introduction to viral reproduction numbers $R_0$ and $R_e$, April 14, 2020, https://www.cebm.net). According to Aronson, Brassey and Mahtani, the basic reproduction number of a virus is affected by the following factors:

- The proportion of susceptible people at the beginning and the population density
- The infectiousness of the virus
- The rate of disappearance of cases by recovery or death

The number of people in a population who can be infected by an infected individual at any specific time is called the effective reproduction number ($R_e$).

It is not uncommon for a virus to jump species to infect humans. In fact, they regularly jump their natural host species to infect humans. However, most of them may not be dangerous — they...
Epidemic diseases like COVID-19 pandemic has demonstrated that outbreak of a new human virus has happened.

It has been pointed out that human activities like deforestation, road building, mining, exploitation of wildlife, encroachment of wildlife habitat and other ecological disturbances have enhanced the chance of virus residing in wild animals coming in contact with humans and infect them. As T.V. Sajeev, former Coordinator, Asia-Pacific Invasive Species Network and Senior Principal Scientist, Kerala Forest Research Institute in his article, "Invasive, alien, most fearsome" in The Hindu (15 April 2020) writes: “All invasive alien species remain unproblematic in their land of origin where natural enemies limit their population increase. But when a species arrives at a new location, it escapes from the control of its natural enemies and its population explodes. In the case of SARS-CoV-2, the individual body of each and every host is a landscape in itself. Unlike in the case of SARS, where the virus jumped from bats to civet cats to humans, the intermediate host for SARS-CoV-2 remains unknown. The host is devoid of immunity against the pathogen. With no prior exposure to it and no antibodies, the body initiates a violent response against the new intruder, which could prove fatal. One way of controlling biological invasion is to slow the spread. The idea of imposing lockdowns originated from this logic of slowing the spread.”

Anand Pandian, of the Johns Hopkins University, USA, has also pointed out that zoonotic diseases (diseases transmitted between species — from animals to humans) are triggered by ecological instability. In his article, entitled “Staying at home on planet earth” published in The Hindu (14 April 2020), Pandian writes: Epidemic diseases like COVID-19, avian influenza and Ebola are zoonotic, crossing to humans from other animals. They are often sparked by ecological instability, by the destruction of natural habitats and cramming of animals into wildlife markets and scarcely inhabitable factory farms. They are symptoms, in other words, of a crisis of homelessness in the animal world, magnified by global networks of trade and resource exploitation.” He further writes: “In April 1970, the first Earth Day was inspired by a photograph from Apollo-8, an image of the Earth as a fragile blue ball in the vastness of a space. Many hoped this vision of a vulnerable world would catalyse environmental consciousness and bring a planetary healing, dissipating the rancour of social and political antagonism. As the 50th anniversary of this moment nears, in 2020, we seem to be edging even closer to ecological catastrophe. And yet the alternative remains, the chance to take the Earth itself as a place of collective shelter” (Anand Pandian, “Staying at Home on Planet Earth”, The Hindu, 14 April 2020)

Viruses are self-assembled nano particles. SARS-CoV-2, like some other viruses — namely Ebola, Zika, dengue, HIV, the viruses that cause hepatitis B and hepatitis C and influenza-causing viruses — have an additional lipid envelop. Soap molecules (sodium or potassium fatty acids salts) are pin-shaped, each of which has a hydrophilic or water-loving head which readily bonds with water and a hydrophobic or water-hating tail which tries to keep away from water and prefers to tie up with oils and fats. When you wash your hands with soap and water, then coronaviruses present on your hands will be surrounded by soap molecules. Now, as the hydrophobic tails of the soap molecules try to keep away from the water molecules, they wedge into the lipid envelopes of the coronaviruses. And in doing so, they tear apart the lipid envelopes and the capsid is destroyed. This means
virus falls apart like a ‘house of cards’. As a result, it becomes inactive and its components are washed away by water. Alcohols also attack and break apart the protein envelop. A sanitizer to be effective it must have at least 60 per cent alcohol.

It is a fact that science (including technology) has no substitute in fighting against deadly viruses. Participation of people is also an important factor and, at times, the most crucial factor. However, willing participation can be ensured only if people can be more scientifically aware. They need to have an idea of how microbiology affects human health. Our young science students and researchers should have clear idea about the problems that the life sciences currently face so that they can take up the challenges. We need to promote scientific temper in society in real earnest. Dealing with new virus onslaught will be much easier if we ‘think scientifically and act scientifically’. Excessive spread of misinformation through social media needs to be curbed. Science communicators have many challenges to cope with. The World Health Organisation (WHO) calls the spread of misinformation as “Infodemic.”

In recent years, a new scientific discipline called Planetary Health has emerged. This will enable scientists to visualise outbreak of a viral disease in much broader perspective. The new discipline will focus on ‘the increasingly visible connections among the well-being of humans, other living things and entire ecosystem’. The concept of ‘One Health’, which was recommended as a response to global disease outbreaks in 2007, is also gaining importance. The One Health Initiative Task Force (OHITF), established by the American Veterinary Medical Association in 2006, defined One Health concept as ‘the collaborative efforts of multiple disciplines working locally, nationally, and globally, to attain optimal health for people, animals and our environment.’

Taming SARS-CoV-2 has proved to be one of the greatest challenges faced by humankind in recent years. At this stage it cannot be said with certainty when the march of the virus will be halted. As stated earlier, the final solution has to come from science. Moreover, this may not be the last onslaught against humankind by a virus. As Claus Wilke of the University of Texas, USA and Sara Sawyer of the University of Colorado Boulders, USA, while commenting on how viruses drive evolution and adaptation in human and other mammalian genomes, said: “[Viruses], not lions, tigers or bears, sit masterfully above us on the food chain of life, occupying a role as alpha predators who prey on everything and are preyed upon by nothing.” (Quoted from The Scientist, https://www.the-scientist.com). While it is true that modern molecular methods have revolutionised virus discovery, surveillance, and diagnostics, these are proving to be inadequate to deal with a deadly virus like SARS-CoV-2. The virus has clearly demonstrated the world’s inability to deal with the deadly, invisible enemy before it leaves its devastating marks.

There is no doubt that virologists, pharmacologists, health professionals, biologists, and researchers from other scientific disciplines from all over the world have mounted a multi-pronged effort to stop the deathly march of the virus. It is hoped, science and scientists will eventually win in their fight against the virus.

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The uneasy marriage of pandemics and virus has continued undetected for a long time in the past. Science and technology progressed after the discovery of the Tobacco Mosaic Virus. It helped identify many a pandemic in the history of mankind to a variety of viral entities. The pandemic of 1918 was a milestone in specimen collection and tracing the source of the disease. The article chronicles the progress in the study of pandemics, the mechanism of their infection and how coronaviruses have stood out getting their notoriety etched in history.

Discovery of virus

A little more than 120 years before the novel coronavirus brought life to a standstill in large parts of the world and made human beings face the choice between life and livelihood, three scientists were intrigued by the microscopic entities that discoloured tobacco leaves and damaged the plants. Between 1892 and 1898, Adolf Mayer, Dmitri Ivanovsky and Martinus Beijerinck demonstrated that extracts from leaves infected with tobacco mosaic disease were still infectious after filtration through a Chamberland-Pasteur filter-candle that retained bacteria. Little did they know that they had chanced upon a pathogen that could change the way in which people saw diseases, got treated and ultimately how people lived.

Virus and pandemics

Many wild animals host viruses which may not be pathogenic to them. The animal reservoir for influenza viruses is known to be enormous and several cases of human infection with viruses coming from the animal reservoir have been observed. The reasons for transmission of viruses from animal to human are many. Loss of their wild habitats due to cutting down of forests and change of climatic conditions, result in their movement to new habitats, often near human settlements. Intensive animal husbandry, such as poultry farming and pig farming, increase the risk of migration of viruses from animals to human hosts, thus leading
to zoonotic diseases. Other hotspots of transmission may be wet markets where animals are slaughtered in unhygienic conditions. Transmission of zoonotic diseases like Ebola has been attributed to practices like eating wildlife. Easy modern-day mobility of humans, food, livestock and other goods escalates the speed of transmission.

The Spanish flu: A milestone in pandemic history

The “Spanish flu” which occurred in 1918 has been one of the most well-documented pandemics in history. The death toll estimated globally was 40-50 million including 12 million in India. Around 500 million to 1 billion people were infected, representing approximately 30-50 per cent of the world’s population. The emergence and subsequent adaptation of the deadly H1N1 virus took several months or years before the start of the outbreak. Two places are suspected of being the site of emergence of the virus. The first hypothesis involves the province of Canton in China, later spreading to the US due to immigration. The second possibility is that the virus originated from the United States. Movement of troops due to the First World War served as a driver for the spread of the virus. While information about the infection was censored by countries which were involved; in Spain which was also hit by the pandemic and was not at war, information was freely available. The Spanish newspapers openly described the epidemic, which led to the name “Spanish flu”. The King of Spain and his court were severely hit by the virus.

Reconstruction and protein analysis of the virus was done to try and find the reason behind its lethality. These showed similarities with avian viruses as well as signatures of mammalian influenza. Sequences of the virus detected in material collected from casualty cases of the 1918 influenza revealed a receptor binding site intermediate
between avian and human. It seems that the virus was developing mutations to adapt to its new host.

**History remembers pandemics galore**

The second pandemic of the 20th century was observed 40 years after the Spanish flu, in 1957. Termed as the Asian flu, it infected up to 500,000 Chinese in Mongolia and Hong Kong, followed by Singapore, and soon all of Asia faced the wrath of the new pathogen.

While the Spanish flu and its progeny have been well studied, it had several pandemic predecessors claiming human blood in history which have been difficult to crack.

The book *Epidemics* by Hippocrates described a highly contagious disease observed in northern Greece whose symptoms resemble influenza. The year AD 664 brings up similar experiences in England. A pandemic of an influenza-like illness was observed in England, France, and Italy in 1173-1174. At this time, the word ‘plague’ was used for every epidemic with significant mortality. The word Influenza came up for the first time to describe an epidemic in 1357 in Florence in Italy.

Reports from European countries suggest that massive influenza epidemics occurred in 1658, 1679, 1708, and 1729 starting in Russia and had three waves. Originating in Florence, the word influenza was widely used and is seen in British reports of influenza-like diseases since 1743. Lord Chesterfield, in a letter to his son in 1767 described an epidemic in London that “has the beautiful name influenza and kills only elderly people”.

In 1775, reports from a French doctor wrote about a common cold of epidemic proportions that started in London and led to movement of people to southern America in the spring of 1781 and moved westwards. This worldwide pandemic was responsible for several deaths. In 1803, a severe epidemic was seen in France was responsible for numerous deaths.

In 1837, a French chronicler reported that half of the population of Paris was in bed, turning Paris into a 'giant hospital'. In 1889, a new epidemic which emanated from Russia reportedly infected approximately 40 per cent of the world’s population. In 1900, a medium-sized epidemic was observed possibly from H3N8 strain responsible for a ‘mild’ pandemic.

**Pandemics study post 1918**

Lack of specimens makes it difficult to ascertain the influenza subtypes responsible for pandemics before 1918. The first influenza viruses to be cultivated *in vitro* were isolated in 1931 from swine and in 1933 from a...
human specimen. One of these early historical strains, a variant of H1N1 is still used for vaccine production. New technologies like reverse-transcription polymerase chain reaction (RT-PCR) and reverse genetics have been developed. RT-PCR is a laboratory technique combining reverse transcription of RNA into DNA and amplification of specific DNA targets using polymerase chain reaction (PCR).

Reverse genetics, a new approach made possible by recombinant DNA technology, works in the opposite direction to regular genetics. Reverse genetics starts from a protein or DNA for which there is no genetic information and then works backward to make a mutant gene, ending up with a mutant phenotype. These technologies have allowed amplification and subsequently reconstruction of viruses from pathological specimens from cases that died from influenza during the 1918 pandemic leading to the “original” viruses of the three pandemics of the twentieth century. Much has been learned about the mechanisms of emergence of these viruses.

**Mechanism of viral infection**

Pathogenesis, the process by which an infection leads to disease, involves mechanisms such as implantation of virus at the portal of entry, local replication, spread to target organs or disease sites, and spread to sites of shedding of virus into the environment. Factors that affect pathogenic mechanisms are accessibility of virus to tissue, cell susceptibility to virus multiplication, and virus susceptibility to host defences.

There are several ways in which the virus damages the cell that it infects. The energy of the cell may be diverted; cell macromolecular synthesis may be shut off; the viral mRNA may compete for cellular ribosomes, the viral promoters and transcriptional enhancers may compete for cellular transcriptional factors such as RNA polymerases; and the interferon defence mechanisms may be inhibited. Indirect cell damage can result from integration of the viral genome, induction of mutations in the host genome, inflammation, and the host immune response.

Which specific body tissues a virus would prefer depends on several factors — cell receptors for the virus; cell transcription factors that recognise viral promoters and enhancer sequences; ability of the cell to support virus replication, physical barriers; local temperature, pH and oxygen tension; enzymes and non-specific factors in body secretions; and digestive enzymes and bile in the gastrointestinal tract that may inactivate some viruses.

Virions, defined as the complete infective virus residing outside a host cell, with a core of RNA and a capsid, implant onto living cells mainly via the respiratory, gastrointestinal, skin-penetrating, and genital routes although other routes can be used. The final outcome of infection may be determined by the dose and location of the virus as well as its infectivity and virulence.

After entering the cell, the virus has to establish and spread itself in the host. The exposure to virus and onset of disease has a gap period called the incubation period. During this usually asymptomatic period, implantation, local multiplication, and spread (for disseminated infections) occur.

While most virus types spread among cells extracellularly, some may also spread intracellularly. The most common route of spread in the human system is the circulation system, which the virus reaches via the lymphatic system. In case of infections like rabies and herpesvirus, and sometimes in polio infections, dissemination occurs via nerves. Sometimes the infections are local, leading to localised disease and localised shedding of virus.

Depending on the balance between virus and host defences, virus multiplication in the target organ may be sufficient to cause disease and death. However, natural selection favours the dominance of low-virulence virus strains.

**Corona gets the bad name**

Coronaviruses or viruses with spiked proteins are a large family of viruses that can cause
illnesses ranging widely in severity. The first known severe illness caused by a coronavirus emerged with the 2003 Severe Acute Respiratory Syndrome (SARS) epidemic in China. A second outbreak of severe illness began in 2012 in Saudi Arabia with the Middle East Respiratory Syndrome (MERS).

Researchers differ in their opinion about the origins of the first coronavirus and date it from 10,000 to 300 million years ago. A dozen strains have been identified, seven of which infect humans. Among the four that cause common colds, the comparatively milder form, two came from rodents, and the other two from bats. The three that cause severe disease — SARS-CoV, which causes SARS, Middle East Respiratory Syndrome MERS-CoV, and SARS-CoV-2, responsible for the present pandemic — all came from bats. But scientists are looking for an intermediary — an animal infected by the bats that carries the virus into humans. With SARS, the intermediary is assumed to be civet cats, which are sold in live-animal markets in China.

The origin of SARS-CoV-2 is still an open question and there are papers waiting to be peer-reviewed which suggest that the virus family may have branched out early and then developed multiple machinations for transforming into new forms. An article in the journal Nature says that the virus shares 96 per cent of its genetic material with a virus found in a bat in a cave in Yunnan, China, making it convincing that it came from bats. However, there is a crucial difference. A unit called the receptor-binding domain in the spike proteins of coronaviruses is central to their efficiency in entering human cells. The capability of the SARS-CoV-2 binding domain stands out, and it differs significantly from that of the Yunnan bat virus, which has not been found to infect people.

The coronavirus family itself is a formidable one. With a diameter of 125 nanometres, coronavirus is one of the largest viruses that infect humans. It is also large for the viruses that use RNA to replicate. With 30,000 base pairs, they have the largest genomes of all RNA viruses — more than three times as large as those of HIV and hepatitis C, and more than twice of influenza.

Armed with a genomic proofreading mechanism, these viruses weed out mutations that can weaken them. This may be the reason behind the lack of effectiveness of common antivirals such as Ribavirin that have been used to successfully stop hepatitis C by inducing virus weakening mutations.

Though in terms of mutations, the influenza virus is up to three times more frequent than coronaviruses, the latter
recombine, often exchanging chunks of their RNA with other coronaviruses. As a result, when two distant coronavirus relatives get together in the same cell, they may lead to versions that can invade new cell types and skip to other species.

Bats, which are known to carry 61 viruses that known to infect humans, are often the seat of many such recombinations. Strangely, bats remain immune to many of these viruses, triggering research about the secret behind their immunity.

**What science has done to contain virus**

Immunity is the best shield of humankind against viruses and vaccines have been one of the most effective ways to counter epidemics and pandemics. Viral tissue culture methods were developed from 1950-1985 and led to the advent of the Salk (inactivated) polio vaccine and the Sabin (live attenuated oral) polio vaccine. Mass polio immunisation has now eradicated the disease from many regions around the world including India. Attenuated strains of measles, mumps and rubella were developed for inclusion in vaccines.

Later, the avian influenza due to H5N1 virus, had forced the scientific community to take up research, production, and manufacture of vaccines. Early vaccines for influenza were crude and impure preparations manufactured by methods such as adsorption to and elution from chicken erythrocytes and high-speed centrifugation or freeze-thawing of virus-containing allantoic fluid (fluid found in the foetal membrane that develops from the yolk sac) harvests. These induced a high incidence of both local and systemic reactions, particularly in infants and children. It was generally considered at that time that this was due to an inherent ‘toxicity’ of inactivated influenza virus. However, the development of more highly purified products by the introduction of technologies like the continuous-flow zonal ultracentrifuge demonstrated that much of the toxic reactions had been due to impurities rather than the virus itself. Still, even highly purified versions showed significant reactions among infants and young children.

Later, sodium deoxycholate was adopted for preparation of a commercial vaccine, and deoxycholate-treated vaccines reduced reactions in both adults and children. The application of molecular genetics leading to better understanding of immunology, microbiology and genomics accelerated vaccinology. It helped in development of recombinant hepatitis B vaccines, the less reactogenic acellular pertussis vaccine, and new techniques for seasonal influenza vaccine manufacture.

**The way forward**

Epidemics tell us that in future we are likely to be besieged by new viruses time and again as viruses evolve and our immunity to them wanes. As organisms constantly evolve, the possibility remains that a new destructive organism will manifest. History may help us prepare to adjust to it scientifically, sociologically, and psychologically.

However, the biological coexistence that emerges out of a pandemic is in stark contrast to its social effects. Diseases do not have a social preference, and pathogens don’t distinguish victims by race, class, religion, gender or other identities. The way out of such a situation is cooperation and collaboration rather than competition. Collaboration in the way we find scientific and technological as well as social solutions for prevention and treatment of the disease, collaboration in the way social measures are implemented to prevent the spread. The ‘me’ time is over. It is time to think as a collective, be it in the sociological or in the scientific context. Scientists need to share notes about the advances made by them so that they can gain in terms of ideas, expertise and skill sets to move forward.

*(This article has been contributed in personal capacity)*

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Evolution of Coronaviruses

BIMAN BASU

The COVID-19 pandemic has turned out to be one of the biggest threats to human life in more than a century. Contrary to the suggestions of the new coronavirus being man-made, rigorous genetic studies found no evidence that the virus was made in a laboratory or otherwise engineered and showed the new virus SARS-CoV-2 to have originated through natural processes.

Surpassing all threats to humanity in recent years has emerged a new scourge that has been spreading its tentacles across the globe steadily since the end of December 2019. First detected in Wuhan city in China, it is a new coronavirus, which has an incubation period of up to 14 days and mainly affects the lungs causing SARS-like symptoms. Initially known as the “2019 novel coronavirus”, it was renamed on 11 February 2020 as “severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2)” by the International Committee on Taxonomy of Viruses (ICTV). On the same day, the World Health Organisation (WHO) announced “COVID-19” as the name of the disease it causes. The WHO has declared it as a ‘controllable pandemic’ if countries step up measures to tackle it. While most cases of COVID-19 are mild, the most serious complication of the infection is a type of pneumonia which may be fatal. Since the first cases were detected in China, the number of people infected worldwide has been rising steadily and exceeded 10 million cases, with more than 0.50 million deaths.

Coronaviruses are a large family of viruses with single-stranded RNA as the genetic material that can cause illnesses ranging widely in severity. The first known severe illness caused by a coronavirus emerged with the 2003 Severe Acute Respiratory Syndrome or SARS epidemic in China. A second outbreak of severe illness began in 2012 in Saudi Arabia with the Middle East Respiratory Syndrome or MERS. Research is still on to determine the structural characteristics of SARS-CoV-2 that underlie the pathogenetic mechanisms and its high infectivity. Led by researchers in Germany, virologic study of COVID-19 has shown that after infection the virus quickly begins producing high viral burden, sheds RNA efficiently, and multiplies rapidly in the upper respiratory tract.

It may be mentioned here that bats are well known as a reservoir for potential new human diseases. The animals carry dozens, perhaps hundreds, of members of the coronavirus family. Most of those viruses are part of the bats’ normal microbiome, living in harmony with their hosts and causing no harm. But coronaviruses, like all forms of life, accumulate random genetic changes as they reproduce, often turning them into deadly agents.

Two critical mutations that made COVID-19 deadly

According to scientists, two critical mutations in the bat coronavirus set us on the path to the COVID-19 pandemic. The first mutation modified the structure of the spike-like structures that protrude from the virus. Those protrusions give the virus its family name: “Corona” means “crown” in Latin. The altered spikes allow the virus to latch onto an enzyme called ACE2, which lines the respiratory tract in humans. The related
virus responsible for the SARS epidemic employs a similar infection mechanism, as does another bat coronavirus that causes common colds in humans.

The second key mutation allowed the coronavirus to grow a protein dagger called a furin, which can slice through other proteins to make the virus bind tightly to throat and lung cells. The furin protein is what made the SARS-CoV-2 virus so infectious and deadly to humans. In that sense, COVID-19 is similar to anthrax and various bird flus that also rely on furins to carry out their infection.

According to the scientists, these mutations could have occurred while the virus was circulating in bats. It is also possible that one or both mutations could have erupted in a person who was infected by an earlier version of the virus but showed no symptoms.

One of the most disturbing aspects of the recent pandemic is the plethora of speculative stories appearing in the social media regarding the origin of SARS-CoV-2, some of which describe it as a bioweapon created in the lab and accidentally released. However, rigorous genetic studies of the virus have revealed that the new virus is the product of natural evolution, according to findings published in the journal *Nature Medicine*. The analysis of public genome sequence data from SARS-CoV-2 and related viruses found no evidence that the virus was made in a laboratory or otherwise engineered. According to scientists, by comparing the available genome sequence data for known coronavirus strains, it can be firmly said that SARS-CoV-2 originated through natural processes.

The scientists analysed the genetic template for “spike” proteins (S proteins) — protrusions on the outside of the virus that it uses to grab and penetrate the outer walls of human and animal cells. More specifically, they focussed on two important features of the spike protein: the receptor-binding domain (RBD) — a kind of grappling hook that grips onto host cells, and the cleavage site — a molecular can opener that allows the virus to crack open and enter host cells.

**Evidence for natural evolution**

This evidence for natural evolution was supported by data on SARS-CoV-2’s backbone — its overall molecular structure. If someone were seeking to engineer a new coronavirus as a pathogen, they would have constructed it from the backbone of a virus known to cause illness.
But the scientists found that the SARS-CoV-2 backbone differed substantially from those of already known coronaviruses and mostly resembled related viruses found in bats and pangolins. According to them, “These two features of the virus, the mutations in the RBD portion of the spike protein and its distinct backbone, rules out laboratory manipulation as a potential origin for SARS-CoV-2”.

Meanwhile, other researchers who sifted through the genetic sequences of dozens of preserved viral samples found that the new coronavirus is a distant cousin of the coronavirus that caused the SARS outbreak of 2002 and 2003, and the coronavirus that gave rise to MERS in 2009. The virus responsible for COVID-19 has distinctive features that separate it from its predecessors by many, many generations, according to their report in the Journal of Virology. But, according to the researchers, none of the genetic mutations looked like the ones “a scientific genius would engineer in a lab to tweak a virus for better performance”. Instead, they have all the hallmarks of the gradual accretion of changes that occur over time as a virus encounters new environments and the immune systems of new organisms. In other words, SARS-CoV-2 looks like a virus that has evolved naturally, the team wrote.

According to a paper published in the journal National Science Review, coronaviruses are naturally hosted and evolutionarily shaped by bats. Indeed, it has been postulated that most of the coronaviruses in humans are derived from the bat reservoir. Several research teams have confirmed the genetic similarity between SARS-CoV-2 and a bat betacoronavirus (one of four genera of coronaviruses). The whole-genome sequence of SARS-CoV-2 has 96.2 per cent similarity to that of a bat SARS-related coronavirus (RaTG13) collected in Yunnan province, China, but has low similarity to that of SARS-CoV (about 79 per cent) or MERS-CoV (about 50 per cent). It has also been confirmed that SARS-CoV-2 uses the same receptor, the angiotensin converting enzyme II (ACE2), as SARS-CoV. Although the specific route of transmission from natural reservoirs to humans remains unclear, several studies have shown that pangolins may have provided a partial spike gene to SARS-CoV-2; the critical functional sites in the spike protein of SARS-CoV-2 are nearly identical to those identified in a virus isolated from a pangolin.

Both SARS-CoV (that causes SARS) and SARS-CoV-2 (that causes COVID-19) bind to ACE2 through the receptor-binding domain of the spike protein in order to initiate membrane fusion and enter human cells. Five out of the six critical amino acid residues in receptor-binding domain were different between SARS-CoV-2 and SARS-CoV, and a 3D structural analysis indicated that the spike of SARS-CoV-2 had a higher binding affinity to ACE2 than SARS-CoV. Intriguingly, these same six critical amino acids are identical between pangolin coronavirus and SARS-CoV-2. In contrast, although the genomes of SARS-CoV-2 and RaTG13 are more similar overall, only one out of the six functional sites is identical between the two viruses. It has been proposed that the SARS-CoV-2 receptor-binding domain region of the spike protein might have resulted from recent recombination events in pangolins. Although several ancient recombination events have been described in spike, it also seems likely that the identical functional sites in SARS-CoV-2 and pangolin coronavirus may actually result from coincidental convergent evolution.

**Probable routes of evolution**

Based on their genomic sequencing analysis, Kristian Andersen, Associate Professor of Immunology and Microbiology at Scripps Research Institute and corresponding author on the Nature Medicine paper, and his collaborators have concluded that the most likely origins for SARS-CoV-2 followed one of two possible routes.

The first possible option is that the virus could have evolved to its current pathogenic state through natural selection in a non-human host and then jumped to humans. This is known to be the route through which previous coronavirus outbreaks had emerged, with humans contracting the virus after direct exposure to civets (SARS) and camels (MERS).
Researchers propose bats as the most likely reservoir for SARS-CoV-2, as it is remarkably similar to a bat coronavirus. However, since there are no documented cases of direct bat-to-human transmission, an intermediate host was likely involved between bats and humans, say the scientists.

In this scenario, both of the distinctive features of SARS-CoV-2’s spike protein that binds to cells and the cleavage site that opens the virus up would have evolved to their current state before entering humans. In this case, the current epidemic would probably have emerged rapidly as soon as humans were infected, as the virus would have already evolved the features that make it pathogenic and able to spread between people.

The second probable route envisions a non-pathogenic version of the virus jumping from an animal host into humans and then evolving to its current pathogenic state within the human population. For instance, some coronaviruses from pangolins (armadillo-like mammals found in Asia and Africa) have a receptor-binding domain structure similar to that of SARS-CoV-2. A coronavirus from a pangolin could possibly have been transmitted to a human, either directly or through an intermediary host such as civets or ferrets.

According to Andersen, after transmission, the other distinct spike protein characteristic of SARS-CoV-2, the cleavage site, could have evolved within a human host, possibly via limited undetected circulation in the human population prior to the beginning of the epidemic. The researchers found that the SARS-CoV-2 cleavage site appears similar to the cleavage sites of strains of bird flu that has been shown to transmit easily between people. SARS-CoV-2 could have evolved such a virulent cleavage site in human cells and soon kicked off the current epidemic, as the coronavirus would possibly have become far more capable of spreading between people, say Andersen.

According to the scientists, it is difficult if not impossible to know at this point which of the scenarios is most likely. If the SARS-CoV-2 entered humans in its current pathogenic form from an animal source, it raises the probability of future outbreaks, as the illness-causing strain of the virus could still be circulating in the animal population and might once again jump into humans. But the chances of a non-pathogenic coronavirus entering the human population and then evolving properties similar to SARS-CoV-2 are lower.

It must, however, be remembered that despite the recent discoveries, several fundamental issues related to the evolutionary patterns and driving forces behind this outbreak of SARS-CoV-2 remain to be fully characterised.

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COVID-19 is a potentially fatal disease inflicted with an exorbitant global public health concern. The person-to-person transmission of COVID-19 infection has led to social distancing and pervasive lockdowns. In epidemiology, the basic reproduction number ($R_0$) is one of the most widely used concepts for understanding the contagiousness of an infectious agent. The value of $R_0$ is the average number of new infections produced by an infectious patient in a given population. The acquired immunity is established at the level of the individual, either naturally through infection by the pathogen or by passive immunisation with a vaccine. Herd immunity arises from individual immunity scaled to the level of the population and thus provides indirect protection from infection to susceptible individuals when a sufficiently large proportion of immune individuals exist in a population. The COVID-19 pandemic would likely get over when an effective vaccine is available or sufficient herd immunisation is acquired. Until either is reached, suppression of the epidemic through immensely intensive measures, such as quarantine and applying contact control resources to slow the spread of the virus, appear to be the only viable and safe strategy.

By the end of 2019, a series of pneumonia-like cases of unknown aetiology emerged in Wuhan city of Hubei province of People’s Republic of China (PRC). A few weeks later by the mid of January 2020, deep nucleotide sequencing analysis from lower respiratory tract samples identified a novel virus as the causative agent. The ongoing outbreak of emerging severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) disease (COVID-19) from Wuhan to more than 200 countries around the world has attracted global attention, making the World Health Organisation (WHO) to declare it as a pandemic on 11 March 2020. The very initial cluster of patients with pneumonia-like symptoms was linked to a local Huanan seafood
market in Wuhan in December 2019. Unfortunately, there are no specific therapeutics and vaccines yet available for disease control and thus the COVID-19 epidemic poses a great threat to global public health. Widespread lockdown of almost half of the human population in their homes, has altered geopolitics leading to immense economic loss and loss of jobs, forth, which clearly brings out the urgent need of understanding the epidemiology of the currently ongoing COVID-19 pandemic. Further, the nationwide declaration of stringent control efforts of lockdown has led to paralyzing economic and social activities. A few medical biology terms, e.g., epidemiology, basic reproduction number (or R naught), and herd immunity are some of the common words, which no more pertain to the medical fraternity, but to a common human to some extent.

Epidemiology of COVID-19

The term epidemiology literally means “the study of what is upon the people”, derived from Greek words, epi— meaning “upon”, demos— meaning “people”, and logos— meaning “study”. Epidemiology is a comprehensive study and analysis of the distribution, patterns and determinants of health and disease conditions in a set of the human population. It is an important aspect of public health and decides policy decisions by identifying risk factors for disease and targets for preventive healthcare and thus epidemiologists help with study design, collection, statistical analysis of data and interpretation, and dissemination of results for policymakers and the public. Thus, the epidemiology helps to develop the methodology used in clinical research and public health studies.

Almost all countries worldwide are affected by the pandemic of COVID-19 and are suffering from a rapidly increasing number of positive cases and unfortunate deaths. Scientific advancements since the pandemic of SARS in 2002-03 and the Middle East Respiratory Syndrome (MERS) in 2012, have accelerated our understanding of the epidemiology and pathogenesis of COVID-19 to some extent, if not fully.

The common symptoms of COVID-19 infection appear after an incubation period of about 5 days and the period from the onset of symptoms to death ranges to a median of approximately 14 days. However, this period depends on the age and immune system of the patient; thus it was shorter among patients of more than 65 years of age. The consensus symptoms at the onset of COVID-19 disease are heavy fever, dry cough, difficulty in breathing (dyspnoea), and fatigue, while secondary symptoms are headache, haemoptysis, diarrhoea, loss of taste and the smell, and lymphopenia. The investigational clinical features through a chest CT scan represent as pneumonia and acute respiratory distress syndrome. The binding of a virion (mature virus particle) with angiotensin-converting enzyme 2 (ACE2) receptors expressed by host cells is the first step of viral infection followed by fusion with the cell membrane. Lung epithelial cells are the primary target of the novel coronavirus virus.

Based on initially a localised number of novel coronavirus infected people had exposure to the wet animal market in Wuhan city where live animals are routinely sold, it is being suggested likely having a zoonotic origin. Researchers are trying to map the reservoir host or intermediate carriers from where initially the infection may have spread to humans. Genomic sequence analysis of COVID-19 has shown almost 88 per cent identity with two bat-derived SARS-like coronaviruses, indicating that bats are the most likely link between disease and humans. Person-to-person transmission occurs primarily through direct contact or by the droplets spread by coughing, sneezing, or talking with an infected individual. According to Yalan Liu at Huazhong University of Science and Technology, and colleagues in their Frontiers in Paediatrics report in a small study conducted on women in their third trimester who were confirmed to be infected with the coronavirus, there was no evidence that there is transmission from mother to child. Because all the pregnant mothers underwent caesarean delivery, hence it has remained unclear whether transmission
can occur during vaginal birth. This is important because pregnant mothers are relatively more susceptible to infection by respiratory pathogens and severe pneumonia.

SARS-CoV-2 is the causative agent of COVID-19. Extensive measures to reduce person-to-person transmission of SARS-CoV-2 have been implemented to control the current outbreak. Special attention and efforts to protect or reduce transmission to the susceptible populations including co-morbid patients, children, healthcare providers, and elderly people have been practised. Amidst the COVID-19 pandemic, the free and fair flow of information, news, and guidelines, is more essential than ever for ensuring an open dialogue and the exchange of vital information between government officials and the public. It has been observed that even a common man, who never would have given attention to disease epidemiology, is today better versed with dozens of medical terminologies, FAQs, and a litany of dos and don'ts. One of the most common words buzzing around is the “basic reproduction number” (R₀) and herd immunity. Are these words so crucial to comprehend?

**Basic Reproduction Number**

The basic reproduction number (R-value, R₀, or R naught) is a way of rating an infectious disease’s ability to spread in society. The basic reproduction number of an epidemic is defined as the average number of secondary cases that an infected subject produces over its infectious period in a susceptible and uninfected population. The R₀ is used to measure the transmission potential of a disease. Among the aerosol-based transmissible diseases, the R₀ value for measles is the highest — up to 18; chickenpox (varicella) 12, pertussis 5.5, common cold 2-3, MERS 0.3-0.8 and influenza 1.5-2.8. Similarly, R₀ for HIV/AIDS is 2-5 with the route of body fluids and for polio it is 5-7 through faecal-oral route.

For example, if the R₀ for SARS-CoV-2 in a geographical population is 3.0, then we would expect that each new case of SARS-CoV2 shall produce 3 new secondary cases (assuming everyone around the case was susceptible and without vaccination). However, the R₀ excludes new cases produced by the secondary cases and the value of R₀ does vary from one population to another and similarly from one geographical area to another. Measles has one of the highest basic reproduction numbers (18) and thus may cause explosive outbreaks in the human population. The ongoing novel coronavirus has a basic
reproduction number of about 2.5-3.0.

The basic reproductive number is affected by several factors, such as

- Rate of contacts in the host population
- Probability of infection being transmitted during contact
- Duration of infectiousness.

A population will rarely be totally susceptible to an infection in the real world. Some contacts will be immune, for example, due to prior infection which has conferred a life-long immunity, or as a result of previous immunisation. The $R_0$ is not a biological constant for an infectious agent as it is also affected by other factors such as environmental conditions (cold and hot weather), geographical location, age of the population, and the behaviour of the infected population (say, immunity of human individuals). The $R_0$ values are estimated from mathematical models and the estimated values are dependent on the model used and the values of other parameters. Thus, values given in the literature only make sense in the given context and it is recommended not to use obsolete values or compare values based on different models. The value of $R_0$ does not alone by itself give an estimate of how fast an infection spreads in the population.

The most pertinent uses of $R_0$ value is to determine how much an emerging infectious disease can spread in a population and to determine what proportion of the population should be either immunised through vaccination to eradicate a disease or other arrangements need to be made if a vaccine is not available. If the value of $R_0 > 1$ then the infection will be able to start spreading rapidly in a population, but if $R_0 < 1$ then the disease will eventually dilute out as not enough new people are being infected to sustain the outbreak. Thus, the larger the value of $R_0$, the harder it is to control the epidemic.

Let us understand an example where the $R_0$ for COVID-19 is 4 in a human population, where half of the population seems healthy, then the effective basic reproduction number shall be $4 \times 0.5 = 2$. In such a circumstance, a single positive case of COVID-19 would produce an average of 2 new secondary cases. The consideration of $R_0$ is very important to impose the lockdown in an infected area and thus the aim of the policymakers of a country is to keep the reproduction number as close to one as possible. The main aim of the imposition of lockdown is to keep people inside their homes to minimise and push back the exponential growth of basic reproduction number to one or even less.

In populations that are not much homogeneous, the estimation of $R_0$ is not straight forward and the same is true to our country, which proudly boasts of “Unity in

Table: Common infectious human diseases, their transmission route and range of their $R_0$ value

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Disease</th>
<th>Transmission Route</th>
<th>$R_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>COVID-19</td>
<td>Respiratory droplets</td>
<td>1.94-5.7</td>
</tr>
<tr>
<td>2</td>
<td>Chickenpox (varicella)</td>
<td>Aerosol</td>
<td>10-12</td>
</tr>
<tr>
<td>3</td>
<td>Mumps</td>
<td>Respiratory droplets</td>
<td>10-12</td>
</tr>
<tr>
<td>4</td>
<td>Polio</td>
<td>Faecal-oral route</td>
<td>5-7</td>
</tr>
<tr>
<td>5</td>
<td>Rubella</td>
<td>Respiratory droplets</td>
<td>5-7</td>
</tr>
<tr>
<td>6</td>
<td>Pertussis</td>
<td>Respiratory droplets</td>
<td>5.5</td>
</tr>
<tr>
<td>7</td>
<td>Smallpox</td>
<td>Respiratory droplets</td>
<td>3.5-6</td>
</tr>
<tr>
<td>8</td>
<td>Measles</td>
<td>Aerosol</td>
<td>12-18</td>
</tr>
<tr>
<td>9</td>
<td>HIV/AIDS</td>
<td>Body fluids</td>
<td>2-5</td>
</tr>
<tr>
<td>10</td>
<td>SARS</td>
<td>Respiratory droplets</td>
<td>3.1-4.2</td>
</tr>
<tr>
<td>11</td>
<td>Common cold</td>
<td>Respiratory droplets</td>
<td>2-3</td>
</tr>
<tr>
<td>12</td>
<td>Diphtheria</td>
<td>Saliva</td>
<td>1.7-4.3</td>
</tr>
<tr>
<td>13</td>
<td>Influenza</td>
<td>Respiratory droplets</td>
<td>1.4-2.8</td>
</tr>
<tr>
<td>14</td>
<td>Ebola</td>
<td>Body fluids</td>
<td>1.5-1.9</td>
</tr>
<tr>
<td>15</td>
<td>Influenza</td>
<td>Respiratory droplets</td>
<td>1.4-1.6</td>
</tr>
<tr>
<td>16</td>
<td>Influenza (2009 pandemic strain)</td>
<td>Respiratory droplets</td>
<td>1.4-1.6</td>
</tr>
<tr>
<td>17</td>
<td>Influenza</td>
<td>Respiratory droplets</td>
<td>0.9-2.1</td>
</tr>
<tr>
<td>18</td>
<td>MERS</td>
<td>Respiratory droplets</td>
<td>0.3-0.8</td>
</tr>
</tbody>
</table>
Diversity”. The small countries, especially those of Europe, do not have much heterogeneous populations and thus have a narrow range of $R_0$ value. To successfully eliminate a disease from a population, $R_0$ needs to be less than 1. This was the only reason to enforce a pervasive lockdown in several countries, including India, when, except for emergency, the common people were forced to remain at their sites and work from home while several businesses and industrial units were shut down. Thus, we were trying to stop the people from coming into contact with each other to cut the virus’ ability to spread further.

**Herd immunity**

Herd immunity is an important concept of epidemiology regarding the population level effect of individual animal immunity to further prevent transmission of pathogens. Herd immunity has several other names such as community immunity, or social immunity and is a form of indirect protection from infectious disease that occurs when a large percentage of a population has become immune to an infection. This could be either through mass vaccination programme or previous exposures of infections, thereby providing a chance of protection for individuals who are not yet immune. Once a substantial fraction of human population possesses immunity, then such people are less likely to contribute to disease transmission, because the likelihood of effective contact between diseased and susceptible individuals gets reduced. It disrupts or slows down the chains of infection of the disease. Thus, as the proportion of immune individuals in a community increases, it leads to a smaller probability that non-immune individuals will come into contact with an infectious individual, helping to shield non-immune individuals from infection.

Primarily, the individuals become immune in two ways, either by recovering back from an earlier infection or through vaccination programme. However, a proportion of individuals may not become immune because of immunodeficiency, immunosuppression, old age, co-morbidity, etc., and thus for such group of susceptible people, herd immunity arises as a crucial method of protection. Upon reaching a particular threshold, this herd immunity gradually kicks out a disease from that population. Such kind of elimination may result in the permanent reduction in the number of new infections to zero, which is otherwise called eradication of the disease. In 1977, the herd immunity
created world-wide by massive vaccination contributed to the absolute eradication of smallpox. Herd immunity is applicable to only contagious diseases. Mass vaccination leading to herd immunity has eradicated many infectious diseases; however, the unfortunate opposition to vaccination programmes has led to a vicious circle of allowing preventable diseases to persist in or re-surfacing in communities that have inadequate vaccination rates. Understanding herd immunity requires consideration of infection dynamics and modes of transmission, as well as the acquisition of immunity by individuals in the population.

A lot many infectious diseases, e.g., measles, mumps, polio, and chickenpox were once quite common but are now rare because vaccines have helped to establish herd immunity. However, we sometimes see outbreaks of vaccine-preventable diseases in communities with lower vaccine coverage because they probably have not developed sufficient herd protection. For many infectious diseases without a vaccine, a lot many adults use to develop immunity because of exposure of prior infection(s), but the disease can still circulate among children and can still infect those with compromised immunity. Common cold or flu virus mutates again and again so often that the resultant antibodies from the previous infection provide short protection. For the flu, this is less than a year. Like other coronaviruses, with SARS-CoV-2 infection, we can expect that people who get infected will be immune for months to years, but probably not their entire lives.

With regard to ongoing infectiousness of the novel coronavirus, the epidemiologists have estimated that at least 60 per cent of the human population is likely to have exposure to get immune to have herd protection [having the R₀ value of 2.5, with the formula as (R₀⁻¹/R₀)x100 = (2.5⁻¹/2.5)x100 = 60 per cent]

Various countries are having persistent week(s)-long lockdown to minimise the current levels of infection until a vaccine becomes available. This would require well-calculated efforts of governments to keep strict vigil to maintain physical distancing for an extended period until an effective COVID-19 vaccine is developed, tested, mass-produced, and made available to the public. By keeping a concerted check on the rate of infection, it is possible to keep a check over too many people getting infected by SARS-CoV-2 in a geographical area. But prolonged efforts will be required to prevent major outbreaks until a promising vaccine is developed and made available for general use. Even though, the novel coronavirus could still infect children before they can be vaccinated or adults after their immunity wanes because of old-age, co-morbidity, or over immunosuppression. But it is unlikely in the long term to have the explosive spread that we are seeing right now because much of the population will get immune in the future. Dr. Michael Ryan, executive director of the WHO’s health emergencies programme says that it is wrong to think that countries can “magically” make their populations immune to the novel coronavirus. He said that the concept of herd immunity is generally used for calculating how many people will need to be vaccinated in a population in order to protect those who are not vaccinated.

This COVID-19 pandemic is a common challenge faced by mankind in the age of expanding globalisation in the 21st century. At present, regardless of who you are, the sharing of resources, experiences, and lessons, seems an inevitable panacea for us to win this so-called Third World War. The real remedy to win over this pandemic is not isolation, but the cooperation of mankind keeping aside the geopolitics and regional differences.

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The world after COVID-19 Crisis

The COVID-19 pandemic has impacted human lives severely in multi-ways, globally. As a safe and efficient vaccine seems to be far and herd immunity is not easy to achieve soon, human race is learning to live with SARS-CoV-2. The governments, organisations and people at individual levels are trying to formulate the newest ways to avoid the SARS-CoV-2 infection and keep life running. Several ‘new normals’ have suddenly entered in the people’s daily lives. This article deals with those ‘new normals’ and the efforts of human race to cope them in the wake of COVID-19 pandemic.

Dr. MEHER WAN

The COVID-19 pandemic has affected human life severely across the world. The lockdowns sustained for a very long time have raised several serious questions about what the future of human life will be post-pandemic. Not only is the way of living changing among the common people, but high-profile diplomatic work culture is also changing due to the COVID-19 pandemic. Mega-events like the Olympics are being postponed and high-profile meetings are being held online. The politicians and officials are appearing for press conferences via online conferencing platforms. The world is preparing itself to accommodate the COVID-19 pandemic and learning to live with the dangerous virus.

The usually crowded public transport is now following social distancing. The passengers in buses, metro rails and trains are advised to sit at a safe distance from each other. The high-speed internet has emerged as a life saving technology for the human race. A plethora of new systems and methodologies have emerged from the internet to cope with the pandemic. Academics and school/colleges are teaching the students through online classes, the assignments and other related works are also being completed online and with the soft copies of the documents. A number of high-profile international scientific conferences have shifted themselves to virtual online platforms for presenting the research to a wide community of researchers.

Prime Minister of India Narendra Modi interacting with Australian PM Scott John Morrison in an online summit (Image Courtesy: Jagranjosh.com)
The newspaper industry is also facing the crisis in a hard way. Circulation of printed newspapers has fallen drastically worldwide and people are preferring online news platforms. The high-budget feature films are being released on OTT (over-the-top) media platforms. People are talking about screening of films on a big screen in a large open space and they will watch by sitting in their cars comfortably to avoid the chances of infection. It is the first time when the state governments are on the verge of allowing the home delivery of alcohol by relaxing the norms and laws. On the international level, many nations have closed their borders to prevent people from entering. For the first time in the Indian history, Hon. President of India accepted the credentials of seven diplomatic envoys in an e-ceremony. It is being termed as ‘digital diplomacy’. For the first time, India and Australia inked a defence pact after an online summit of the PMs of both the nations. Now high-profile diplomatic meetings in the world are being held online to discuss the global affairs during the pandemic.

As big social gatherings are not allowed and are not safe, restaurants are putting plastic curtains to isolate groups of people in the same place. To avoid chances of infection, ‘hugging stations’ are being set up to allow the loved ones to hug safely.

It is still not clear how the events and human behaviour will shape in the wake of the current pandemic. Will our President shake hands with Padma Awardees at the award ceremony which the Excellency used to do in normal times? How will the Oscar/Nobel Awards ceremony be conducted? When will the salons open for haircut and how will the new styles of haircuts emerge?

It is a bit early to estimate the damage worldwide due to the novel coronavirus and experts are claiming that the after-effects of this pandemic will last for a very long time. There are many imponderables. For example, what will be the social structure of society? How will people behave? How will the technological needs of the world change? How will the scientific community change its priorities? Will there be a positive climate change? How will be the life? And many more. It will be important to understand the future after the very first wave of this pandemic.

Vulnerable economy

Strict lockdowns have affected the world economy in a very harsh manner. The world is facing a serious recession and companies and startups are on the verge of collapsing and bankruptcy. Pandemics are not similar to wars. During wartime, the production goes higher and higher to satisfy various kinds of needs. However, during this pandemic the production is going lower. It requires resilience and planning to scale up the production in industries after the long lockdown which can support livelihoods.

The job market will undergo a thorough transformation. The governments and economists will be forced to work towards the creation of decent and sustainable jobs in the market. The economists will search for the new market in the post-COVID-19 era. A paradigm shift will be observed focusing on creation of highly paid new jobs in essential services sector in place of the non-essential sector. There are enormous opportunities for establishing the government sector in the market.

Automation will hit the job market. (Source: AFP)
Supply chain 4.0

Due to the present pandemic, several disruptions in the global supply chains are being observed. Several companies are completely shut down due to the lockdown. Several countries have imposed export bans in the case of many essential commodities. Core technologies of the fourth industrial revolution are waiting to make the paradigm shift in the supply chain with the help of Big Data, cloud computing, the Internet of Things (IoT) and blockchain. Acceleration of Artificial Intelligence will be observed in the human jobs.

The public transport and travel

The public transport will undergo a drastic transformation which will change the way we have travelled in the pre-COVID-19 era. At the airports, people will be seen with masks and covering the whole body with Personal Protection Equipment (PPEs). Checking them for security will require more sophisticated scanners and no-touch mechanisms will prevail to get the boarding passes and other processes. The travellers shall have to prove their health status to airport authorities to cross the borders of countries. There will be more thermal scanners with 3D infrared vision at the airports for surveillance and security in addition to thermal screening for fever.

In the trains and railway stations, physical distancing norms shall be practised, and online medium will be preferred for ticket purchasing and robotic equipment might be deployed at inquiry counters.

At metro stations and high-security places where security check is necessary by a security personal, thermal/X-ray 3D scanners will be deployed and zero-touch policy might be practised. The coaches and public places will be disinfected regularly to avoid the spread of infection.

Automobile sector

Climate experts have always been suggesting that the use of public transport must be encouraged to curb pollution, but after the pandemic, the advisory will not be same and people may prefer travelling alone in their own cars. It gives hope for the U-shaped recovery in the automobile sector but will result in increasing vehicles on the road exponentially which will further increase the pollution and worsen the climate conditions. The service-based transport models like the lease, pay-when-travel or taxi services will be affected severely in the post-COVID-19 world.

Tourism

One of the most severely hit sectors of the economy is tourism. The countries and places are hit hard by the lockdown and closure of international borders. However, it is still unclear how long this pandemic will last and how much time it will take to reopen all the tourist places. It is certain that the tourism scenario will not be the same as...
it was in pre-pandemic times for a very long time. The scientists and policy makers are struggling hard to bring the situation to normalcy. The United Kingdom is considering issuing “immunity passports” to the travellers for crossing the international borders. Needless to say, the countries will have also to show that they are safe for tourists. Although it is not clear as of now, if it is proved scientifically that COVID-19 survivors become immune to subsequent infections then governments may issue immunity certificates to such people.

**Food habits**

When a large fraction of the world’s population will starve due to the crashing economy and discontinued supply chain, rest of the world will be forced to change the food habits across the globe. In the restaurants, the sharing of food will be avoided, and people will order single item as per their demand. The restaurants, pubs, bars, and roadside local cuisine shop will be affected hard due to the novel coronavirus pandemic. However, restaurant owners are working hard to create a physically distanced environment in their venues, but after the pandemic, people may not appear in common food joints as before. The kitchens of the restaurants will become more open to watching from outside than ever before to increase the transparency and gain public confidence regarding hygiene. There will be a decline in banqueting and catering business and the marriages will become smaller in gathering.

In the book *Future Shock*, the famous writer Alvin Toffler talks about ‘certain psychological state of individuals or a society when confronted with too much change in a short period of time.’ During the time of COVID-19 pandemic, the world has seen numerous changes in social behaviour like never before. The concerns about hygiene, personal safety, and physical distancing became too important suddenly. The food supply chain involves producers, agricultural and fisheries people, processing, and storage, transportation, marketing, and then consumers. It is likely that in the case of a large number of COVID-19 cases and high spread of infection, the need of testing will be very important at all levels of the supply chain. The international standards regarding hygiene and working conditions will be changed in the wake of the novel coronavirus pandemic.

A new trend of home cooking will re-emerge in the post-COVID era. The packaged food like pizza and the home delivery from the restaurants will be avoided by the common public due to fear of infection. Online tutorials for cooking will become the new teacher for those who wish to learn cooking. Many new accessories to make the cooking easy will hit the market which we have never seen before as food was easily available in restaurants with home delivery options.

Coronavirus has created an awareness towards immune system in the public and people are more likely to go for more organic and healthy food in place of packaged food.

**Sports**

Japan and Olympics authorities have announced the postponement of the upcoming...
Tokyo Olympics, which is one of the largest sports events in the world. The sportspersons are stuck in homes due to lockdown and fear of getting infected. It is a challenging time for the sportspersons both physically and mentally. Especially the sportspersons who play team games have a different kind of mental condition in contrast with individual games like shooting or golf.

The coaches, sports persons, federations, and planning experts are working to look for new protocols for post-COVID games when the training and competitions resume after normalcy returns. In the meantime, it is being suggested to sports person to keep their fitness well.

**Human behaviour**

Fear of getting infected will make humans very insecure and mentally isolated from the others. It is known that touching objects, being with other people, breathing air in an enclosed space is risky. The comfort of being with others will be replaced by looking for the absence of others nearby, especially unknown people.

Regulatory barriers to online tools will cease and online activity will be at the highest in the post-pandemic era. The meetings will be online, and several congresses and symposia shall happen online only. Online teaching will become popular. The experts will try to make the digital lifestyle healthier.

Virtual reality will get a boom in usage. The telemedicine will be more used by both doctors and patients as the risk of infection will be more in hospitals. More robust and secure online platforms and apps will be made to make telemedicine easier, safer, and more effective. For the elections, planning experts will try to establish the electronic online voting mechanism as a mainstream voting method.

**Climate change**

Climate change is the result of not only large-scale industrialisation but also change in human social behaviour, which contributes indirectly. The lockdowns across the world have shown positive changes in climate. There are several pictures from across the globe circulating in the social media which indicate a sharp drop in pollution levels due to lockdowns and restricted human activity during this period. Tackling the coronavirus and climate change both needs a reduction of the non-essential economic activity.

For coronavirus, less outdoor activity can reduce the chances of infection. Reduced economic activity can also help arrest climate change because if the less is produced, less will be the energy consumption and less greenhouse gases emission.

**Education**

Educational institutions are hit hard by the COVID-19 pandemic. It is not sure when normalcy will be achieved, and when it will be safe to be present in the classes and in morning gatherings in the schools. Distance learning is the new normal which is being implemented in schools and colleges. However, only classes can be conducted online, but the lab classes are impossible to be taught online. It is expected that new technology will come up with the new ways to teach students much more effectively in the online classes and involve them in lab activities with the help of virtual reality platforms. The use of technology in the education sector will redefine the role of educators. In the classes,
life skills will also get the focus of educators apart from the core subjects.

**Entertainment**

The entertainment sector is on the verge of a paradigm shift in the distribution of films and video-series. People will avoid going to the big gatherings in cinema halls. The filmmakers and distributors will try to find out the new ways to release the films and series. There are already several online video platforms that screen movies and other video content, but it will rise and expand its limits from video series to full-length commercial feature films. There will be a great challenge before technologists to secure the content and restrict the piracy activities of the films.

**Health sector**

In the telehealth sector, there are new experiments and achievements-in-waiting during the post-COVID-19 era. It will be effective in providing service in the primary health care sector. Robots will be used to take primary data and diagnostic input from the patients in the hospitals.

**Technology will become the saviour**

Technology will be at the heart of everything in post-pandemic time. It would make life easier and safer at offices, public places, hospitals and everywhere. There will be a huge dependence on technology to not only run a company but to interact with the customers also. The Internet of Things (IoT) will also play an important role in the new normal in the post-pandemic era.
The companies, agencies and at public places, the surveillance system will have different 3D scanners including thermal scanner for security, safely and assuring safe physical distance. There might be a thermal scanner at the door of an office that allows the person to go inside when the body temperature of the person is in safe limits, i.e., no symptom of COVID-19 infection. A new method of taking attendance may evolve which will be different and touchless unlike the present biometric methods.

Companies are also in the process to increase the use of technology in how they deliver their services to the customers. Chatbots will become more smart and able to serve better.

The automation will increase and cause loss of jobs in the post-COVID-19 era. Robots will become the new normal at the enquiries and will deliver the services to the people. Online shopping and robot deliveries will be the hottest phenomenon which the companies will try to achieve in the near future. The driverless cars are already in market, but their importance will really be understood in the post-COVID-19 era.

The digital payments will be preferred in the post-coronavirus era. People will be afraid to use cash for purchasing and payments to avoid the chances of infection through the cash notes. The digital and contactless payments will be the new normal in the industry and the markets.

The COVID-19 crisis has opened new opportunities for development of the new technologies to enable the people to work from the homes. The remote working is being enabled by technologies including virtual private networks (VPNs), voice over internet protocols (VoIPS), virtual meetings, cloud technologies, and even facial recognition technologies to provide better experience during work from home. Several new and better technologies will evolve due to new work culture and requirements of the different office environments. The remote work also imposes additional challenges to employers and employees regarding security, privacy, and tech support. In view of the above, the labour laws will have to get updated. Let us prepare ourselves to realise the need of change and make the change possible for a better humanity.

Use of telemedicine is increasing after COVID-19

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The way we do business and interact could be fundamentally changed by COVID-19 (Credit: Getty Images)
A New Scenario in Sports

RAKESH THAPLIYAL

We are witnessing a new sporting world where the doors of stadiums have been shut for sports globally and turned into quarantine centres or hospitals for saving the lives of those afflicted with COVID-19. A new virus has forced sportspersons to use modern technology and scientific training to keep abreast of the situation. Health awareness has taken over and athletes have started training and competing in empty stadiums as they need to be very careful because one mistake, and it could be ‘Game over’ for them.

The year 2020 will go in the history of world sports as a year of new scenario for all of us. The COVID-19 pandemic has led to either cancellation or postponement of domestic and international championships as well as training sessions all over the world, including the biggest sporting extravaganza — the Tokyo Olympics 2020. It is an unprecedented crisis for mankind, as one has never seen such a spread of a virus before, and an unparalleled challenge for the sports world. Athletes and coaches were forced to be in 'house arrest'-like situations to save themselves from the virus.

Time is changing and after almost four months of stand still, type situations (postponements and cancellations in February-March), we are fortunate enough to see the sporting events and training camps on the path of resumption. The Indian government has given permission to resume training with requisite safety measures for Olympic-bound players in 11 disciplines, such as athletics, hockey, badminton, boxing, shooting, weightlifting, archery, cycling, fencing, wrestling and table tennis.

Professional leagues — from football, rugby to basketball — around the world have started and many more in different sports have been making desperate attempts to get players back on the field, following necessary and important safety guidelines. But one has to be very careful because recently we have seen many top sportspersons, including the world’s top-ranked men's tennis player Serbia's Novak Djokovic, have tested...
New Dates for Tokyo Olympics 2020

The two World Wars of the 20th century led to cancellation of some editions of the Olympic Games, but this will be the first time in the Olympics history that the Games are postponed because of a virus. Comparisons are always dangerous as they can be interpreted in different ways. To compare a postponement with a cancellation due to a World War would not be right, considering the losses and human suffering that a war brings with it. What we can say is that it is an unprecedented crisis for humankind, as we have never seen such a spread of a virus before, and a humongous challenge for the Olympic Games. The IOC in March took the historic decision to postpone the Games, scheduled to open in Tokyo on 24 July 2020, until 23 July to 8 August 2021. It is the first peacetime postponement of the Games. The Tokyo 2020 Paralympic Games have also been rescheduled to take place between 24 August and 5 September 2021.

According to the IOC, “A cancellation of the Olympic Games would have destroyed the Olympic dream of 11,000 athletes from all 206 National Olympic Committees, from the IOC Refugee Olympic Team, and for all the people who are supporting the athletes, including coaches, doctors, officials, training partners, friends and families. It would also have destroyed the work and the enthusiasm of our great Japanese hosts, with Tokyo being the best-prepared city for the Games ever. The Olympic Games Tokyo 2020 now will be celebrated from 23 July until 8 August 2021. It is a very complex event to organise, and its postponement is a real challenge. It is like a huge jigsaw puzzle where every piece is important and must fit together. It is the responsibility of the Tokyo 2020 Coordination Commission to work with all the stakeholders involved, starting with the Organising Committee Tokyo 2020, the 33 International Federations, the 206 National Olympic Committees, athletes, sponsors and broadcasters to work on all the questions coming from the decision taken to postpone the Olympic Games Tokyo 2020.”

“A dedicated Task Force — called “Here we go” — has been established under the umbrella of the Tokyo 2020 Coordination Commission. We all agree that the Olympic Games in Tokyo can stand as a beacon of hope to the world during these troubled times. Humankind currently finds itself in a dark tunnel. The Olympic Games Tokyo 2020 and the Olympic flame can be a light at the end of this tunnel. Therefore, it was agreed that the Olympic flame will stay in Japan. It was also agreed that the Games will keep the name ‘Olympic and Paralympic Games Tokyo 2020’. Hosting the Games in 2021 is already very symbolic, and we hope the Olympic Games Tokyo 2020 will be a celebration of humankind.”

On the question what will happen if the pandemic is still not contained by summer 2021, IOC said, “We will follow the risk management and mitigation measures set out by the World Health Organisation (WHO) for mass gatherings in the context of the current COVID-19 outbreak. We will continue to follow the principle that has driven all our decisions so far, which is to organise Olympic Games only in a safe environment for all people involved. We are committed to following this principle in the future.”
positive for COVID-19, Djokovic took part in a tennis exhibition series he organised in Serbia and Croatia. The Pakistan Cricket Board has also confirmed that ten players have tested positive for COVID-19 ahead of the team’s departure for England on June 28.

In the wake of the COVID-19 outbreak, the world is experiencing a bizarre moment in its history. Use of more and more modern technology, scientific training and health awareness has taken over the world of sports. Athletes have to be more conscious while practising and competing. One mistake and it could be ‘Game over’ for them.

There are more questions and fewer answers. ‘Hope for the best’ and ‘light at the end of the tunnel’ are the most commonly used phrases in these times of crisis. We are witnessing a new sporting world where the doors of stadiums have been shut for sports and turned into quarantine centres or hospitals for saving the lives of those suffering from the virus globally. During the lockdown, most of the athletes were forced to do workouts in the room or terrace of their houses. Applications like Zoom or Google Meet have now become the ‘in-thing’ replacing ‘team meetings’. No doubt, most of the top athletes are gadget-freaks and enjoy social media platforms to stay in touch with their family, friends and fans, but using these applications on a daily basis is something which was never done before. They have turned tech-savvy during the lockdown.

In February-March, governments of several countries, including India, stopped all sports activities such as competitions, meetings and training on sportsgrounds due to the lockdown. There is complete uncertainty when the situation will become normal and conducive to international travel, training and for the competitions to be organised smoothly. But the fact remains that sports will find it very difficult to get back to the same form and shape when
international championships start again in full swing. Nobody knows when this will happen but athletes are hoping for the best.

The American Ultimate Fighting Championship (UFC) has brought about a sense of normalcy, signalling the resumption of the first major competition in live action. The UFC 249 became the first ever contact-sport event to resume action, although behind closed doors and with full medical precautions. The event, watched by the world, even drew praise from US President Donald Trump, who mentioned it as ‘important’. The South Korean football league, K-League, also resumed on 8th May.

In Germany, the Bundesliga football league system restarted from 16th May. With players resuming individual training at their respective clubs and everything falling in place, Bundesliga is the first European League to restart matches in the postcoronavirus world. Spain’s La Liga restarted on June 11, but without spectators.

However, amidst the COVID-19 pandemic there were also some countries that continued professional sports. Belarus and Nicaragua continued sporting activities, although with mandatory restrictions and precautions. On the other hand, countries like Tajikistan and Turkmenistan stopped sporting action like football for a brief period but have now resumed.

This is a very important year for athletes all over the world, as they have been busy preparing with the dream of winning medals in the Olympics and world championships in many sports. The president of International Olympic Committee (IOC), Mr. Thomas Bach, has said, "We have to be vigilant and patient," Asked how the IOC might manage sports at the Tokyo Olympics involving human-to-human contact without a vaccine being available by then, Bach said, "We're one year away from these Games, and then we will take all the necessary decisions at the right time relying on the advice of the World Health Organisation, after discussing it in our joint task force. But I think nobody can at this moment in time really give you a reliable answer on how the world will look like in July 2021."
Prohibition of saliva to shine the cricket ball

Cricket players the world over will not be permitted to use saliva to shine the ball. The International Cricket Council (ICC) has confirmed a few interim changes to its playing regulations, which include the ban on the use of saliva to shine the ball and teams will be allowed to replace players displaying symptoms of COVID-19 during a Test match. It is aimed at mitigating the risks posed by the COVID-19 virus and protect the safety of players and match officials when cricket resumes. The ICC Chief Executives’ Committee (CEC) ratified recommendations from the Anil Kumble-led Cricket Committee in this regard.

The ICC has made it clear that if a player does apply saliva to the ball, the umpires will manage the situation with some leniency during an initial period of adjustment for the players, but subsequent instances will result in the team receiving a warning. A team can be issued up to two warnings per innings but repeated use of saliva on the ball will result in a 5-run penalty to the batting side. Whenever saliva is applied to the ball, the umpires will be instructed to clean the ball before play recommences. The ICC Cricket Committee heard from the Chair of the ICC Medical Advisory Committee Dr Peter Harcourt regarding the elevated risk of the transmission of the virus through saliva, and after that ICC agreed that the use of saliva to shine the ball be prohibited. The ICC also noted the medical advice that it is highly unlikely that the virus can be transmitted through sweat and saw no need to prohibit the use of sweat to shine the ball.

“We are living through extraordinary times and the recommendations the Committee have made are interim measures to enable us to safely resume cricket in a way that preserves the essence of our game whilst protecting everyone involved,” said Anil Kumble, Chairman, ICC Cricket Committee.

Teams will be allowed to replace players displaying symptoms of COVID-19 during a Test match. In line with concussion replacements, the Match Referee will approve the nearest like-for-like replacement. However, the regulation for COVID-19 replacements will not be applicable in ODIs and T20s.

In another change, the requirement to appoint neutral match officials will be temporarily removed from the playing conditions for all international formats owing to the current logistical challenges with international travel. The ICC will be able to appoint locally based match officials from the Emirates ICC Elite Panel of Match Officials and the Emirates ICC International Panel of Match Officials.

The CEC has also confirmed an additional unsuccessful DRS review for each team in each innings of a match, keeping in mind that there may be less experienced umpires on duty at times. This will increase the number of unsuccessful appeals per innings for each team to three for Tests and two for the white-ball formats.

The ICC Cricket Operations team will support Match Referees when processing breaches of Code of Conduct, and a neutral Elite Panel match referee will conduct any hearing remotely via video link.
So we have to be vigilant and we have to be patient at the same time to take the right measures to ensure the safe participation of everybody in the Games”.

According to the new guidelines issued by the Ministry of Home Affairs, sports stadiums and complexes are allowed to open across the country to host matches but without spectators. The new rules are a big relief for athletes in the country. The Sports Authority of India has said that for the safety of players a COVID-19 Task Force must be constituted at each training centre to guide and monitor all trainees and staff within the centres. The Task Force also has to ensure that each athlete and National Sports Federation (NSF) provides a signed consent form declaring their acknowledgement of all the limitations and risks associated with training under current circumstances. According to the laid down protocols and precautions for training, the Standard Operating Procedure (SOP) demands the NSFs to appoint a Hygiene Officer in every national coaching camp to ensure compliance and implementation of all protective measures for the safety of athletes and staff. Any athlete found to be in violation of the protocols will be removed from training immediately and reported to Hygiene Officer for “appropriate action”.

Sportspersons are adopting new guidelines: training sessions are conducted in small groups to ensure social distancing; players consciously rub their hands with sanitizers, not just before entering the ground, but also everytime there is a break; and each one of them carries his/her own bottle and ensure they don’t share. Hockey players are also forced to change the grip on stick regularly and their temperature is recorded after the session as well while it is monitored closely everyday to check for any irregularities. This is the ‘new normal’ for them and they need to follow it. Minister for Youth Affairs & Sports Mr. Kiren Rijiju has clearly stated that “the government had to tread a careful path to ensure that athletes remained free from COVID-19. A roadmap is being prepared by the Sports Ministry for a phased resumption of national camps for Olympic-bound athletes, starting with the athletes currently based at NIS Patiala and SAI Centre in Bengaluru. If something happens to top athletes it will be a setback and so we are careful and that’s why there are no positive COVID-19 cases for our athletes till now. Players are the pride of

Some questions that are being asked

Which is the safest sport to start early — athletics, archery, shooting, weightlifting, badminton, squash, table tennis and tennis — as non-contact sports? How and when should team sport resume in the country — basketball, football, hockey, volleyball and doubles in badminton, tennis, and table tennis? How and when should water sport resume in the country — swimming, sailing, rowing, canoeing, and kayaking?. How and when should contact sports — boxing, wrestling, judo, karate, taekwondo and wushu — resume in the country?

Doubts over social distancing, body contact and touch balls

Some doubts that crop up. Remember, training equipment is shared, and athletes will touch them. How can a sport like athletics maintain social distancing in track events? Since players have to touch tennis balls, shuttlecocks, table tennis balls, basketballs, handballs and volleyballs, how safe would it be to resume these sports and when? In sports like basketball, football, handball, hockey, kabaddi, kho-kho and wrestling, which see body contact, how safe would it be to resume training and competition in these disciplines? As each sport has its own distinctive features, the questions will vary from discipline to discipline.
Mr. Rijiju very clearly said, “Preference will be given to athletes who have qualified for Tokyo Olympics or those who have to go for Olympic qualifiers”. He added: “Other athletes might have to wait till at least September but this shouldn’t make them sad as everyone will come back to the field in a planned manner. Players requested to allow them to play. But everyone can’t be given permission together as it would be risky and so top athletes who have qualified for the Olympics or have to go for qualifiers will be given preference. No need to be sad for other athletes. Federations are requesting and I know how boring it is without sports, but this challenge is for everyone and we will have to wait. We are planning in that manner and the roadmap is ready.”

Training of the athletes was at the peak when the lockdown was enforced on 25th March and they had to stop their training immediately, although it differed from sport to sport. The risk of athletes and coaches losing motivation is real. Since there are no sports activities, sponsorships and media coverage have substantially reduced. When there are thousands of positive COVID-19 cases and so many casualties across the country, the priority of sports has diminished. In the present scenario, one has to find out what the way forward is and how athletes can resume sports activities, training and eventually competitions. It goes without saying that resumption of sports will have to be guided by the Central and state governments and the public health policies laid down.

It is too early to look for return to action, but within its guidelines, national and international federations have produced a process showing the route back to something resembling normalcy. It starts with a return to a carefully managed regime of training sessions, with social distancing measures in place. The next stage will be resumption of domestic competitions once local and international air travel starts, followed by travel between neighbouring nations. Trans-continental competition will follow, and finally, once a vaccine is in place, it is hoped there will be a return to normal competitions. There is no timescale for these stages to be reached and it will vary from country to country.

There is no doubt that the events will look very different in the foreseeable future. When competitions do resume, organisers will need to be hugely conscious of safety measures that will need to be implemented in order to keep the sports workforce and the fans safe. While everyone is excited about the return to action, one must realise that this needs an act of counterbalancing together with the knowledge and understanding that global health and wellness is a much bigger priority and one that transcends everything else.

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A classification of disciplines

**Individual sports:** Archery, Athletics, Cycling, Equestrian, Fencing, Golf, Shooting, Squash, Table tennis, Tennis, Weightlifting, etc.

**Team sports:** Basketball, Cricket, Football, Handball, Hockey, Kabaddi, Kho-kho, Volleyball, etc.

**Contact sports:** Boxing, Judo, Karate, Taekwondo, Wrestling, Wushu, etc.

**Water sports:** Canoeing and Kayaking, Rowing, Sailing, Swimming, Water Polo, etc.
On the late evening of 24 March 2020, the Government of India announced a 21-day nationwide lockdown to be observed from the midnight. Barring essential services, the movement, and activities of entire 1.3 billion population were restricted as a preventive measure to arrest the spread of virus, SARS-CoV-2. However, in later stages, gradually some relaxations were granted to the public for resuming some economic activities. Initially, at the time of commencement of lockdown the number of confirmed COVID-19 cases in the country was close to only 600. But with the time the number started swelling. Looking at the large counts of SARS-CoV-2 positive cases, a commoner may feel that the lockdown could not contain the transmission of the disease; perhaps it was not effective at all. But the situation is quite different. In this article we shall try to communicate logically, how many people could be saved from the highly contagious virus’ influence and related fatality. In fact, the lockdown slowed down the spread of the disease and this period had been gainfully utilised by the government to ramp up its health infrastructure and generate new resources to take up the fight against COVID-19 disease.

On 22 May 2020 Dr. V.K. Paul, Member NITI Aayog, and Mr. Praveen Srivastava, Secretary to Govt. of India, Ministry of Statistics and Programme Implementation, jointly addressed a press conference at the National Media Centre to explain the impact and advantages of the lockdown. It was mentioned by them that when the lockdown began the growth rate of the COVID-19 patients on the 26th March was around 15.8 per cent. It continued to grow the same way for the next few days and on 3rd April reached to 22.6 per cent at its maximum. After this peak, the effect of lockdown started reflecting upon and the growth rate of COVID-19 witnessed a steady fall. By 5th May it came
down to 5.5 per cent. Although the overall number of corona-positive cases has increased, its growth rate has decreased. If the growth rate had remained either 15.8 per cent or 22.8 per cent, at the time of beginning and peak periods, respectively, the number of cases today would have reached millions.

NITI Aayog and Ministry of Statistics assigned the task of assessing the effect of lockdown to five different groups of experts or agencies. They analysed the situation with the help of their statistical models using various available inputs. On the basis of their analysis the government has reached the conclusion that around 14-19 lakh people were saved from getting COVID-19 infection and also approximately 37,000-78,000 lives were saved.

Assessment-1:

The Boston Consulting Group took two approaches based on analysis of reproduction rate of COVID-19. Their study shows that in the absence of lockdown, there would have been 36-70 lakh more cases. So indeed, the lockdown saved between 1.2 and 2.1 lakh lives. They based their analysis on the assumption that one infected person was transmitting the disease to 3.5 persons on the average.

Assessment-2:

Public Health Foundation of India (PHFI) worked on modelling the number of deaths in the country and its states using statistical modelling techniques. By comparing their extrapolation with the actual status, it was evident that there would have been 78,000 more deaths in the absence of preventive containment and mitigation strategies during the lockdown.

Assessment-3:

In a similar manner, results derived from the analysis done by two independent economists show that 23 lakh COVID-19 cases and around 68,000 deaths have been averted by lockdown.

Assessment-4:

A study by independent experts, including retired scientists, also shows that 15.9 lakh cases and 51,000 deaths have been averted.

Assessment-5:

The Ministry of Statistics and Programme Implementation and Indian Statistical Institute have estimated that around 20 lakh cases and 53,773 deaths have been averted because of lockdown and other preventive measures.

Confinement of the disease

Though apparently there was a steady rise in the number of positive COVID-19 cases during the lockdown period, but in reality, restricted human activities and their home confinement helped a lot in breaking the disease transmission chain. Despite being a large nation, the spread of infection in India has mostly remained contained within certain areas. More than 80 per cent of the active COVID-19 cases were just limited to 5 states — Maharashtra, Tamil Nadu, Delhi, Gujarat, and Madhya Pradesh. Above all, more than 60 per cent COVID-19 cases were confined within the boundaries of five cities — Mumbai, Delhi, Chennai Ahmedabad, and Thane. Ten states — Maharashtra, Tamil Nadu, Gujarat, Delhi, Madhya Pradesh, Rajasthan, Uttar Pradesh, West Bengal, Bihar, and Karnataka — had 90 per cent of the total cases.

Officials also put forward quantitative analysis of deaths due to COVID-19. Out of the total, 80 per cent deaths were reported in five states — Maharashtra,
Gujarat, Madhya Pradesh, West Bengal, and Delhi. Nearly 60 per cent of the deceased were from the cities of Mumbai, Ahmedabad, Pune, Delhi, and Kolkata. On the other hand, around 70 per cent of the total deaths occurred in ten cities. Besides the aforementioned cities, the other five were Indore, Thane, Jaipur, Chennai, and Surat.

**Doubling duration**

Before the 24th March, when the lockdown was announced by the government, the doubling rate of positive COVID-19 cases was 3.4 days, meaning thereby the number of positive COVID-19 patients was getting doubled in just 3.4 days. Doubling rate started decreasing after that and by the 15th of May, it came down to 13.3 days. The facts quite obviously indicate that the lockdown has successfully slowed the rate of transmission of the disease. Slowing of propagation rate relieved sudden stress from the government machinery and the time was utilised to review and ramp up the basic infrastructure for fighting against the new disease. Obviously, being a new disease, we neither had understanding, nor enough resources to fight with at the time when the disease entered our boundaries. Lockdown took us to a better position in comparison to many other affected countries, as far as the doubling rate was concerned.

**Availability of one million hospital beds**

COVID-19 being a communicable disease, its patients cannot be treated in general hospitals. So the hospitals with isolation wards equipped with proper protective equipment and trained medical staff were needed to handle the patients, but we did not have any such exclusive hospitals or wards in the beginning when the disease began to spread in March.

But now the country has 1,093 dedicated hospitals for COVID-19 patients and these hospitals have 1,85,306 beds which include 31,250 beds having intensive care facility. These hospitals are also equipped with ventilators intended for the treatment of those critical patients who require either intensive care or life support system. Each district of the country has at least one such hospital.

Similarly, we have now 2,402 COVID-19 health centres where relatively less serious patients can be treated. These level-2 hospitals have 1,38,652 beds equipped with oxygen support. As many as 3.24 lakh beds are available in both the above categories.

Asymptomatic positive and mild COVID-19 cases can be treated in 2,402 level-3 designated hospitals in the country. These COVID-19 care centres have 6 lakh beds and can take care of the COVID-19 patients who do not require much medical care except isolation.

Together, all the three categories of hospitals have 9.74 lakh beds and the number goes up to 10 lakh if we add the facilities available with the armed forces.

According to the information provided by the Ministry of Health, less than 5 per cent of COVID-19 patients sought medical help at a critical stage where intensive care was needed. Among the rest of 95 per cent patients, only a small numbers of patients needed continuous medical attention having co-morbidities, while 85 per cent of them were required to be isolated.

**Training**

In the beginning, health personnel were not aware of the treatment of COVID-19 patients. But at the moment we have lakhs
of doctors, paramedical staff, and health workers who have been trained by the experts online, even at the village level. ASHA workers have been trained so that they could identify the suspected COVID-19 patients. The Health Ministry of Government of India is continuously imparting training to health staff through its online courses.

Guideline/Protocol

Meanwhile, with the help of Indian Council of Medical Research and other institutes, the Ministry of Health has prepared appropriate guidelines on each and every aspect related with SARS-CoV-2 and COVID-19. These guidelines incorporate protocols needed to be followed in regard to isolation, treatment, home quarantine, travel, transportation of dead bodies of infected persons and their last rites, use of PPE kits and face masks, and the treatment of patients in non-COVID hospitals. It even includes the protocol required during travel by all modes and social distancing protocol at public places. Following these protocols will certainly help in preventing spread of the disease.

PPE kits

There was not a single manufacturing unit for PPE kits India at the time of outbreak of the disease and medical staff throughout the country did not have sufficient number of kits to protect themselves. In the short span of a few months now, 109 companies have started making 3 lakh pieces of PPE kits every day. The country has now reached in a stage of exporting these kits. Similarly, N-95 face masks, which we used to import from other countries, are now being manufactured locally in large quantities. Manufacture of Sanitizers and other related products have also got a sudden boost because of the high demand.

Testing

Likewise, diagnostic testing facilities for COVID-19 have also been increased and today, throughout the country around 1.1 lakh samples are being tested every day. Currently, 610 laboratories, including 178 in the private sector, have a capacity to test 1.4 lakh samples in a day using the RT-PCR technique. The capacity will be increased to 2 lakh tests daily in near future.

(Translated by Pramod Pande)

Common Hygiene Products and the Stories Behind Them

It is without doubt that the highly contagious disease COVID-19, caused by a new coronavirus, will go down in history for posing unprecedented challenges to humanity and bringing the world to a grinding halt. Amidst the chaos, a few simple hygiene measures are becoming lifesaving tools and our frontline defences in the battle against the contagion.

The significance of handwashing, sanitising or wearing protective gear to arrest disease transmission appears to be evident to us today. It is surprising that until recently we were not so aware of the importance of these practices. Modern hygiene measures took ages to evolve and for centuries, doctors were in the dark about the apparent link between hygiene and infections.

Have you ever wondered how health and hygiene products such as soap, sanitizers, masks, and gloves came into existence? How long have they been in use to prevent the spread of infections? When did they emerge out of the surgical rooms to become a safety net for public health?

Much as we take these products for granted today, masks and gloves were unheard of — even during surgeries until the late nineteenth century! And, surprisingly, even the cheap and
readily available soap got its due importance as a germ-buster only in the past few decades.

History is rife with extraordinary and fascinating events that led to the discovery of these hygiene items. Here are some of those stories.

**Soap**

Soap is so commonplace that we assume its role in personal hygiene has existed forever. On the contrary, soap has had a long journey from its initial discovery to the present-day use. It took several thousand years to be recognised as a simple and economical product that could help to keep ourselves clean. Another century went by before it was realised that soap could destroy germs as well, in turn, helping us stay healthy. It was not until the 1980s that soap was introduced as a primary agent against infectious diseases and promoted as a public health measure in the wake of outbreaks.

Soap is more than five thousand years old, and it was discovered accidentally. As the story goes, once, in ancient Rome, when some women went to wash their clothes in the Tiber River, they noticed a clay-like substance in the water. The fat from animal sacrifices made on a nearby hill would run down into the river, mix with the river water, and turn into the unknown material. Although the Romans were unaware that the substance was soap, the women noticed to their delight that it made their washing easier. In essence, clothes were cleaner and free from grime much better than washing with just water.

Inscriptions on clay containers from around 2800 BC provide evidence that the Babylonians were the first to make soap. The engravings clearly indicate their formula of mixing animal fats, wood ash and water to get soap. The product so obtained was used to wash wool and cotton yarn for textiles. Although soap was widely used, civilisations were still unaware that it could be used for bathing. By around 1500 BC, the Egyptians too began soap-making by combining animal and vegetable fats, salts and water. However, along with washing cloth, they found that soap had clinical uses as well — to wash sores and skin diseases.

Whereas, the Greeks combined lye (hydroxides) and ash and used it as a scouring agent to clean their pots, pans and statues, by AD 79, the Romans turned soap-making into a thriving industry. An entire soap factory was unearthed at the ruins of Pompeii.

The soap industry grew rapidly, and by AD 1200, France and Italy became the primary manufacturing centres. However, bathing soap was an expensive commodity and accessible only to the rich and elite (the commoners still scrubbed their bodies with sand, pumice or ash). A few made their own crude soap for in-house use, by boiling fats from their livestock and wood ash.

Soap grew popular in the 16th century when animal fats were replaced by vegetable oils. The Arabs developed aromatic and exotic soaps by adding olive and thyme oils.
Modern soap

It was not until the 19th century that the surplus availability of oilseeds made soap an affordable commodity and a personal hygiene product. In 1837, an English businessman Robert Hudson introduced the world to soap powder and detergents. By the end of the century, English businessman Andrew Pears developed a high-quality, transparent soap, which gained popularity, and became a well-established brand.

It was also around the same time that Eugene Chevreul, a French chemist, deciphered the science of soap, explaining the process of saponification in soap formation. His work brought to light the chemical relationship between fatty salts, glycerol and fats.

In 1916, the Germans developed the first synthetic detergents, spurring a new era for both commercial and industrial use of soap.

After the First World War, Procter & Gamble, an American company, modified the existing laborious soapmaking method. They developed a quicker process by which soap could be made within a day. Their soapmaking process is so robust that, to this day, several manufacturers follow their method.

The hygiene link

Until the mid-1800s, doctors were unaware of hand hygiene! Physician Ignaz Semmelweis and Florence Nightingale championed handwashing in clinical practices. However, their advocacy was scorned and poorly received among their peers. It was only after the germ theory emerged a couple of decades later that many began propagating handwashing. As modern medicine evolved, handwashing was incorporated as a mandatory procedure before examining patients.

By the next century, soap was well established as a cleaning agent in clinical procedures. In 1980, the US faced a series of food-borne disease outbreaks. It was then that the Centres for

How soap gets rid of germs

Soap has a unique molecular structure resembling a pin. The ‘head’ end is hydrophilic (water-loving) while the ‘tail’ end is hydrophobic (water-repelling) but is attracted to lipids (fats).

Germs such as the coronavirus are usually covered by a fatty outer layer. When soap encounters them, the fat-loving tails get attracted to the lipid layer of the virus. They wedge through and pry apart the lipid outer covering and when the outer protective layer is broken, the virus gets denatured or destroyed.

The hydrophilic pins cluster together to form what are called ‘micelles’ which trap the broken fat bits. When soap is mixed with water, the hydrophilic ends act as emulsifiers dispersing the micelles in water, thereby washing away the germs.

Soap takes a little time to chop away the fatty bits, and hence, the 20-second scrubbing mantra for washing hands.
Disease Control and Prevention endorsed the importance of handwashing on a public scale to arrest the spread of these infections. Since then, handwashing with soap and water has been mandated as a safety measure to curb illnesses during epidemics.

Sanitizers

Unlike the age-old soap, its cousin, the hand sanitizer is just over 50 years old. Lupe Hernandez, a student nurse from California, USA, is credited with formulating the hand sanitizer in the year 1966. Reportedly, she was looking for easier ways to disinfect hands in the hospital wherever water and time were in short supply. When she came across the information that alcohol could be delivered in gel form, she quickly worked upon it to develop the hand sanitizer. Sadly, there is no concrete evidence of a published paper or patent credited in her name for her discovery. Owing to this, the origins of the sanitizer are still debatable.

Sanitizers have found extensive use in hospital environments as antiseptic rubs and an alternative to antiseptic soaps to disinfect hands before surgery. Presently, hospital hand rubs must conform to specified standards so that they eliminate 99.99 per cent of the germs. Further, contamination while using them is reduced by fitting elbow-operated or infrared sensors to the pumps to dispense the gel.

Sanitizers entered the commercial market first in 1997 when a US-based company introduced it under the brand name of Purell. The formulation and portable packaging revolutionised hand hygiene in many ways for the general public.

The demand for sanitizers rose during outbreaks like SARS, swine flu and other epidemics. However, with the H1N1 outbreak in 2009, sanitizers turned into a regular commodity.

Today, sanitizers are a common sight everywhere: from handbags to public spaces where soap and water are not handy. In fact, the World Health Organisation categorises alcohol-based sanitizers under the list of essential medicines needed in a health system.

What is a sanitizer made of?

Alcohol has antiseptic properties and was used for clinical purposes since the 14th century. The primary ingredient of a good quality sanitizer is 60-95 per cent alcohol. Usually, a combination of isopropyl alcohol and ethanol, water, and glycol or glycerol gel is used. Glycerine and fragrances are added to make the sanitizer more hand-friendly.
Whereas alcohol-free sanitizers are made for specific purposes, the antiseptic formulation usually contains benzalkonium chloride or triclosan. Such sanitizers work well when left for longer durations on the skin. However, compared to alcohol-based sanitizers, the alcohol-free formulations are not effective on a broad spectrum of pathogens. Moreover, the absence of alcohol itself poses a contamination problem.

**Action on germs**

Alcohol evaporates quickly and has a drying effect. It is this property that comes to use in its action against disease-causing microbes. Alcohol kills bacterial cells by destroying their cell membrane and dissolving the proteins. On viruses, the alcohol disrupts the outer lipid layer. The higher the alcohol content, the more potent is the sanitizer in killing germs.

Sanitizers can eliminate many pathogens. However, they are not 100 per cent fool-proof protection against diseases. Since sanitizers cannot clean grime and grease, handwashing with soap and water is any day a better choice.

**Did you know?**

- Sanitizer-making companies found the product running into losses until the 2000s.
- However, when sanitizers became available for the general public as a hygiene tool, the sales began to rise. They are now one among the most sought-after purchases even during regular times.
- According to PTI, amidst the recent COVID-19 pandemic, the sales of hand sanitizers globally skyrocketed, rising by tenfold.
- India too saw a surge in demand and high pricing for sanitizers in the wake of the present pandemic. The Council of Scientific and Industrial Research (CSIR) rose to the occasion by manufacturing quality and affordable sanitizers in their labs. These formulations not only met the in-house consumption demand but also catered to the general public through their technology transfer initiative.

**The right way to sanitize hands**

Just as with soap, there is a specific way to use the sanitizers.

Apply a blob of the gel on the palm of one hand. Then rub both palms vigorously such that it covers the palms and fingers thoroughly.

Leave the alcohol to dry naturally.

**Gloves**

We cannot think of a surgeon performing an operation without gloves, can we? Gloves keep both doctors and patients safe from infections. Shockingly, until the end of 1800s, surgeons never wore gloves while treating their patients.

Around this time when the germ theory came to light, Sir Joseph Lister, the famous British surgeon,
introduced sterilizing of surgical instruments with carbolic acid before performing a surgery. He even devised a machine that would spray a fine mist of the liquid around the surgical site. His measures dramatically reduced sepsis during operations, earning him the title of ‘Father of Modern surgery’. 

Far away in the United States, another distinguished surgeon and founder of the Johns Hopkins Hospital, William Stewart Halstead, improvised Lister’s procedures. He used a combination of carbolic acid and mercuric chloride as a disinfectant.

Halstead’s fiancée Caroline Hampton, an efficient chief nurse, was also his assistant. As the scrubbing nurse in-charge, she would handle the disinfectants frequently. In the process, her hands would break out in rashes due to the harsh chemicals. Affected by her plight, Halstead wrote to the Goodyear Rubber Company to order a pair of thin rubber gloves that would protect her hands while handling the chemicals.

Surprisingly, Halstead did not immediately notice that in his gesture of affection lay a powerful tool for medicine. Wearing gloves attracted the attention of others in the hospital, who, too, preferred wearing them to protect their hands. It was in due course that Halstead realised that using gloves was reducing surgical infections. Thus, so evolved the all-important standard item for surgeries.

During epidemics, the use of gloves forms a barrier between surfaces and the user’s hands, thereby arresting the contagion from entering the body.

**Masks**

Masks are a universally accepted hygiene tool for modern medical practice to prevent surgical wound infections. Face masks evolved randomly; there is no exact date or period when they came into vogue in the surgical field. Around 1897, European surgeons Johann von Mikulicz Radecki and C Fluegge are said to have covered their mouth with a gauze cloth while performing surgeries. They believed that exhalation and conversation during surgical procedures could transfer bacteria-laden droplets to the wound area.

In the following years, several other investigators propagated
the use of a face mask during surgeries and suggested improvisations. Over the next two decades wearing masks reduced droplet-borne sepsis in patients. Also, it was observed that the wearer, too, was protected from contracting any disease from the patient.

By the 1920s, the single gauze layers were gradually replaced by multiple layer and fine-meshed masks. By the 1930s, filters and deflectors were added to the design; different materials were used between layers of gauze: rubber, used X-ray films, waxed paper-covered by a gold-filled frame, plasticine and cellulose, to name a few.

When the masks were screened for their efficiency, it was found that those that had compressed cotton filters offered the best protection. This type of mask not only retained its ability to filter germs for extended periods but could also be sterilised and reused.

However, with the advent of antibiotics in the 20th century, the use of face masks took a backseat. Surgeons assumed these were not necessary as the new medicines would control the infections. However, gradually the medical fraternity realised that masks held their place of importance in the prevention of disease propagation. Once again, several models and modifications began surfacing through the 1950s.

The first disposable mask was developed in 1961. The design incorporated a cotton filter placed inside a plastic shell. The single-use cover was secured in place by elastic bands that fit snugly to the face. The contraption gave high bacterial filtration.

Evaluation of face masks is an ongoing study. Several researchers have employed different methods, such as high-speed photography or sampling chambers, to assess the range of contamination.

In recent times, post-operative infections are again on the rise, further escalating the importance of masks.

"Humanity has been ravaged by outbreaks over the ages. From each of these episodes, we have learnt valuable lessons in preventive methods and the profound impact they have on containing the disease transmission. By exercising a collective responsibility and diligently practising these measures, we can emerge victorious in the battle against the coronavirus pandemic. Stay safe and healthy

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Coping with Abnormal Times

Dr. SUKANYA DATTA

*Mens sana in corpore sano* is a Latin phrase, usually translated as “a healthy mind in a healthy body”. It is supposedly the prayer for every newborn. The phrase has endured because it encapsulates an eternal truth: mental health is as important as physical health.

The pandemic raging today has focused our attention on health matters as never before. The virus itself represents an unknown threat. Work is on to study its molecular make-up and to find a gap in its genetic structure so that a vaccine may be developed. Scientists are working around the clock to find a medicine that can work. Meanwhile, hand sanitizers and masks have been pressed into action on an unprecedented scale to ensure that physically, we remain infection free.

However, in a not-so-obvious manner, lifestyle changes are also being ushered in. Social distancing and, self-isolation are words that were not in our vocabulary before the pandemic struck. Today, we recognise these behaviour patterns are efficient at keeping the virus at bay. It is ironic because human beings have always been proud of being a ‘social species.’ And being social always meant close interactions... the pandemic has brought all that to a halt with even free movements being restricted in
Parents are afraid to let their kids play in the park; beloved pets are being abandoned out of fear of cross-infection, marriages are being solemnised with the bride and groom wearing masks and just four or five members of the family attend the last rites of a loved one. There are unforeseen threats...temporary (or permanent) unemployment, pay cuts, working from home without adequate infrastructure, constraints of home-schooling/online education of children or even the pressures of finding a dentist in case of acute toothache when all hospitals seem to have been overtaken by the COVID-19 crisis.

No, these are not normal times. And it has brought fear, worry and an enormous level of stress in its wake. In February 2020, a review published in Lancet, on the psychological impact of quarantine — the separation and curtailed movement of people potentially exposed to a contagious disease — during previous epidemics such as SARS, found proof of a range of psychological conditions, from post-traumatic stress symptoms to confusion, anger, depression, stress, insomnia and emotional exhaustion. Stressors included extended quarantine duration, fear of catching infection, frustration, boredom, inadequate information, financial loss, worries about inadequate supplies of food/medicines and societal stigma. Having inadequate basic supplies during quarantine was a source of frustration and the memory continued to be associated with anxiety and anger up to six months after release.

Longer durations of quarantine were associated with poorer mental health specifically, post-traumatic stress symptoms, avoidance behaviours, and anger. Interestingly, the anger does not go away when the quarantine is lifted.

In this context, mental health concerns are valid. This is especially important since pressures created by the crisis are exacerbating existing mental issues and creating new ones. “A lot of anxiety is rooted in worrying about the unknown and waiting for something to happen — coronavirus is that on a macro scale,” explained Rosie Weatherley, spokesperson for the mental health charity Mind. So, while mental stress is on a huge upswing, it so happens that those receiving mental health treatment before the crisis are now receiving much less support or no support at all. Those who were on the verge of requiring support but were not in acute need are at high risk of needing it urgently now. Many people have developed mental disorders as a direct result of the coronavirus disruption — e.g., social isolation, and increased stress. This is a cycle we have to break and it is only when we acknowledge that there may be a problem that we find a solution to it.

To most of us COVID-19 is a new threat. Our initial response is therefore one of uncertainty coupled with fear of the unknown. To that fear is added the inconvenience of the forced changes to our daily lives. It is
natural to feel lonely or afraid, even angry although logically we know that the lockdown is for our safety. It is undeniable that the first couple of days at home felt like a holiday but as the days passed it began to feel unbearable. We chafed to go out and resume our daily routine. Yet, that is not to be for many weeks yet. Dr. Michael Ryan, Executive Director, WHO Health Emergencies Programme, has gone on record to say, “This virus may never go away.” Even if the immediate threat level comes down, psychiatrists have warned of a “tsunami” of mental illness from problems stored up during lockdown. They are particularly concerned that children and older adults are not getting the support they need because of school closures, self-isolation and fear of hospitals.

We have to learn to live with this reality. However, certain attitudinal changes can help make the situation more bearable. For example, the lockdown has imposed restrictions on movements. Under the condition it is easy to feel isolated, helpless and lonely. Some may suffer intense anxiety. The trick is not to deny that some things are beyond our control but to actively focus on things we can control. For example, if feeling socially cut-off and lonely, we can make a phone/video call to a loved one. The conversation will be good for both parties. For those without access to a phone, just stepping up to the gate/door and having a conversation albeit with raised voices while maintaining proper distance will work wonders.

Of course, while it is acceptable to acknowledge that some things are beyond our control, encouraging constant thoughts about it will lead to a lot of anxiety.

The World Health Organisation (WHO) has published a list of simple recommendations that can be followed by everyone. The first is to stick to our daily routine as far as possible. During the lockdown period, the structured pattern of daily routine breaks down. There is no longer the pressure to take the child to school or even get ready for office. It is easy to descend into a chaotic pattern starting with discarding the alarm clock, getting up late, snacking through the day and surfing through the night. This disrupts the body's established daily bio-clock and may lead to insomnia which itself is the precursor of many issues. Thus, WHO recommends that we get up and go to bed at around the same time as we did earlier and also adhere to regular meal timings; just like before. It goes without saying that the meals should be nutritious and not junk food. This helps the body to maintain an even keel of functioning. A structured routine will also benefit the kids and help prevent them from becoming 'cranky' because routines give order, predictability, and a sense...
of control over what is happening.

Time must be created for some exercise, work and rest. Since regular walks have been ruled out for many, getting the daily quota of exercise has become difficult. It is recommended therefore that we do simple yoga stances or freehand exercises for a few minutes at least every day. It is not enough that we simply carry out the daily drudgery of routine housework. We must get some sunshine and some fresh air every day, even if it is from the window or the balcony. Most importantly, we must do something we enjoy. This may be listening to music, painting, writing...indulging a hobby of some kind or even something as common place as going up to the terrace to see the birds return in the evening. This pleasurable activity will cheer us up and help fight the boredom and listlessness that comes with the restrictions imposed on us. Usually when we feel anxious, our thoughts spiral out of control and we end up imagining all sorts of catastrophic outcomes. Doing something enjoyable directs the brain away from such negative thought processes.

Watching television is one way of passing the time. However, with the reportage on COVID-19 hogging the prime time, it can sometimes overwhelm the senses. It is recommended that we minimise newsfeeds. If too much news is making us anxious or distressed, it is better to switch to some light entertainment and restrict news to just once or twice a day to keep abreast. Time spent in front of a screen every day must be monitored mindfully. We need to take regular breaks from binge watching or playing addictive video games for hours on end. This is especially true for children who may take the opportunity to overindulge as their parents work from home.

We should also remind ourselves not to get stressed by hysterical reporting of sensational news; there is a lot of misinformation/fake news making the rounds. We have to avoid panic by relying on news emanating from trusted sources of information. While news can spread like wildfire via social media, we have to keep our feet on the ground and not be swayed by fake news showing up on our hand-held devices. On the other hand, we can take back power into our own hands by actively correcting misinformation on our social media pages. This will give satisfaction and serve society too.

Staying at home often lulls us into thinking that it is alright to neglect grooming ourselves. While not being able to go to a salon may mean longer hair and beards, neglecting to pay attention to personal hygiene will just open the door for more ailments. The standard of personal hygiene should not be allowed to drop. While washing hands multiple times is mandatory these days, a daily bath is also a must. As are combing hair and trimming nails. These may appear to be insignificant or trivial details. However, the contribution to
both physical health and mental satisfaction is large. How nice it feels when a fresh and clean face looks back at us as a reflection in the mirror. In a subtle manner it boosts self-esteem and signals that even during the lockdown we are as well-groomed and presentable as we used to be.

Social contact is important. If our physical movements are restricted, we can keep in regular contact with people close to us by telephone and online channels. This is particularly helpful when we have been recently bereaved and need support and companionship. Self-isolation doesn’t mean cutting off all communication. In truth, this is the time, more than ever, to remain connected...to listen and to share thoughts and feelings. Chatting with loved ones enlivens our mood.

Having a lot of free time often carries with it the temptation to use relaxants and stimulants...for example, alcohol and drugs because these are perceived as tools to address fear, anxiety, boredom, and social isolation. However, it is precisely what we should avoid at this time. If it is not possible to abstain, we ought to at least limit the amount of alcohol we consume daily.

Doctors advise that we avoid using alcohol and drugs as a way of dealing this ‘vortex of uncertainty’ into which the virus has plunged us.

Michael Farrell, Director, National Drug and Alcohol Research Centre at the University of New South Wales, Sydney, says, "...people will often take alcohol to take the edge off their anxiety in the short term...[but] the paradox of it is, if people are taking it for that, instead of reducing their anxiety over the medium term it actually makes the anxiety worse. It's like a bounce back effect." This is because alcohol affects the brain's messengers or neurotransmitters. Initially, as the blood alcohol level rises, our mind relaxes and we feel disorientation and euphoria. Yet, as the body starts eliminating the alcohol from the system we start feeling uncomfortable and even more stressed.

WHO categorically states, "Alcohol consumption is associated with a range of communicable and non-communicable diseases and mental health disorders, which can make a person more vulnerable to COVID-19. In particular, alcohol compromises the body's immune system and increases the risk of adverse health outcomes. Therefore, people should minimise their alcohol consumption at any time, and particularly during the COVID-19 pandemic. Fear and misinformation have generated a dangerous myth that consuming high-strength alcohol can kill the COVID-19 virus. It does not. Consuming any alcohol poses health risks, but consuming high-strength ethyl alcohol (ethanol), particularly if it has been adulterated with methanol, can result in severe health consequences, including death".

There is another fallout associated with alcohol abuse in
confined space. This is the risk of domestic abuse. The United Nations has warned of a surge in domestic violence across the world during quarantine. Children and women are more vulnerable to abuse, especially in small confined spaces. If faced with abuse, or if sensing the potential of being abused, we should not hesitate in calling for help. Help may be sought from family, a friend, a neighbour, the police or even via a Helpline.

The issues emanating from lockdown are fuelling an escalating fear psychosis among many people. This is not limited to those with pre-existing conditions like anxiety, depression and obsessive compulsive disorder, but also includes the elderly who are struggling with heightened levels of loneliness and sense of helplessness. A limited study on about 400 individuals in India, showed that 30 per cent of those taking part in it study had signs of depression. This is a remarkably high rate considering that it included people from all walks of life. Depression can lead to anxiety, panic attacks and suicidal tendencies.

There appears to be little sign of the pandemic loosening its hold on society in the near future. Apart from the physical distress of being confined there is the mental distress that comes from reading/hearing about how hard this virus has hit the less fortunate. We would not be human if we did not feel the pain. And when we feel overwhelming pain and distress our minds bear the brunt of it all. Slowly, the burden becomes too heavy to bear and cracks appear. So, is there no way to break this escalating situation? No way to escape falling into the pit of depression?

There is!

One shortcut to happiness is to help others less fortunate. It lies in taking steps to contribute in whichever way we can to society. It may mean feeding a stray animal or offering a glass of water to a thirsty stranger walking home. It may mean donating to the community kitchen. It may mean asking sick or elderly neighbours if they need you to pick up any item (milk/bread/medicines/vegetables) when you go shopping for your household item. It may mean paying the bills online for neighbours who are not online-savvy. If you feel you are helpless and cannot contribute in any way, just pick up the phone to say hello.

The bottom line is: social distancing and quarantine notwithstanding, we remain social creatures. With communication, empathy and fellow-feeling, we will emerge victorious. Meanwhile, let us take care of our physical health as well as mental well-being by following some simple steps.

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In the past few months, we have learnt a lot about the SARS-CoV-2 and the COVID-19, but the illness still remains baffling.

Questions begging answers

We know that the spike protein of the virus SARS-CoV-2 has the receptor binding affinity to the ACE2 receptor on the epithelial cells of the human respiratory organs, including lungs. Is this the only mechanism the virus uses to infect human cells? Ebola virus has two candidates for host cell entry proteins. First, the cholesterol transporter Niemann-Pick C1 (NPC1) protein and second receptor-binding domain of the EBOV glycoprotein TIM-1 (a.k.a. HAVCR1).

While in some the infections of SARS-CoV-2 are deadly, in others it is mild and in a large number of cases just asymptomatic. Why it affects some virulently, while in others it only causes few bouts of...
cough, sneeze and light fever is not known.

Among the patients, few require a ventilator for a long time, while others get better earlier. In some, cytokine storm (when the body starts to attack its own cells) takes the patient to the brink of death, while others sail through smoothly. Is there a pattern?

Why at some places, like Italy, does the infection seem rampant and unabating, while in some regions such as Kerala or South Korea, it is under control? Sure, the pandemic control measures have an impact. Is it only that or there is more than what meets the eye?

Flu and most respiratory viral infections are highly infective among children. In contrast, SARS-CoV-2 seems to hardly affect the children and the young.

All viruses mutate. Are there specific mutations which are dominant in Indian patients? Are these mutations significant? Will the mutations affect the efficacy of the vaccines that are being developed?

The study

The premier CSIR institutions, Delhi-based Institute of Genomics and Integrative Biology (CSIR-IGIB) and the Hyderabad-based Centre for Cellular and Molecular Biology (CSIR-CCMB), have teamed up to undertake a vital study in association with National Centre for Disease Control (NCDC) to study the novel coronavirus. Called the digital and molecular surveillance project, the programme aims to simultaneously monitor at three levels — the virus, the patient and the clinical course of the patient.

Virus samples would be obtained from across the country, and the isolates would be sequenced. Variants would be examined for genetic mutations. Further, the samples would be collected from those who are asymptomatic and from those who show mild, moderate, severe and critical symptoms. The virus isolates would be sequenced to find any connection between the disease types and the viral variants. In the second part, the clinical care data or hospital data would be gathered. Some patients require ventilators, while others can recover on their own. A few patients develop life-threatening cytokine storms, while many can sail through the infection. The patient profile and the virus variant afflicting them would be studied. The data collected is relevant for learning about modes of transmission, infection, morbidity, and vaccine design.

The genetic sequence of SARS-CoV-2

By 31 December 2019, the Chinese medical authorities found a cluster of 27 pneumonia cases in Wuhan City of Hubei province, China. Their radiology report showed bilateral lung infiltrates, and they had symptoms such as fever, dry cough, and shortness of breath. By 10 January 2020, the first novel coronavirus genome sequence was uploaded to Global Initiative on Sharing All Influenza Data (GISAID) and made publicly available.

The genome of the novel coronavirus, or SARS-CoV-2 as it is formally known, is an RNA, with about 30,000 base pairs. In contrast, a human genome, made up of DNA, is more complex and
has about 3 billion base pairs. Although small in comparison with a human genome, novel coronavirus is perhaps the biggest of all known RNA viruses. It is twice the size of deadly Ebola and common influenza. It is three times as big as the RNA of HIV and hepatitis C.

The genome could be thought of as a cookbook, containing recipes for making the vital proteins, instructions for making copies of the DNA and a manual for preparing a daughter cell. The book of recipes in English is written using just twenty-six alphabets and few symbols (like space between words, or a stop symbol at the end of a sentence). Various combinations of these twenty-six alphabets produce thousands of words and sentences. These sentences, when combined appropriately, can virtually record the preparation process of any conceivable cuisine on earth. Incidentally, the book of life, DNA (or in case of certain viruses, RNA) is just written with four alphabets, (technically called as nucleotides) ‘ACGT’. The unique combination of the four chemicals adenine (A), cytosine (C), guanine (G), and thymine (T), called nucleotides, is what uniquely identifies each species. Laying out the order, or the pattern of the arrangements of these four nucleotides is what is the genomic sequence. From drug discovery to vaccine development, the genomic sequence is of immense help.

**Typos in duplication**

The name of the game called life is reproduction. The virus infects and abducts the cells of the host to make copies of itself, by duplicating its genetic sequence. Copying always has the danger of committing a mistake. The duplicates end with errors. Unlike many viruses, coronaviruses have genomic proofreading mechanism, which weeds out copying mistakes. Yet the process of duplicating the viral RNA is so sloppy that the proofreader is not able to catch all the typos and the duplicates end up with errors. These are called mutations.

For example, take the case of much talked about L-type and S-type. Both types belong to the same clade ‘S’ (A clade is a group of organisms that have evolved from a common ancestor). All the members of this clade have typos in a gene called ORF8. The ORF8 gene underwent a mutation of the amino acid L (leucine) at the 84th position of the gene’s protein to the amino acid S (serine), and the mutation is called as ORF8-L84S. ORF8-L84S is but one of the mutations that have been recorded until today. Interestingly in another mutation, ORF8-S84L, the S and L mutate in the opposite direction. In the clade ‘G’, a variant called S-D614G, in a gene called ‘S’ the aspartic acid (D) at position 614 of the gene’s protein is changed to glycine (G). The variant of the clade ‘V’, labelled NS3-G251V, at the 251st position of NS3 gene glycine (G), is replaced with valine (V).

Watching horror movies and adolescent comic books, mutation immediately evokes a picture of a malevolent creature that is out to destroy the world. However, on most of the occasions, the mutations are not that dramatic or consequential. They are just mundane. Such inconsequential changes are called lineages or variants rather than strains. Until now, none of the mutations discovered has been found to have significant consequences.

**Recombination**

The rate of mutation in SARS-CoV-2 is just one-third of the flu
This has to do with the structure of the virus. Typos are not the only way a virus mutates. A much more potent change occurs when two or more strains recombine. Take the case of the flu virus. It has eight genomic segments. One can imagine that the genetic code of the flu is written in eight separate sheets. Duplicating the virus RNA is akin to taking photocopy. The photocopy machine, in this case the ribosome, a cellular organelle in the human cell, replicates the genome. Imagine two persons A and B, jousting to make copies of their eight-page reports. In the brawling, page 1 of A’s document may be mixed up with B’s. Some set of prints may have such mixtures. Such swapping of genetic segments is called recombination.

Often a cell is not infected with only one strain. When multiple strains of the same family of virus pass through the cell, new recombinations create more and more new strains. That is why flu is not easy to catch. It changes its avatar. So many flu strains develop that it is estimated that roughly a person in his or her lifetime gets about 200 flu infections.

In contrast to flu, the genetic sequence of SARS-CoV-2 is ‘unsegmented’, that is, its code is written in one single sheet. The page tends to stay together. However, on a rare occasion, the top half of the page from A may tear and fuse with the bottom half of the page from B. Such recombinations happen but are exceedingly rare. The pages have to rip at similar spots.

**Drift and shift**

The typos type mutations may be an “i” smudging in a photocopy and appearing as “I”. When a copy of the copy is made, such typo
Errors are carried on to the next generation of the virus. If such a typo results in malfunctioned protein production, such mutations would be weeded out. Very rarely, a single change in the amino acid sequence may change the fate of the virus. A typo change at a single location of the genome in the Ebola virus resulted in a far deadlier strain. However, in most cases such changes are harmless. They have no consequence. The variants gradually change as more and more typos cumulatively accumulate. This process is called ‘drift’. Once in a while, the accumulated ‘drifts’ might be powerful enough to cause significant change; we now say a new strain has evolved.

However, when a strain of virus swaps an entire page with another, or rips its unsegmented code and recombines with another, the effect is dramatic. Such striking changes are called ‘shift’. Almost all new variants from ‘shift’ are typically a new strain. Not all shifts may be beneficial to the virus. The resultant mutation may make, say, a process malfunction. The modification may not be advantageous to the virus. Such variations would be weeded out in the natural process of evolution. Some may provide the new strain with advantage. Then that strain tends to proliferate.

Shifts and drifts in the genetic code of virus have an impact on our immune system as well as vaccine developments. As long as the changes are just inconsequential typos, our body can recognise the new variant as being related to the old familiar variant. Our immune system, at least partly, is prepared, and the infection is milder. However, if the new strain has developed thorough shift, that is, by swapping parts of the genetic code from a less familiar strain, then we suffer badly. A vaccine developed for one strain may still be effective for a new strain as long as the changes are not substantial; however, when a new strain is developed through recombination, the vaccine could become ineffective. As the flu virus is segmented and often recombine to produce new strains, it has been a significant challenge to develop a vaccine for it.

**Molecular surveillance**

Once we get a better handle on the dynamics of the virus genome, we would be able to identify which part of the viral genome is mutating faster or slower. Such a piece of information is crucial for vaccine and drug development.

Dr. Rakesh Mishra, Director, Centre for Cellular and Molecular Biology (CSIR-CCMB) says, “Once we have a database of the genomic sequence from hundreds of isolates from India, we would be able to understand the network through which the
virus has spread in India, estimate the mutation rate, identify the part of the genome that is less susceptible to mutation so that we can target that part for vaccine development. Further, we would also be able to find if the variants found in India show any difference in its virulence or disease-causing capacity.”

One of the major mysteries of a viral pandemic is how come it can slip through and reach even the remotest corners of the country. “Tracking mutations helps us visualise how the virus travelled around different geographic locations, from country to country and within a nation from one place to another,” says Dr. Mishra. Full-genome sequences of the first two SARS-CoV-2 viruses from India were published as early as March 2020 by scientists from ICMR-National Institute of Virology, Pune. They showed that two SARS-CoV-2 sequences obtained from India represent two different introductions into the country. “Genetic data shows multiple introductions of the virus in India,” says Dr. Mishra. Once we construct the phylogeny of variants in India, compare it with the ones in the rest of the world, it would be possible to find the route the virus took to enter India. By mapping the viral variants across the country, one would be able to understand the genomic epidemiology.

Disease surveillance

As anticipated, the genome is mutating while transmitted in India. Newer variants have emerged. However, there is no evidence as of now if any of the variants is less or more virulent. “Though we are seeing relatively lower level of mortality and symptoms rate in India, there is no explanation at the moment for this observation. Only a rigorous study would illuminate”, says Dr Anurag Aggarwal Director of CSIR-IGIB.

Keeping an eye on the mutations of the virus is important even for testing, says Dr Aggarwal. Typically, the RT-PCR or any testing that tries to identify the virus and looks for pattern at a particular location of the genomic sequence. If there is a genomic change in that particular region, then the test might show negative, while the person may be infected by a different strain. “Understanding the dynamics of the genomic sequence is crucial for developing tests,” says Dr Aggarwal.

While molecular surveillance is one part, the clinical course of the patient is another aspect of this project. The Institute of Genomics and Integrative Biology (CSIR-IGIB) takes the leadership of this component. Dr Aggarwal says, “We are working with the National Centre for Disease Control (NCDC) for the pan-India representation of samples. We are setting up an end-to-end network in which we club all data.” The data on people infected with SARS-CoV-2 but are asymptomatic or showing mild impact will be collected. Likewise, the information on the clinical course of people who needed hospitalisation would also be collated. “The surveillance will be able to monitor the population in which the spread is virulent and the population in which the spread is controlled,” says Dr Aggarwal.

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Global Patent Landscape of COVID-19 Technologies

MAYUREE SENGUPTA AND Dr. H. PURUSHOTHAM

In late November-December 2019, patients suffering from viral pneumonia on account of an unidentified microbial agent were reported in Wuhan, China. A novel coronavirus was subsequently identified as the causative pathogen. The Coronaviridae Study Group (CSG) of the International Committee on Taxonomy of Viruses has recognised the virus of this acute respiratory disease called coronavirus disease-19 (COVID-19) virus as forming a sister clade to the prototype human and bat severe acute respiratory syndrome coronaviruses (SARS-CoVs) and designated it as SARS-CoV-2. The COVID-19 disease has spread to 213 countries and the death toll stands at a perilous 347,907. Research reveals that amongst the two, SARS-CoV-2 is more transmissible/contagious than SARS-CoV. While researching methods to contain the virus or developing a cure is still in progress, a feasible way would be to delve into the patent landscape to locate pertinent innovations on the block. Therefore, both patent applications and granted patents on SARS-CoV may offer beneficial insights towards understanding and treating COVID-19 disease. It is with this goal that we explore the patent landscape of COVID-19 and SARS-CoV.

COVID-19 patents

The patent portfolio of COVID-19 related technologies could be broadly categorised into the following as depicted in Figure-1, namely, biomedical devices and diagnostic methods, therapies and vaccines, protective devices, and plant-based pharmaceutical composition. For the purpose of this study, patent refers to both patent applications and granted patents. The core inventive concepts of COVID-19 patents are further enumerated in Table-1.

Patents about SARS-CoV pharmaceutical compositions

Select pharmaceuticals, compounds and chemicals identified from patents which have been claimed to be effective against SARS-CoV are listed in Table -2.
Table-1: Patent categories of COVID-19 related technologies

<table>
<thead>
<tr>
<th>Category</th>
<th>Title</th>
<th>Core concept</th>
<th>Claim</th>
<th>Technology domain</th>
<th>Country of origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application of host marker for COVID-19 infection.</td>
<td>Host marker with COVID-19 and comprises at least one of RNR1, MFSD11, SYNE3 and SLC10A3 genes. The invention analyses the difference of gene expression of the patients with COVID-19 positive pneumonia and the patients with COVID-19 negative pneumonia.</td>
<td>Diagnostic capability of the COVID-19.</td>
<td></td>
<td>Biotechnology</td>
<td>China</td>
</tr>
<tr>
<td>COVID-19 novel coronavirus nucleic acid detection method capable of improving accuracy.</td>
<td>COVID-19 novel coronavirus nucleic acid detection method capable of improving accuracy.</td>
<td>Virus detection of patient as per fluorescence signal intensity vide recombinant technique.</td>
<td></td>
<td>Biotechnology</td>
<td>China</td>
</tr>
<tr>
<td>Fluorescence immunochromatography device for detecting COVID-19 and using method thereof.</td>
<td>Assay device with brief detection time.</td>
<td>Screening of asymptomatic infections.</td>
<td></td>
<td>Analysis of biological materials</td>
<td>China</td>
</tr>
<tr>
<td>Proposed Therapy to Reduce Effects of Viral Infections (may help with COVID 19).</td>
<td>Combination of lifestyle changes, vitamin supplements and prescription medicines.</td>
<td>Nicotinamide Mononucleotide (NMN) supplement, Resveratrol &amp; Metformin combination may prove to be significantly beneficial to combat COVID-19.</td>
<td></td>
<td>IT methods for management pharmaceuticals</td>
<td>Australia</td>
</tr>
<tr>
<td>Category</td>
<td>Title</td>
<td>Core concept</td>
<td>Claim</td>
<td>Technology domain</td>
<td>Country of origin</td>
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<tr>
<td></td>
<td>Adenovirus vector vaccine for preventing SARS-CoV-2 infection.</td>
<td>Recombinant vaccine for preventing SARS-CoV-2 infection comprising at least one drug having a therapeutic effect on COVID-19 and also preparing a COVID-19 detection reagent in another embodiment.</td>
<td>Vaccine for preventing SARS-CoV-2 infection.</td>
<td>Pharmaceuticals</td>
<td>China</td>
</tr>
<tr>
<td>Protective device</td>
<td>Device for blocking transmission of diseases such as new coronavirus through droplet</td>
<td>A device for blocking the transmission of droplets such as the infection of new coronavirus diseases, which comprises a chemical sterilisation unit, a physical steriliser, an air filter, a head cover and other auxiliary units.</td>
<td>Air sterilisation and disinfection device for blocking or reducing cross infection of infectious diseases such as new coronavirus COVID-19 diseases.</td>
<td>Medical technology. Other consumer goods</td>
<td>China</td>
</tr>
<tr>
<td></td>
<td>Multifunctional medicine core, mask and application.</td>
<td>A multifunctional medicine core, a mask and application, wherein the multifunctional medicine core comprises bacteriostatic drugs, aromatic drugs and bacteriostatic drugs, wherein the bacteriostatic drugs comprise cortex moutan, red paeyon root and indigo naturalis; the aromatic medicine comprising lignum Aquilariae Resinatum, lignum Santali albi, herba Agastaches, parched rhizoma Atractylodis, radix Angelicae Dahuricae and folium Perillae; the medicine for inhibiting drug comprises Coptidis rhizoma and cortex Phellodendri.</td>
<td>Multifunctional mask comprising multifunctional medicated core with an early warning color band that develops color when it adsorbs pathogenic bacteria or viruses including coronavirus, SARS virus or COVID-19 virus.</td>
<td>Basic materials chemistry. Other consumer goods. Pharmaceuticals</td>
<td>China</td>
</tr>
<tr>
<td>Category</td>
<td>Title</td>
<td>Core concept</td>
<td>Claim</td>
<td>Technology domain</td>
<td>Country of origin</td>
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</tr>
<tr>
<td>Plant-based composition</td>
<td>Sarva jura kudineer</td>
<td>A composition comprising ingredients, roots of Kandangkattari, Shindil Kilanku, Chukku, Chirukanchori Veer, Chiruthakk, Muthakaasu, Thippili Veer, Nilavembu Veer, Parppadaakam and Kottam.</td>
<td>Claims to be potent and having antipyretic effect against zoonotic/communicable diseases that results in infections such as Corona virus (COVID-19), H1N1, ZIKA virus, HIV virus, etc.</td>
<td>Pharmaceuticals</td>
<td>India</td>
</tr>
<tr>
<td></td>
<td>Composition of anti-coronavirus macleaya cordata benzyl isoquinoline alkaloid and resveratrol and application thereof.</td>
<td>A bocicloram benzyl isoquinoline alkaloid and resveratrol composition claiming unique binding activity on a coronavirus-related protein target spot.</td>
<td>Composition is used for preparing a medicament for treating Covid-19 coronavirus infection.</td>
<td>Pharmaceuticals</td>
<td>China</td>
</tr>
</tbody>
</table>

**Table-2: Pharmaceutical substances claimed to be potent against SARS-CoV**

<table>
<thead>
<tr>
<th>Patent No.</th>
<th>Active Agent</th>
<th>Mechanism/Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN1699354, CN1699355</td>
<td>2,3,5-trisubstituted-4-thiazolidone compounds</td>
<td>SARS-CoV virus 3CL protease inhibitor</td>
</tr>
<tr>
<td>KR101097189</td>
<td>Dihydroxychromone derivatives</td>
<td>Virus serine protease and virus polymerase inhibitor.</td>
</tr>
<tr>
<td>EP1940385</td>
<td>Ruthenium oxalate compounds</td>
<td>Potent inhibitory activity and cytoprotective activity to infected cell.</td>
</tr>
<tr>
<td>DE10361945</td>
<td>Peptide derivatives, of which C-terminal epoxy ketone structures contain - A - β-lactone derivatives Aclacinomycin and lactacystin; modified peptide aldehydes such as MG132, its boric acid derivative MG232, llnl, etc.</td>
<td>Proteasome Inhibitor and/or a Ubiquitin-Proteasome-Pathways (UPS) Inhibitor</td>
</tr>
<tr>
<td>EP1703901</td>
<td>2,4-dichlorobenzyl alcohol and amylnetacresol</td>
<td>Exhibits viricidal activity against SARS-associated coronavirus, particularly the phenotype Urbani SARS-associated coronavirus.</td>
</tr>
<tr>
<td>WO2007075145A1</td>
<td>Benzopyranone derivatives</td>
<td>Inhibiting the transcription or replication of 3CL proteinase (3CLMpro) of SARS virus.</td>
</tr>
<tr>
<td>KR20200029639</td>
<td>Cyclosporin analog molecules</td>
<td>Antimicrobial agent</td>
</tr>
<tr>
<td>JP2020502258</td>
<td>Glucosamine based composition</td>
<td>Immunomodulatory agents, liposomes containing immunopotentiating compositions</td>
</tr>
<tr>
<td>US20190055256</td>
<td>7-thio-substituted-3-nitro-1,2,4-triazolo [5,1-c]-1,2,4-triazin-4(1H)-one compounds.</td>
<td>Effective against single strand RNA virus infections.</td>
</tr>
<tr>
<td>WO2019135003</td>
<td>Atlantic cod (Gadus morhua) sourced trypsin i.e. trypsin obtained from marine serine protease.</td>
<td>Viricidal activity</td>
</tr>
</tbody>
</table>
Conclusion

There is a prominent difference between the patent landscape of SARS-CoV and SARS-CoV-2 i.e., COVID-19. While SARS-CoV patents could be classified under diagnostic methods, vaccines and pharmaceutical compositions categories, COVID-19 patent landscape additionally has categories pertaining to biomedical rapid detection devices and protective gear or equipment to prevent widespread transmission of the contagious ailment. The patent landscape is thus an indicator of the fact that humans must make peace with a new socially distanced lifestyle until a cure of COVID-19 arrives.

References:


ARTICLES INVITED

Articles are invited for publication in Invention Intelligence from science writers, scientists, inventors, innovators, researchers, technologists, entrepreneurs, and others. Invention Intelligence publishes articles on current topics in science, new technologies, inventions and innovations, research & development in various fields, and Intellectual Property Rights issues.

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- The article should be written in a lucid language. The length of the article may be about 3,000 words. The write-up prepared for a column may be up to 1,500 words. To make the article easily comprehensible and interesting, suitable photographs/diagrams must be enclosed with the article. The captions of photographs/diagrams should invariably be given. If some data have been used in the article then the reference to the original source must be given.
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A "Compendium of Indian Technologies for Combating COVID-19 (Tracing, Testing and Treating)" prepared by National Research Development Corporation (NRDC) was launched by Dr. Shekhar C. Mande, Director General, CSIR and Secretary, DSIR, Govt. of India at CSIR Headquarters, New Delhi on 5 May 2020. The compendium carries information about 200 COVID-19-related Indian technologies, ongoing research activities, technologies available for commercialisation, initiatives and efforts taken by the Government of India, categorised under 3Ts of Tracking, Testing and Treating. Most of these technologies are proof-of-concept (POC) tested and can help the entrepreneurs to take the product to market faster as they do not have to reinvent the wheel. Dr. Mande appreciated the initiative of NRDC for bringing out the Compendium of Indian Technologies for Combating COVID-19 as it is very timely and would benefit the MSMEs, Startups and the public at large.

Dr. H. Purushotham, CMD, NRDC, informed that team-NRDC has made an attempt to compile most relevant and indigenously developed emerging technological innovations, including those which are at research stage, to fight COVID-19 for the benefit of all stakeholders and this compendium will serve as a ready-reference for policymakers, industries, entrepreneurs, startups, MSMEs, research scholars, scientists and others. He also informed that several of the technologies compiled are approved by ICMR.

The information presented in the compendium is sourced from various government bodies and premier academic institutions including Department of Science and Technology (DST), Department of Biotechnology (DBT), Indian Council for Medical Research (ICMR), Ministry of Electronics and Information Technology (MeitY), Council of Scientific and Industrial Research (CSIR), Defence Research and Development Organisation (DRDO), Indian Institute(s) of Technology (IITs), Science and Engineering Research Board (SERB), Technology Development Board (TDB), National Innovation Foundation (NIF), Startup India, All India Council for Technical Education (AICTE), Sree Chitra Tirunal Institute for Medical Sciences and Technology (SCTIMST), and Indian Institute of Science (IISc). For more information, including transfer of technology, one may reach NRDC, an enterprise of Department of Scientific and Industrial Research (DSIR), Ministry of Science & Technology, Govt.of India at cmdnrdc@nrdc.in.

— Dr. P. BHAVYA MANJEERA
NRDC Licenses NavRakshak PPE Suit Manufacturing Know-how to Five MSMEs Developed by Indian Navy

National Research Development Corporation (NRDC) has licensed the manufacturing know-how of a PPE Suit being named as NavRakshak to five MSME clients: M/s Greenfield Vintrade Pvt Ltd (Kolkata), M/s Vaishnavi Global Pvt Ltd (Mumbai), M/s Bharat Silks (Bangalore), M/s Sure Safety (India) Ltd (Vadodara) and M/s Swaps Couture (Mumbai) to meet the ongoing countrywide demand of quality PPE kits. These five manufacturers put together are planning to mass produce more than 10 million PPEs per year.

The manufacturing know-how of NavRakshak PPE has been developed at the Innovation Cell of the Institute of Naval Medicine, INHS Asvini Hospital (Mumbai) of the Indian Navy from where the name ‘NavRakshak’ is derived. The PPE has been tested and certified at the INMAS, DRDO which is one of the nine NABL accredited labs authorised by Ministry of Textile currently in India for PPE prototype sample testing as per the prevailing ISO standards and Ministry of Health & Family Welfare/Ministry of Textile guidelines and has been found to meet the synthetic blood penetration resistance criteria for both the fabric, suit, and seam. It is cost effective as it does not require any major capital investment and can be adopted even by gown manufacturing units using basic stitching expertise. The technology and quality of fabric is so superior that there is no need of sealing around the seam of the PPE suit, thus eliminating the need of importing costly sealing machines and tapes. The PPE fabric even does not require any lamination with polymer or plastic-like film. This enables the PPE to permeate heat and moisture from the skin of the user. It gives protection but does not compromise on comfort. This uniqueness of the PPE makes it way different from the existing PPEs which are being used during the ongoing COVID pandemic.

The PPE suit is available in single-ply as well as double-ply versions as per the need of the end-use conditions. It also comes with a headgear; face mask and shoe cover up to the mid-thigh level.

With the country significantly ramping up the production of PPE suits to end its import dependence, there has been several news reports mentioning the flooding of market with dubious-quality PPE kits. While there has been a clarion call to strictly implement the testing and certification standards for manufacturers, a quality product is also the need of the hour. NavRakshak has been designed by a Naval doctor incorporating personal experience in using the PPE for the comfort and protection of the doctors. The enhanced breathability factor in the PPE suit makes it an attractive proposition to be used by the frontline health workers who are required to wear these suits for long hours and face extreme discomfort while working.

Intellectual Property Facilitation Cell of Directorate General of Quality Assurance (DGQA), Department Of Defence Production, Ministry Of Defence along with Indian Navy and NRDC partnered in protecting the IP and its commercialisation. Since the concept of using uncoated, un laminated or untaped PPE has been provided for the first time, and using such PPE was not practised at all, there was a need to protect the IP rights of this innovation. A patent application has been filed for the NavRakshak PPE by the inventors through NRDC. This technology can resolve many issues at one go. It makes manufacturing easy without requiring big capital investment. It does not require coating and taping related equipment. Therefore, foreign import and costly machines are not required. It gives protection as well as comfort to the user. Above all, it gives self-sustainability to the country. In future, it may so appen that this simple yet highly effective PPE suit may become the benchmark standard of PPEs.

— Dr. SANJEEVA MAJUMDAR & SHASHANK SONAL, NRDC
NRDC is engaged in the development, promotion and transfer of technologies emanating from various national R&D institutions/ universities. The Corporation offers its IPRs and Technology Transfer services in wide ranging areas like: Agriculture, Chemical, Agro & Food processing, Life Sciences, Mechanical, Electrical & Electronics, Energy and Telecom. It acts as an effective catalyst in translating innovative research into marketable industrial products. NRDC has the largest repository of Indian technologies and signed about 5000 licence agreement with entrepreneurs/start-ups/corporate in India and abroad. Some Innovative technologies are available with NRDC for Commercialization having great potential in India and Abroad:

- Extraction of Azadirachtin from Neem Seeds Kernel and its Pesticide formulation
- Super absorbent Hydrogel
- Preserved Sugarcane Juice in glass bottles
- Potassium Humate
- Ready to eat Honey Pan Beeds
- Process for the production of Honey Powder with Natural Profiles
- Process for preparation of Wheat based Chocolate Bar
- Low Cost Jute Based Sanitary Napkin
- Karnataka Rice Hybrid (KRH-4)
- Silver Nano Particle as Antidandruff Agents
- Live-attenuated Salmonella Typhimurium Vaccine
- Trichoderma harzianum, a biocontrol agent against Phytophthora foot rot
- Zinc solubilizing PGPR for soil drenching
- Porous and Ultra-Light MgO and ZnO Nano-Crystalline Powders
- Novel method of storing and delivering PGPR/microbes through biocapsule
- Seed coating composition and a process for its preparation
- Micronutrient compositions for ginger (for soils with pH above 7 & pH below?)
- Micronutrient compositions for turmeric (for soils with pH above 7 & pH below?)
- Micronutrient composition for Black Pepper
- Micronutrient composition for Cardamom
- Non-invasive Breath Analyzer for Diabetes Monitoring
- Ayush-82, Ayush-64, Ayush-56, Ayush SG
- Bala Rasayana
- Anti-Arthritis and Anti Fungal Ointments
- Herbal Mouthwash
- Herbal Hand Sanitizer
- Herbal after-shave lotion
- TOCO (Toilet Care Unit)
- Pochonia chlamydosporia, a biocontrol against nematodes
- Pochonia chlamydosporia liquid formulation
- Mosquito larvicidal Formulation based on Bacillus Thuringiensis var. Israelensis
- PGPR talc formulation for Ginger
- Manufacture of Nata-de-Coco from Coconut Water
RECYCLING OF WASTE PLASTIC TO Tiles

ATTENTION
OF ALL MUNICIPAL AUTHORITIES / ENTREPRENEURS

Prime Minister Shri Narendra Modi urged the nation to make Mother India plastic-free and exhorted municipalities, NGOs and the corporate sector to come up with ways for safe disposal of accumulated plastic waste. India generates about 10 million tonnes waste plastics per year which is toxic to environment and all living beings.

To move forward in the direction to achieve this environment-friendly goal, an Innovative technology to convert waste plastic into useful products like tiles, pavement blocks and other structural components etc. is available for Commercialization. The technology is Licensed by NRDC. For more details please contact NRDC.

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