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MONTHLY POPULAR SCIENCE MAGAZINE

DNA as a medium to store vast computer data: a reality very soon?

plus

New innovatively-designed low cost material to combat air and water pollution

Tricking the body: a new preventive way to tackle allergies

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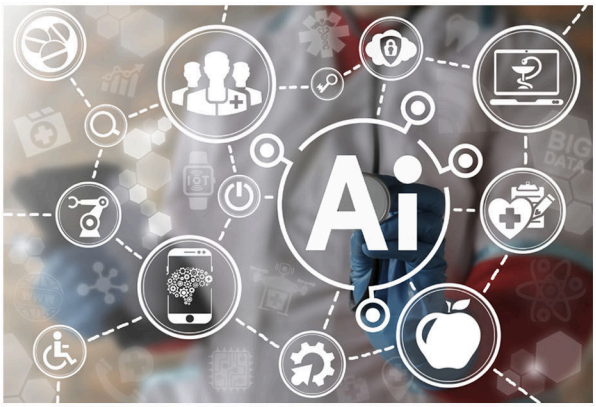

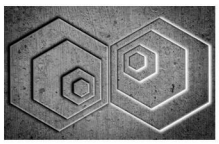

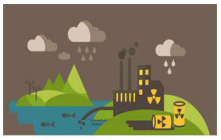

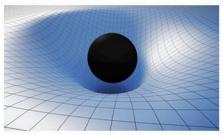

NOTE FROM THE FOUNDER & EDITOR-IN-CHIEF

We are delighted to bring nine articles on promising advancements in science that hold great potential to improve millions of lives –computer storage on DNA, graphene as superconductor, sustainable agriculture, combating air and water pollution and many more.

Hope you find them an enjoyable read!

Umesh Prasad

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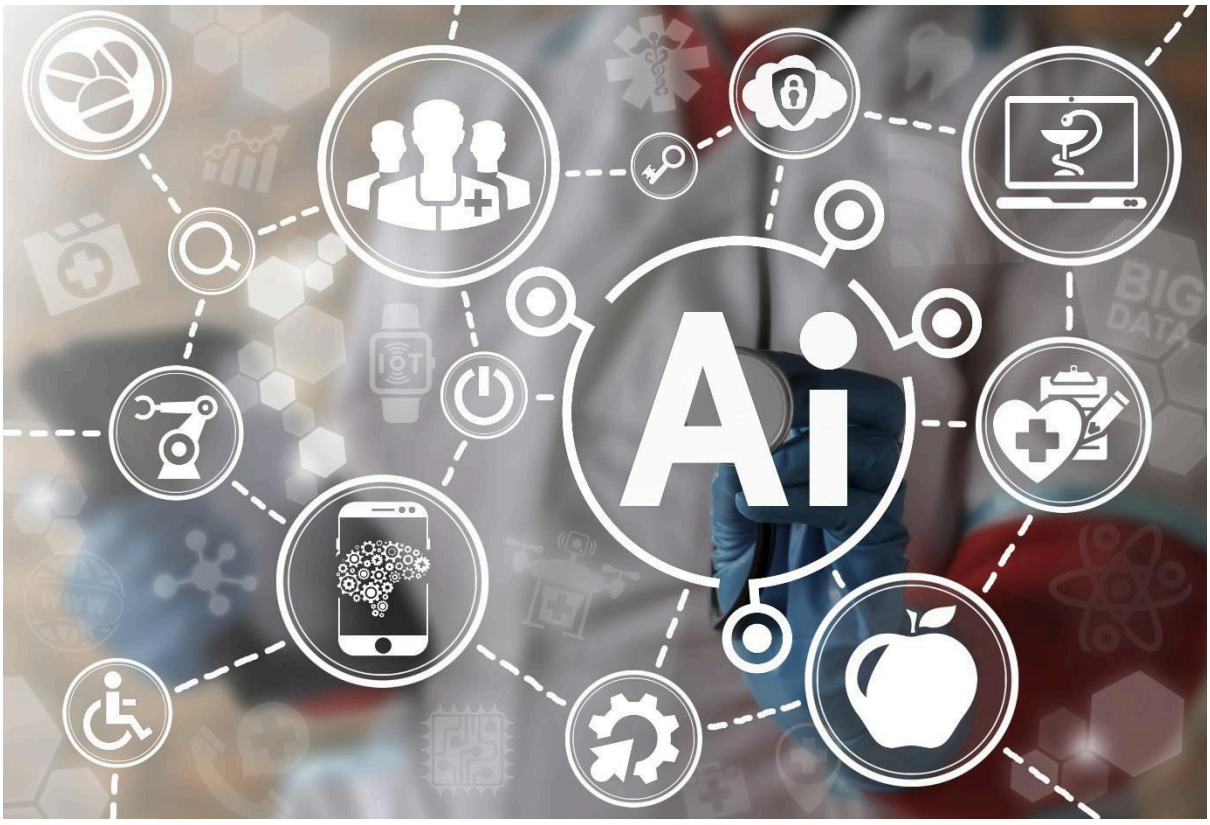
Artificial Intelligence Systems: enabling fast and efficient medical diagnosis?

Recent studies have shown the capability of artificial intelligence systems in medically diagnosing important diseases



Artificial Intelligence (AI) systems have been around for quite some time and are now getting smarter and better with time. AI has applications is multitude areas and is now an integral of most fields. It is now strongly believed that AI can be an essential and useful component of medical science and research as it has immense potential to impact the healthcare industry.

Artificial Intelligence in medical diagnosis?

Time is the most valuable resource in healthcare and early appropriate diagnosis is very important for the final outcome of a disease. The current healthcare is often a lengthy and a time and resource consuming process, delaying effective diagnosis and in turn delaying the correct treatment. AI can help to fill the gap between availability and time management by doctors by incorporating speed and accuracy in the diagnosis of patients. It could help to overcome limitations of resources and healthcare professionals specially in low- and middle-income countries. AI is a process of learning and thinking just like humans through a concept called deep-learning. Deep learning utilizes broad sets of sample data to create decision trees by itself. With this deep learning, an AI system can actually think just like humans, if not better, and therefore AI could be deemed fit to carry out medical tasks. When diagnosing patients, AI systems keep looking for patterns among patients with same illnesses. Over time, these patterns can lay the foundation for predicting diseases before they are manifested.

In a recent study[1] published in *Cell*, researchers have used artificial intelligence and machine learning techniques to develop a new computational tool to screen patients with common but blinding retinal diseases, potentially speeding diagnoses and treatment. The researchers used an AI-based neural network to review more than 200,000 eye scans conducted with a non-invasive technology that bounces light off the retina to create 2D and 3D representations of tissue. They then employed a technique called 'transfer learning' in which knowledge gained in solving one problem is stored by a computer and applied to different but related problems. For example, an AI neural network optimized to recognize the discrete anatomical structures of the eye, such as the retina, cornea or optic nerve, can more quickly and efficiently identify and evaluate them when it is examining images of a whole eye. Such a process effectively allows the AI system to gradually learn with a much smaller dataset than traditional methods which require big datasets and is expensive and time-consuming.

This study focused on two common causes of irreversible blindness which are treatable when detected early. Machine-derived diagnoses were compared with diagnoses from five eye doctors or ophthalmologists who reviewed the same scans. In addition to making a medical diagnosis, the AI platform also generated a referral and treatment recommendation which not been done in any previous study. Thus, this trained AI system acted just like a well-trained ophthalmologist and could generate a decision within 30 seconds on whether or not the patient should be referred for treatment, with more than 95 percent accuracy. Further, they also tested their AI tool in diagnosing childhood pneumonia, a leading cause of death worldwide in children under the age of 5, based on machine analyses of chest X-rays. Interestingly, the computer program was able to differentiate between viral and bacterial pneumonia with more than 90 percent accuracy. This is crucial because though viral pneumonia is naturally rid by the body after its course, bacterial pneumonia on the other hand tends to be a more serious health threat and requires immediate treatment with antibiotics.

In another major leap[2] in artificial intelligence systems for medical diagnosis, scientists have found that photographs taken of a retina (back of the eye) of an individual can be analysed by machine-learning algorithms or software to predict cardiovascular heart risk by identifying signals which indicate towards heart disease. The status of blood vessels in the eye which is captured in the photographs was shown to accurately predict age, gender, ethnicity, blood pressure, any prior heart attacks and smoking habits and all these factors collectively predict heart-related diseases in an individual.

The eye as an information block

The idea of looking at the photographs of the eye to diagnose health has been around for some time. It's well established that the rear interior wall of the human eyes has a lot of blood vessels which reflect the overall health of the body. Thus, by studying and analysing the appearance of these blood vessels with a camera and a microscope, a lot of information about an individual's blood pressure, age, smoker or non-smoker etc can be predicted and these are all important indicators of health of an individual's heart.

Cardiovascular disease (CVD) is the number one cause of death globally and more people die of CVDs compared to any other disease or condition. This is more prevalent in low- and middle-income countries and is a huge burden on economy and mankind. The cardiovascular risk depends on a multitude of factors like genes, age, ethnicity, sex, in combination with exercise and diet. Thankfully, most cardiovascular diseases can be prevented by addressing behavioural risks like use of tobacco, obesity, physical inactivity and unhealthy diet and making significant lifestyle changes to address the possible risks.

Health diagnosis using retinal images

This study conducted by researchers at Google and its own health technology company Verily Life Sciences, showed that an Artificial Intelligence algorithm was used on a large dataset of retinal photographs of around 280,000 patients and this algorithm was able to successfully predict heart risk factors in two completely independent datasets of around 12000 and 1000 patients with reasonably good accuracy. The algorithm used entire photograph of the retina to basically quantify the association between the image and the risk of heart attack. So, this algorithm could predict a cardiovascular event 70 percent of the time in a patient and in fact a smoker and a non-smoker were also distinguishable in this test 71 percent of the time. Further, the algorithm could also predict high blood pressures indicating heart condition and also predict the systolic blood pressure -the pressure in the vessels when the heart beats- within a range of most patients with or without high blood pressure.

The accuracy of this prediction, according to authors is very similar to a cardiovascular check in the laboratory, where blood is drawn from the patient to measure cholesterol levels looking in parallel with the patient's history. The algorithm in this study, published in *Nature Biomedical Engineering*, could in most likelihood also predict occurrence of a major cardiovascular event - e.g. a heart attack in the future.

An extremely interesting and crucial aspect of these studies was that in both these studies the computer can also tell where it is looking in an image to arrive at a diagnosis, allowing us to understand the prediction process. Example, the study by Google exactly showed "which parts of the retina" contributed to the prediction algorithm, in other words how the algorithm was making the prediction. This understanding is important not only to fully understand the machine learning method in this particular case, but also for generating confidence and faith in this entire methodology by making it transparent.

Challenges

It must be pointed out that such medical images come with its challenges since observing and then quantifying associations based upon such images is not straightforward mainly because of several features, colours, values, shapes etc in these images. This study uses deep learning to draw out the connections, associations and relationships between changes in the human anatomy

(internal morphology of the body) and disease in the same way as a healthcare professional would do when he or she is correlating patients symptoms with a disease. Also, these algorithms obviously require more testing before they can be used in a clinical setting. For instance, it's still unclear how the various factors add up and, in some individuals, it may be anyway necessary to perform sophisticated tests, like coronary calcium CT scans to identify the risks.

Despite discussions and challenges, AI has huge potential to revolutionize disease diagnosis and management by doing analyses and classifications involving immense amounts of data that are difficult for human experts and it provides fast, cost-effective, non-invasive alternative image-based diagnostic tools. The most important factors for success of AI systems would be more computational power and more experience of the people. With each developing AI for medical diagnosis, healthcare delivery is improving significantly for potentially everyone. A probable future is visible in which new medical insights and diagnosis would be achievable with AI without human direction or oversight.

Source:

1. Kermany, Daniel S. et al., 2018, 'Identifying Medical Diagnoses and Treatable Diseases by Image-Based Deep Learning', *Cell*, vol. 172, no. 5, pp.1122 – 1131. DOI: 10.1016/j.cell.2018.02.010
2. Poplin, Ryan et al., 2018, 'Prediction of cardiovascular risk factors from retinal fundus photographs via deep learning', *Nature Biomedical Engineering*, vol. 2, pp.158–164. DOI:10.1038/s41551-018-0195-0

A hopeful alternative to antibiotics for treating Urinary Tract Infections

Researchers have reported a new way to treat Urinary Tract Infections (UTIs) in mice without using antibiotics

A urinary tract infection (UTI) is an infection in any part of the urinary system - kidneys, ureters, bladders or urethra. Most of such infections attack and affect the lower urinary tract, which is the bladder and urethra. UTIs are caused by microorganisms, generally bacteria which live in the gut and then spread to the urinary tract. It is the most common and recurring type of bacterial infection and a person of any age or gender can develop UTI. It is estimated that close to 100

million people acquire UTI every year and almost 80 percent of UTIs are caused by the bacteria *Escherichia coli* (*E. Coli*). These bacteria live harmlessly in the gut but can spread to the opening of the urinary tract and up to the bladder, where they can cause problems.

UTIs are recurrent in nature because bacterial populations from the gut are continually filling the urinary tract with disease-causing bacteria. The symptoms include painful and burning sensation when passing urine and these bacteria might also travel till the kidney causing pain and fever and they may even reach the bloodstream. Such bacterial infections are treated by using oral medicines called antibiotics. Unfortunately, doctors are running out of oral antibiotics to treat such infections mainly because the bacteria which cause them are becoming more and more resistant to these antibiotics with each passing day and thus majority of antibiotics that are available at the pharmacy are not working anymore.

Antibiotic resistance is on the rise globally and one example which clearly shows where we have failed is the rise in the resistant strains of the bacteria *E. Coli* since it is responsible for causing most UTIs. In such cases when the infection occurs, its treated with antibiotics on the first go but when it occurs again and again 10 to 20 percent of cases do not respond to the antibiotic which was previously used. Thus, to treat reoccurring UTIs, the doctors have no choice but to either prescribe older, less effective antibiotics or have to inject the medicine into the blood because oral dose taken via mouth is not working anymore.

Alternative drug for UTIs

A new study conducted by researchers at Washington University School of Medicine in St. Louis, USA, shows a new way to treat UTIs without using antibiotics. The main goal is to block the bacteria from adhering or attaching to the urinary tracts and thus treating the infection, making this approach a completely novel way to tackle the problem of UTIs and antibiotic resistance as well by providing an alternative to our dependency on antibiotics. When causing a UTI, bacteria *E. Coli.* first latches onto the sugars on the surface of the urinary bladder using long, hair like structures called pili. These pili are like a 'Velcro' which allow bacteria to stick to the tissues and thus thrive and cause infection. The bacteria pili are therefore very important and the sugar to which they connect to are of various kinds, though *E. Coli.* is seen to favour a particular sugar called mannose.

The researchers created a chemically modified version of mannose, called mannoside and they observed that when they released these mannosides, the bacteria via the pili grabbed hold of mannosides molecules instead and hence they were swept away as these mannosides were free flowing molecules, finally getting flushed away with urine. Further, they also found that the sugar galactose attaches to adhesive proteins at the end of the bacteria's pili. Similarly, the researchers made galactoside against this galactose and they found that after pitting galactoside against galactose, the bacteria latched on to galactoside instead of urinary tract-anchored galactose, basically the bacteria got tricked! To test the significance of galactoside, once *E.Coli.* was injected into mice, galactoside or a placebo was injected. It was seen that number of bacteria in the bladder and kidney dropped significantly. Both these treatments together were most impactful, with bacteria in the bladder dropped many-fold and in kidney they were nearly eradicated.

Therefore, these two different inhibitors have a synergistic therapeutic effect because both these processes are involved in the attachment process during the infection. The bacterial pili which attaches to mannose plays an important role in urinary bladder, while the galactose attaching pili are more important in kidney. Not letting the bacteria latching on to these sugars can help fight this infection in bladder and kidney. The results of this study, published in *Proceedings of National Academy of Science of the USA*, are encouraging and suggest this new 'decoy' molecule approach

to trick the bacteria and flush them out of the system. The pilus which have been used as a target in this study are found in most strains of *E. Coli.* and in other bacteria as well.

Theoretically speaking, the mannoside treatment could also cause to flush away many other bacteria, just like an antibody kills extra bacteria along with the target. This can cause imbalance and lead to growth of harmful bacteria and destruction of good bacteria. To understand what actually happens, researchers measured the composition of the gut microbiome after this mannoside treatment. They found that mannoside treatment had minimal effect on other intestinal bacteria which were not responsible for UTIs. This is in stark contrast to the massive changes in the abundance of many microbial species seen after treatment of a bacterial infection with antibiotics.

Very hopeful for future

The ultimate goal of this study is to manage and prevent the common problem of recurrent urinary tract infections by providing an alternative to antibiotics. This assumes relevance because its high time that the worldwide crisis of antibacterial resistance is suitably tackled. Though, the strain of bacteria was not entirely eliminated the results are nevertheless promising. Since the bacteria is unable to stay in the body, it is less likely to drive resistance because, unlike antibiotics, the drug would not force bacteria to die or evolve resistance in order to survive.

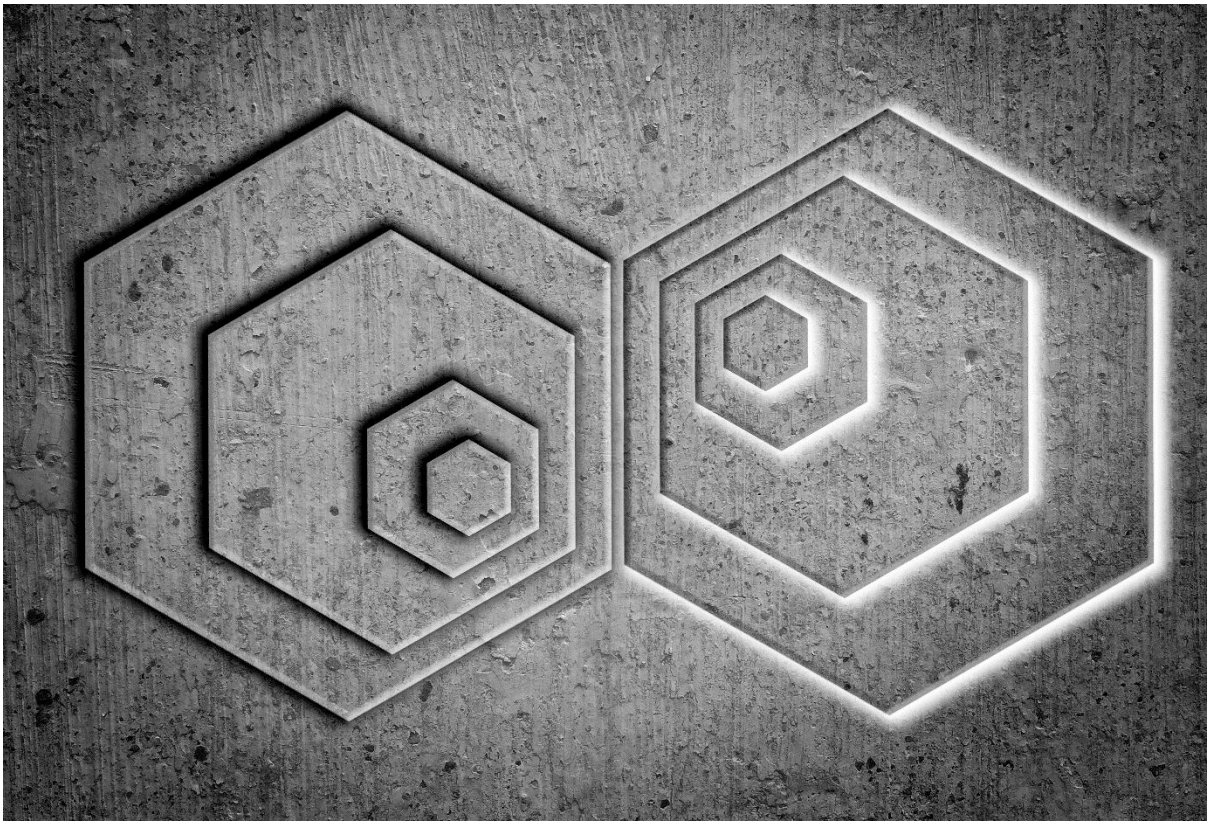
These findings have been proved so far in mice and human testing is the plan now. Since the first step for many disease-causing bacteria is to bind a sugar on a surface inside the body, this approach could be applied to other pathogens besides *E. coli.* By identifying other such proteins that the bacteria is likely to use to attach to specific sites, we should be able to design compounds to inhibit their binding. However, before the galactoside enters human trials, further work is needed to show that it is not toxic and can be absorbed into the circulation when taken by mouth. Nevertheless, researchers are confident that they have taken an important step toward developing alternatives to antibiotics. Since mannoside is not an antibiotic, it can be potentially used to treat UTIs that are caused by antibiotic-resistant strains of bacteria as well.

A company called Fimbrion Therapeutics - co-founded by the lead authors of this study – is developing mannosides and other drugs as potential therapies for UTI. Fimbrion is working with Phramaceutical giant GlaxoSmithKline on the preclinical development of mannosides for use in combating UTIs in humans.

Source:
Kalas, Vasilios et al., 2018, 'Structure-based discovery of glycomimetic FmlH ligands as inhibitors of bacterial adhesion during urinary tract infection', *Proceedings of the National Academy of Sciences*, DOI: 10.1073/pnas.1720140115

Graphene: A giant leap towards room temperature superconductors

Recent ground-breaking study has shown the unique properties of material graphene for a long-term possibility of finally developing economical and practical-to-use superconductors



A superconductor is a material which can conduct (transmit) electricity without resistance. This resistance is defined as some loss of energy which occurs during this process. So, any material becomes superconductive when it is able to conduct electricity, at that particular 'temperature' or condition, without release of heat, sound or any other form of energy. Superconductors are 100 percent efficient but unfortunately, most materials require to be in an extremely low energy

state in order to become superconductive, which basically means that they have to be very cold. Most superconductors need to be cooled with liquid helium to very low temperature of about -270 degrees Celsius. Thus, any superconducting application is generally coupled with some sort of active or passive cryogenic/low temperature cooling. This cooling procedure requires an excessive amount of energy in itself and liquid helium is not only very expensive but also non-renewable. Therefore, most conventional or "low temperature" superconductors are inefficient, have their limits, are uneconomical, expensive and impractical for large scale use.

High-temperature superconductors

The field of superconductors took a major leap in mid 1980s when a copper oxide compound was discovered which could superconduct at -238 degrees Celsius. This is still cold, but much warmer than liquid helium temperatures. This was known as the first "high-temperature superconductor" (HTC) ever discovered, winning the Nobel prize, though its "high" only in a greater relative sense. Therefore, it occurred to scientists that they could focus on eventually finding superconductors which work, let's say with liquid nitrogen (-196° C) having the plus that its available in plenty and is also cheap. High temperature superconductors also have applications where very high magnetic fields are required. Their low-temp counterparts stop working at around 23 teslas (tesla is a unit of magnetic field strength), so they can't be used to make more stronger magnets. But high temperature superconducting materials can work at more than twice that field, and likely even higher. Since superconductors generate large magnetic fields they are an essential component in scanners and levitating trains. For example, the MRI today (Magnetic Resonance Imaging) is a technique which uses this quality to look at and study materials, disease and complex molecules in the body. Also, other applications include grid scale storage of electricity by having energy-efficient power lines (example, superconducting cables can provide 10 times as much power as cooper wires of the same size), wind power generators and also supercomputers. The devices which are capable of storing energy for millions of years can be created with superconductors.

The current high temperature superconductors have their own limitations and challenges. Apart from being very expensive because of requiring a cooling device, these superconductors are made of brittle materials and are not easy to shape and thus cannot be used to make electrical wires. The material also might be chemically unstable in certain environments and also extremely sensitive to impurities from atmosphere and water and thus it has to be generally encased. Then there is only a maximum current that superconducting materials can carry and above a critical current density, superconductivity breaks down limiting the current. Huge costs and impracticalities are hindering the usage of good superconductors especially in developing countries. The engineers, in their imagination, would really want a soft, malleable, ferromagnetic superconductor which is impervious to impurities or applied current and magnetic fields. Too much to ask for!

Graphene could be it!

The central criterion of a successful superconductor is to find a high temperature superconductor, the ideal scenario being room temperature. However, newer materials are still limited and are very challenging to make. There is still continuous learning in this field about the exact methodology these high-temperature superconductors adopt and how scientists could arrive at a new design which is practical. One of the challenging aspects in high-temperature superconductors is that it's very poorly understood what really helps the electrons in a material to pair up. In a recent ground-breaking study, it has been shown for the first time that the material graphene has intrinsic superconducting quality and we can really make a graphene superconductor in the material's own natural state. Graphene, a purely carbon-based material,

was discovered only in 2004 and is the thinnest material known. It is also light and flexible with each sheet comprised of carbon atoms arranged hexagonally. It is seen to be stronger than steel and also it expresses much better electrical conductivity compared to copper. Thus, it's a multidimensional material with all these promising properties.

Physicists at Massachusetts Institute of Technology and Harvard University, USA, whose work is published in two papers[1,2] in *Nature*, have reported that they are able to tune the material graphene to show two extreme electrical behaviour – as an insulator in which it doesn't allow any current to pass and as a superconductor in which is allows current to pass without any resistance. A "superlattice" of two graphene sheets was created stacked together rotated slightly at a "magic angle" of 1.1 degrees. This particular overlaying hexagonal honeycomb pattern arrangement was done so as to potentially induce "strongly correlated interactions" between the electrons in the graphene sheets. And this did happen because graphene could conduct electricity with zero resistance at this "magic angle" while any other stacked arrangement kept graphene as distinct and there was no interaction with the neighbouring layers. Therefore, they showed a way to make graphene adopt an intrinsic quality to super conduct on its own. Why this is highly relevant is because, the same group had previously synthesized graphene superconductors by placing graphene in contact with other superconducting metals allowing it to inherit some superconducting behaviours but could not achieve with graphene alone. This is a ground-breaking report because graphene's conductive abilities have been known for a while but it's the first time ever that graphene's superconductivity has been achieved without altering or adding other materials to it. Thus, graphene could be used to make a transistor-like device in a superconducting circuit and the superconductivity expressed by graphene could be incorporated into molecular electronics devices with novel functionalities.

This brings us back to all the talk on high-temperature superconductors and though this system still needed to be cooled to 1.7 degrees Celsius, producing and using graphene for large projects looks achievable now by investigating its unconventional superconductivity. Unlike the conventional superconductors, graphene's activity cannot be explained by the mainstream theory of superconductivity. Such unconventional activity has been seen in complex copper oxides called cuprates, known to conduct electricity at up to 133 degrees Celsius, and has been the focus of research for multiple decades. Though, unlike these cuprates, a stacked graphene system is quite simple and the material is also understood better. Also, only now graphene has been discovered as a pure superconductor, but the material in itself has many outstanding capabilities which are previously known. This work paves way for a stronger role of graphene and development of high-temperature superconductors that are environment-friendly and more energy efficient and most importantly function at room temperature eliminating the need for expensive cooling. This could revolutionize energy transmission, research magnets, medical devices especially scanners and could really overhaul how energy is transmitted in our homes and offices.

Source:

1. Yuan Cao et al., 2018, 'Correlated insulator behaviour at half-filling in magic-angle graphene superlattices', *Nature*, DOI:10.1038/nature26154
2. Yuan Cao et al., 2018, 'Unconventional superconductivity in magic-angle graphene superlattices', *Nature*, DOI:10.1038/nature26160

Sustainable Agriculture: Economic and environmental conservation for smallholding farmers

A recent report shows a sustainable agriculture initiative in China to achieve high crop yield and low use of fertilizers using an elaborate network of researchers, agents and farmers

Agriculture is defined as production, processing, promotion and distribution of agricultural products. For several decades, agriculture was often associated only with the production of

essential food crops (wheat, maize, rice etc). Presently, it includes much diverse products and goes beyond farming by including forestry, dairy, poultry and fruit cultivation. Agriculture is the backbone of a country's economy and it's the central essence on which a country flourishes because agriculture not only provides food and raw material but also provides employment opportunities to a large percentage of population. It's the main source of livelihood for many people especially in the fast-growing economics in the developing world where up to almost 70 percent of the population depends on agriculture, while for many countries export of agriculture products is a main source of income. Agriculture is very crucial to ensure economic growth, employment growth and food security for a nation.

Agriculture sustainability and productivity

In agriculture, productivity growth –measured as Total Factor Productivity (TFP) growth – is the key to measure the economic performance of agriculture and is important to drive income. It represents how efficiently the agricultural industry combines inputs to produce outputs by using available resources. Obviously, these outputs and inputs are adjusted according to produce and costs based upon the demography. There have been recent improvements in this productivity due to continuous growth in agricultural production (food, fuel, fibre and feed – the 4fs) enabling farmers to lead to better outputs. This higher productivity has also at the same time raised farm household incomes, improved competitiveness and contributed to a country's growth.

It is imperative to recognize that the prevailing agricultural practices of a vast number of smallholder farmers, in developing countries like China and India, do not meet requirements for sustainable productivity. To cater to the needs of a growing population worldwide, global food production must increase by 60 to 110 percent over 2005 levels by 2050 in order to meet the demand. Also, various impact of climate change and environmental degradation are already makes farming more difficult and need to be factored in, example agriculture itself produces greenhouse emissions of up to 25 percent. Therefore, food security together with environmental degradation are the two primary and closely linked challenges which mankind will face in the coming time. Thus, it is important to increase the efficiency of farmers while limiting the costing and environmental impact to ensure that agriculture provides a sustainable food source for the world's increasing population.

A recent report published in *Nature* shows an extensive collaboration of scientists from University of Pennsylvania, USA and China Agricultural University in successfully implementing a long-term, broad-scale intervention that both improved yields and reduced fertilizer application across China, marking it as a big step towards sustainable agriculture. This effort, which was enacted over a course of 10 years from 2005 till 2015, engaged nearly 21 million farmers across the country covering 37.7 million hectares of land.

The first step in this project was to assess the different factors which affect agricultural productivity in various regions, these factors included irrigation, plant density and sowing depth. These were used as the guide to spread best practices across several regions. So, no sharing of agricultural tools was required, instead only information was gathered and scientific data was pooled based upon the local conditions and agricultural needs. As a result of this programme, an increase in yield was seen on average of more than 10 percent, with maize (corn), rice and wheat outputs growing by some 11 percent over this decade. Also, the fertilizer use was lowered by 15 and 18 percent depending on the crop. The overuse of nitrogenous fertilizers is one of the biggest challenges in agriculture causing almost two-third of the world's nitrogen pollution leading to reduced fertility of soils, algal blooms in lakes and ground water pollution. Therefore, these practices saved the use of almost 1.2 million tons of nitrogenous fertilizers leading to savings of

$12.2 billion. This led to the farmers making more money from their land rather than spending on it.

It was not as simple and straightforward as it may sound, mainly because sharing and encouraging the farmers to adopt certain good practises is challenging because they have very limited resources which they have invested into their livelihood and their number is huge, running into millions in China and also let's say for example India. But, the unthinkable was achieved and it was seen that the agricultural yield showed huge improvement, and on the hand other the use of fertilizers was decreased.

These practises have been around for quite some time, but the new thing about this particular initiative was the enormous scale on which it was carried out, and with close, massive, nation-wide, multitiered collaborations between scientists, agents, agricultural businesses and farmers (a whopping number of 1,152 researchers, 65,000 local agents and 1,30,000 agribusiness personnel). The project was carried out in two parts. In the first part, scientists and technicians helped gain a sense of what agriculture in the region was like and what the farmers desired. They devised strategies based upon weather, soil type, nutrient and water supply requirements and resources available. In the second part, agents and agriculture business personnel received training on how to implement scientist's recommendations. These agents then trained the farmers to apply these scientific agricultural principles on the farms and also helped in designing fertilizer products which matched the needs of the farmers. In working closely together, data on nutrient, pesticide, water and energy usage etc was gathered for further reach and to gain insights researchers conducted a survey of 8.6 million farmers from 1944 regions across the nation and found that the yields were improved by 10 percent and also up to 50 percent for some crops.

What made this study unique and also exciting at the same time is the larger scale on which it was performed with successful collaboration giving good and sometimes unexpected results. This programme must be monitored, updated and fine-tuned to the needs of farmers in specific regions while taking into account climate change. And, about 200 million smallholdings which are still not part of this programme in China must be brought in. Success of this nation-wide intervention can mean significant learning terms of the scale of bringing such sustainable management practices to a large section of a country's farming community. So, it should be applicable elsewhere and broadly speaking, could be translated to Asia and sub-Saharan Africa, because demographically these countries have small scale farmers who cultivate maybe only a few hectares of land but they are significant and dominating on the overall agricultural landscape of the nation. For example, India also has a lot of small land holding farmers with 67 per cent of them holding a farm of the size of less than one hectare. India also has a problem of low yields and high overuse of fertilizers and in countries of sub Saharan Africa both yield and fertilizer use are low. This study throws light on the basic aspects of engaging farmers and gaining their trust. However, one challenge that remains in translating this study beyond China to other countries is that China has a well-developed regional infrastructure, while other countries like India do not. So, it looks difficult but it's not entirely impossible.

This study shows how a sustainable agriculture practise can produce economic and environmental benefit balancing the double objectives of adequate food production and environmental conservation. It provides hope towards making farming on smaller pockets of land more sustainable through suitable management practices.

Source:
Zhenling Cui et al., 2018, 'Pursuing sustainable productivity with millions of smallholder farmers', *Nature*, vol. 555, pp. 363–366, DOI:10.1038/nature25785

Tricking the body: a new preventive way to tackle allergies

A new study shows an innovative method to tackle food allergy in mice by tricking the immune system into avoiding giving out an allergic reaction response

An allergy is when our immune system reacts to a foreign substance - called an allergen - by treating it as an invader and generating chemicals to defend the body from it. The immune response of the body here is called an allergic reaction. The allergen could be either a food item, something we inhale, inject into our body or simply make contact with via touch. Allergy is the reaction that occurs and it could be coughing, sneezing, itchy eyes, a runny nose and a scratchy throat. In very severe case allergy can also cause rashes, hives, low blood pressure, breathing trouble, asthma attacks and even death. Such allergic diseases are affecting the lives of more than one billion people worldwide and the prevalence of allergy is expected to reach up to four billion by 2050. Allergy affects not only individuals but also has a major socioeconomic impact because of health care and loss of productivity. Till date no cure is available for allergies and they can be managed only by prevention and treatment of the symptoms. Globally, it is a common disease but

is generally overlooked. Different types of allergies like food allergy, sinusitis (allergic reaction in sinuses), drug, insect, general allergies all constitute to the direct and indirect costs in an economy while significantly affecting the life of the sufferers. Since no straightforward cure is available, the impact of allergies is greater and there is need to fully understand the disease mechanisms, prevention and patient care to deal with allergies.

Food allergy is a medical condition in which exposure to a particular food item triggers a harmful immune response (or allergic reaction) in the body because the immune system attacks proteins (the allergen in these types of allergy) in the food that are normally harmless and are not the enemy. The symptoms of an allergic reaction to food can range from mild (itchy mouth, a few hives) to severe (throat tightening, difficulty breathing). Also, anaphylaxis is a serious allergic reaction that takes place suddenly and can cause death. A total of 170 foods, most of them harmless, have been reported till date to cause allergic reactions with the major food allergens being milk, egg, peanut, wheat, soy and shellfish.

Food allergy is one of the most devastating types of allergies requiring considerable time to manage and constant vigilance in patients especially children in whom food allergies are seen to be extremely common. The only way to manage a food allergy is to firstly watch out and avoid consuming the food that causes problems and secondly, by learning to recognize and treat allergic reactions symptoms. This tends to pose a burden for both the food-allergic individual and his or her caregiver affecting their quality of life. Most food-related symptoms occur within two hours of ingestion; often they start within minutes and thus have to be managed very carefully. This leads to many changes like planned meal preparation, social activity, anxiety issues etc. Also, symptoms caused by a food allergy can range from mild to life-threatening and unfortunately the severity of each reaction is unpredictable.

Lot of research is happening to resolve food allergy condition and maybe even prevent them; however, most food allergy therapies are under study in clinical trials and none have been proven yet for general use.

A recent innovative study has revealed a new way of treating food allergies by simply "teaching our immune system a new trick". In this study published in *Journal of Allergy and Clinical Immunology*, researchers used mice bred to have a food allergy from peanut, and "reprogrammed" the mice's immune system such that the body did not express a life-threatening reaction to peanut exposure. Peanuts are among the most common food allergen and if consumed, they can trigger a life-threatening immune response. Since peanuts are common, people have to be extremely vigilant in their everyday food choices. The authors from Duke-NUS Medical School in Singapore, say that their study is a unique way to treat peanut food allergy. Before this study, other approaches like desensitization – i.e. effectively treating or gradually desensitizing people allergic to peanut - have been carried out which have been labeled as time-consuming and also risky. Their long-term efficacy is also questionable and such therapies are yet to be officially approved for treatment.

An allergic reaction in the body basically results from an imbalance of important messages between cells (which are called cytokines). The authors focused on the The2-type cytokine immune response. In this context it was understood that whenever an expected (or appropriate) immune response occurred, Th2 cells worked in tandem with another Th1 cells. On the other hand, when an unexpected immune response occurred i.e. an allergic reaction occurred, Th2 cell was overproduced while the Th1 cells were completely gone. Thus, it was clear that it's here that the imbalance was happening during an allergic reaction to peanut. Based upon this observation researchers found a simplistic approach towards restoring the balance by delivering Th1-type cells before the person comes in contact with the allergen. The idea was not to have the imbalance to take place, hence avoiding the allergic reaction. In peanut-allergy mice, researchers delivered

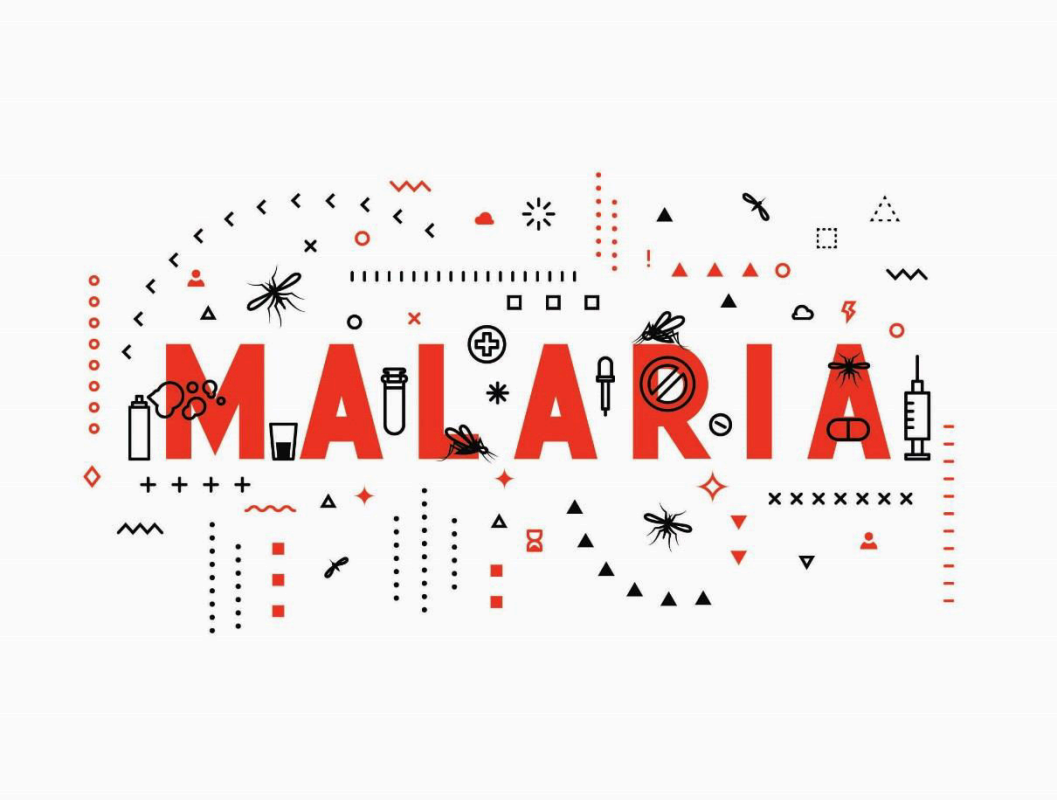
nanoparticles (which carried Th1-type cells) into the skin to the lymph nodes (which is the place where immune cells are produced). These nanoparticles travelled into the body, delivered their cargo -Th1-type cells- at the origin point of the immune response and completed the desired task assigned to them. The animals which received this manual "therapy" did not show the acute allergic response when they were subsequently exposed to peanuts. Interestingly, this new tolerance was seen to be long-lasting, effective and only one dosage was enough for any subsequent exposure to the allergen. Therefore, this scenario is said to be a "re-education" (a better word for "tricking") of the immune system, telling it that the allergic reaction response is not the suitable one and it should be not done.

These studies are conducted on mice, however suitable human studies need to be completed before broader application can be assumed. It does come with multiple challenges, for example the authors themselves were unable to use this approach for asthma therapy as a massive dose of cells was required for the lungs and it turned out to be ineffective. This approach could be applied in a similar manner to other food allergens like milk or egg for example and also to other allergens like environmental triggers including dust and pollen. This study does raise hope for preventing allergic reaction to peanut and other allergens by intervening a typical path followed by the body's immune system. This could be a boon to tackle food allergies which are seen to be plaguing adults and children with no efficient prevention or even a treatment strategy in sight.

Source:
Ashley L. St. John, Gladys W.X. Ang, Abhay P.S. Rathore, Soman N. Abraham, 2018, 'Reprograming Immunity to Food Allergens', *Journal of Allergy and Clinical Immunology*, DOI: 10.1016/j.jaci.2018.01.020

New hope for attacking the deadliest form of Malaria

A set of studies describe a human antibody which can effectively prevent the deadliest malaria caused by the parasite *Plasmodium falciparum*



Malaria is one of the most severe public health problems worldwide. It is a life-threatening disease caused by parasites - microscopic single celled organisms called *Plasmodium*. Malaria is transmitted to people through the bite of a "very efficient" infected female *Anopheles* mosquito. Every year approximately 280 million people get affected by malaria in more than 100 countries resulting in 850,00 deaths globally. Malaria is predominately found in the tropical and sub-tropical areas of Africa, South America and Asia. It is one of the most important tropical parasitic disease and the second most deadly communicable disease after tuberculosis. The African region carries a disproportionately high share of the global malaria burden with more than 90 percent cases and deaths in this region alone.

Once bitten by a parasite-carrying mosquito, the parasite infects people and causes the symptoms of malaria like high fever, chills, flu-like symptoms, and anemia. These symptoms are particularly dangerous for pregnant women and also children who sometimes have to suffer lifelong side effects of the disease. Malaria can be prevented and is also curable if its detected and treated with

timely appropriate care, otherwise it can be fatal. There are two aspects to malaria research, one is controlling mosquitoes and the other is to create drugs and vaccines to prevent and control the infection. An understanding of how a malaria infection affects the human immune response can help in the larger goal of creating vaccines to prevent malaria.

Less than 100 years ago, malaria was endemic throughout the world including North America and Europe though now it has been eradicated in these continents. However, for humanitarian cause, it is important that malaria research stays relevant because worldwide huge number of people are affected by malaria and factually, three billion people live in at-risk areas for malaria. Multiple reasons have been cited why developed countries which face no occurrences of malaria, should be committed to eradicating malaria in developing and poor countries. These reasons include ensuring the basic human rights of every human being through justice and bolstering world security and peace. The risk is not just health wise, as it also affects the stabilization of economies and populations in developing parts of the world with people at risk for malaria by imposing high costs to both individuals and governments. Thus, it is imperative for developed nations to outreach and contribute to economic prosperity of not just these countries but also their own as they are interconnected.

Progress in malaria drugs and vaccines

Though, targeted prevention and treatment over the decades has reduced the number of malaria cases and also deaths, but the malaria parasite is a very tough enemy. The drug treatments often have to be taken daily to be effective and can be difficult to access, particularly in poor countries. Drug resistance is a major challenge for the known anti-malarial drugs hindering the control of malaria. This resistance generally occurs because each anti-malarial drug targets a particular strain of the parasite and when newer strains originate (because of the fact that some parasites evolve and survive the attack by a drug), the drugs are rendered useless.

This problem of resistance is compounded by cross resistance, in which resistance to one drug confers resistance to other drugs that belong to the same chemical family or having similar modes of action. Currently there is no singly, highly effective and long-lasting vaccine to prevent malaria. After decades of research, only one malaria vaccine (called PfSPZ-CVac, developed by the biotechnology firm Sanaria) has been approved which requires four shots over a series of months and is seen to be only 50 percent effective. Why vaccines are mostly ineffective is because malaria has an extremely complex life cycle, and vaccines generally work when the malaria infection is at a very early stage i.e. in the liver. Once the infection moves to a later blood stage, the body is not able to create protective immune cells, and their antibodies and thus counteracts the mechanism of the vaccine rendering it ineffective.

A new candidate is here!

In a recent advancement[1, 2] in malaria vaccine research published in two papers in *Nature Medicine*, scientists have discovered a human antibody that was able to protect mice from infection by the deadliest malaria parasite, *Plasmodium falciparum*. The researchers at National Institute of Allergy and Infectious diseases, Fred Hutchinson Cancer Research Center, Seattle and Center for Infectious Disease Research, Seattle, USA have proposed this new antibody as a potential candidate to not only provide short term protection against malaria but they state that this new compound might also assist in design of vaccines for malaria. Antibody, in general is one of the biggest and best defense mechanism of our body because they circulate throughout the body and bind/stick to very specific parts of the invaders – the pathogens.

Researchers isolated a human antibody, called CIS43, from a volunteer's blood who had received a weaker dosage of an earlier experimental vaccine. This volunteer was then exposed to infectious malaria-carrying mosquitoes (under controlled conditions). It was seen that he was not infected with malaria. Also, these experiments were done on mice and they were also not infected, suggesting that CIS43 is highly effective in preventing malaria infection. How this CIS43 actually works was also understood. The CIS43 binds to a specific portion of an important parasite surface protein blocking its activity and hence disrupting the infection which was about to occur in the body.

This disruption happens because once CIS43 is bound to the parasite, the parasite is unable to make it through the skin and into the liver where it's supposed to start an infection. This kind of preventive action makes the CIS43 a very attractive candidate for a vaccine and could be useful for health care workers, tourists, military personnel or others who travel to areas where malaria is common. Also, even if the antibody works only for several months, it can be combined with anti-malarial drug therapy for mass drug administration for total elimination of the disease.

This is a very exciting and revolutionary research in the field of malaria and discovery of this antibody could be a turning point in terms of therapeutics for this disease. Interestingly, the region on the parasite surface protein which binds to CIS43 is same or conserved almost 99.8 percent in all the known strains of *Plasmodium falciparum* parasite thus makes this region an attractive target for developing newer malaria vaccines apart from CIS43. This particular area on the malaria parasite has been targeted for the first time making it a novel study with scores of potentials in the future. Researchers plan to further assess the safety and efficacy of the newly described CIS43 antibody in human trials in the near future.

Source:

1. Neville K Kisalu et. al., 2018, 'A human monoclonal antibody prevents malaria infection by targeting a new site of vulnerability on the parasite', *Nature Medicine*, DOI: 10.1038/nm.4512
2. Joshua Tan et. al., 2018, 'A public antibody lineage that potently inhibits malaria infection through dual binding to the circumsporozoite', *Nature Medicine*, DOI:10.1038/nm.4513

New innovatively-designed low cost material to combat air and water pollution

Study has produced a new material which could adsorb air and water pollutants and could be a low cost sustainable alternative to the currently used activated carbon

Pollution makes our planet's land, water, air and other constituents of the environment dirty, unsafe and unsuitable to use. Pollution is caused by artificial introduction or entry of a contaminant(s) into a natural environment. Pollution is of various types; example land pollution is caused mostly by household discard or garbage and industrial waste by commercial companies. Water pollution is caused when foreign substances are introduced to water include chemicals, sewage water, pesticides and fertilizers or metals like mercury. Air pollution is caused by particles in the air from burning fuels, like soot, containing millions of tiny particles floating

in the air. Another common type of air pollution is dangerous gases, such as sulphur dioxide, carbon monoxide, nitrogen oxides and chemical vapours. Also, air pollution can also take the form of greenhouse gases (such as carbon dioxide or sulphur dioxide) and aid the warming of our planet through greenhouse effect. Other type of pollution is noise pollution when the sound coming from planes, industry or other sources reaches harmful levels.

Despite major efforts that have been made over recent years to clean up the environment, pollution remains a major problem and poses continuing risks to health, affecting 200 million people worldwide. The problems are undeniably greatest in the developing world, where traditional sources of pollution such as industrial emissions, poor sanitation, inadequate waste management, contaminated water supplies and exposures to indoor air pollution from biomass fuels affect large numbers of people. Even in developed countries, however, environmental pollution persists, most especially amongst poorer sectors of society. Though the risks are generally higher in developing countries, where poverty, economical constraints for adopting technology and weak environmental laws combine to cause high pollution levels. This risk is further compounded by unsafe water, poor sanitation, poor hygiene and indoor air pollution. Pollution has detrimental effects on unborn and growing children, and life expectancy may be as low as 45 years because of cancers and other diseases.

Air and water pollution is a silent killer and is thought to adversely affect our planet and in turn mankind. The air which we breathe has a very definite chemical composition which is 99 percent of nitrogen, oxygen, water vapor and inert gases. Air pollution occurs when things that aren't normally added to the air. Particulate matter - solid particles and liquid droplets found in the air and emitted from power plants, industry, automobiles and fires - is now ubiquitous in cities and even suburban areas. Also, millions of tons of industrial effluents are released into the world's waters every year. Both particulate matter and dyes are highly toxic to environment, ecosystem and to humanity.

Various methods and procedures are routinely used for tackling air and water pollution, including filtration, ion-exchange, coagulation, decomposition, adsorption etc and each of these methods exhibit different rates of success. When compared, adsorption is considered most feasible because of being simple, easy to operate, having high efficiency, convenience to use etc. Among the various adsorbents, in pollution abatement of air and waste water, activated carbon is the most commonly used adsorbent. Also called activated charcoal, it is a form of carbon processed to have small, low-volume pores that increase the surface area available for adsorption or chemical reactions.

In fact, activated carbon is the gold standard in adsorbents. Carbon has a natural affinity for organic pollutants like benzene, which bind to its surface. If you "activate" carbon i.e. steam it at 1,800 degrees it forms little pores and pockets that increase its surface area. Pesticides, chloroform, and other contaminants slide into the holes of this honeycomb and hold fast. Also, no carbon remains in the water once it's been thoroughly treated. Water treatment plants in developing countries like China and India routinely use activated carbon. Similarly, activated carbon has special properties which help in removing volatile compounds, odours, and other gaseous pollutants from the air. The way it works is quite straightforward. There are a few downsides of activated carbon, firstly it is very expensive and has a very short shelf life as it can only be used until its pores fill up - which is why you have to change the filter from time to time. Activated carbon is also difficult to regenerate and its effectiveness decreases over time. They are not effective at removing those contaminants which are either not attracted to carbons or pathogenic bacteria and viruses.

An economic and sustainable alternative

In a recent study published in *Frontiers in Chemistry*, researchers have a created an affordable low-cost and sustainable material for tackling air and water pollution. This new "green" porous material produced from solid wastes and abundant organic natural polymers looks very promising in terms of adsorbing pollutants in wastewater and air when compared to activated carbon and is being labelled as an "economical alternative". This new "green" adsorbent is a combination of a naturally abundant raw material – a polysaccharide called sodium alginate which can be extracted from seaweed and algae– with an industrial by product – silica fume (by product of silicon metal alloy processing). It was synthesised very easily and consolidated by the gelling properties of alginate and by decomposition of sodium-bicarbonate controlled porosity at low temperatures at different scale lengths.

For testing in the wastewater pollution, a blue dye was used as a model pollutant. It was seen that the new hybrid material adsorbed and removed the dye with efficiency of about 94 percent, which was very encouraging. Even very high concentrations of this dye were removed. This material displayed encouraging capabilities for trapping particulate matter from diesel exhaust fume. The study led by Dr. Elza Bontempi from the University of Brescia, Italy, concludes that this material was able to replace activated carbon very efficiently in its capability to capture both fine particulate matter in air and also organic pollutants in wastewater thus cutting down on the pollution.

This is exciting work, as this new material is produced in a very innovative and inexpensive manner from naturally abundant polymers and industrial waste by-product which is anyway is always discarded. This new material being termed as an "organic-inorganic hybrid" is not only low cost, it's also sustainable and regenerable and could actually displace the activated carbon and become a preferred choice. It even consumed less energy when being produced (the "embodied" energy) and thus leaves a much lower carbon footprint.

This material is also self-stabilizing and does not require a thermal treatment at high temperatures and also can be scaled up for different experimentation. Ongoing tests further indicate that it can be stored at ambient conditions and it only becomes more stable over time while not degrading at all. Thus, its highly versatile and could have a wide range of applications in air and water filtration. This generates huge hope for combating air and water pollution and protecting mother earth as well as mankind.

Source:
Alessandra Zanoletti, et al., 2019, 'A New Porous Hybrid Material Derived From Silica Fume and Alginate for Sustainable Pollutants Reduction', *Frontiers in Chemistry*, vol. 6, DOI: 10.3389/fchem.2018.00060

DNA as a medium to store vast computer data: a reality very soon?

A breakthrough study takes significant step forward in the quest to develop a DNA-based storage system for digital data.

Digital data is growing at an exponential rate today because of our dependency on gadgets and it requires robust long-term storage. It is safe to say that data storage is slowly becoming challenging because current digital technology is not able to provide a solution. An example being that more digital data has been created in the past two years than in all of history of computers, in fact 2.5 quintillion byte {1 quintillion byte = 2,500,000 Terabytes (TB) = 2,500,000,000 Gigabytes (GB)} of data is being created every day in the world. This includes data on social networking sites, online banking transactions, records of companies and organization, data from satellites, surveillance, research, development etc. This data is huge and unstructured. Therefore, it is now a big challenge to tackle huge storage requirements for data and its exponential growth, especially for organizations and corporations who require robust long-term storage.

The options available currently are hard disk, optical disks (CDs), memory sticks, flash drives, and the more advanced tapes drive or optical BluRay discs which store roughly up to 10 Terabytes (TB) of data. Such storage devices though being used commonly have some obvious disadvantages. Firstly, they have a low-to-medium shelf life and they need to be stored under ideal temperature and humidity conditions to be able to last many decades and thus require specially designed physical storage space. Almost all of these consume a lot of power, are bulky and impractical and can be damaged in a simple fall. Some of them are very expensive, are often plagued with data error and thus are not robust enough.

An option which has been universally accepted by organization is called cloud computing - an arrangement in which a company basically hires an "outside" server for handling all its IT and data storage requirements, referred to as the "cloud". One of the primary disadvantages of cloud computing are security and privacy issues and vulnerability to attack by hackers. There are also other issues like high costs involved and limited control by the parent organization not to mention platform dependency. Nevertheless, cloud computing is still seen a good alternative for long-term storage. However, it looks like the digital information being generated worldwide is certainly overtaking our ability to store it and even more robust solutions are needed to cater to this data deluge while providing scalability to take into account the future storage needs as well.

Can DNA help in computer storage?

Our DNA (Deoxyribonucleic acid) is being considered as an exciting alternative medium for digital data storage. DNA is the self-replicating material present in nearly all living organisms and is what constitutes our genetic information. An artificial or synthetic DNA is a durable material which can be made using commercially available oligonucleotide synthesis machines. A primary benefit of DNA is its longevity as a DNA lasts 1000 times longer than silicon (silicon-chip - the material used for building computers). Amazingly, just a single cubic millimetre of DNA can hold a quintillion of bytes of data! DNA is also an ultracompact material which never degrades and can be stored in a cool, dry place for hundreds of centuries. This idea of using DNA for storage has been around for a long time, in fact way back to 1994. The main reason is the similar fashion in which information is being stored in a computer and in our DNA – since both store the blueprints of information. A computer stores all data as 0s and 1s and DNA stores all data of a living organism using the four bases - thymine (T), guanine (G), adenine (A) and cytosine (C). Therefore, DNA could be called a standard storage device, just like a computer, if these bases can be represented as 0s (bases A and C) and 1s (bases T and G). DNA is quite tough and long-lasting, the simplest reflection being that our genetic code – the blueprint of all our information stored in DNA- is efficiently transmitted from one generation to next in a repeated manner.

All software and hardware giants are keen on using synthetic DNA for storing vast amounts to achieve their goal of solving long-term archival of data. The idea is to first convert the computer code 0s and 1s into the DNA code (A, C, T, G), the converted DNA code is then used to produce synthetic strands of DNA which can then be put into cold storage. Whenever required, DNA strands can be removed from cold storage and their information decoded using DNA sequencing machine and DNA sequence is finally translated back to binary computer format of 1s and 0s to be read on the computer.

It's been shown[1] that just a few grams of DNA can store quintillion byte of data and keep it intact for up to 2000 years. However, this simple understanding has faced some challenges. Firstly, it is quite expensive and also painfully slow to write data to DNA i.e. the actual conversion of 0s and 1s to the DNA bases (A, T, C, G). Secondly, once the data is "written" onto the DNA, it is challenging to find and retrieve files and requires a technique called DNA sequencing - a process of

determining the precise order of bases within a DNA molecule -after which the data is decoded back to 0s and 1s.

A recent breakthrough[2] by scientists from Microsoft Research and the University of Washington have achieved a "random access" on DNA storage. The "random access" aspect is very important because it means that information can be transferred to or from place (generally a memory) in which every location, no matter where in the sequence, can be accessed directly. Therefore, using this technique of random access, files can be retrieved from DNA storage in a selective manner as compared to earlier, when such a retrieval required the need to sequence and decode an entire DNA dataset to find and extract the few files one wanted. The importance of "random access" is further elevated when the amount of data increases and becomes huge. "random access" basically reduces the amount of sequencing that needs to be done. It is for the first time ever the random access has been shown at such a large scale.

Researchers have also developed an algorithm for decoding and restoring data more efficiently with more tolerance to data errors making the sequencing procedure also faster. More than 13 million synthetic DNA oligonucleotides were encoded in this study which was data of 200MB size consisting of 35 files (containing video, audio, images and text) ranging in size from 29kB to 44MB. These files were retrieved individually with no errors. Also, authors have devised new algorithms which are more robust and error tolerant in writing and reading the DNA sequences. This study published in *Nature Biotechnology*, in a major advancement which shows a viable, large-scale system for DNA storage and retrieval.

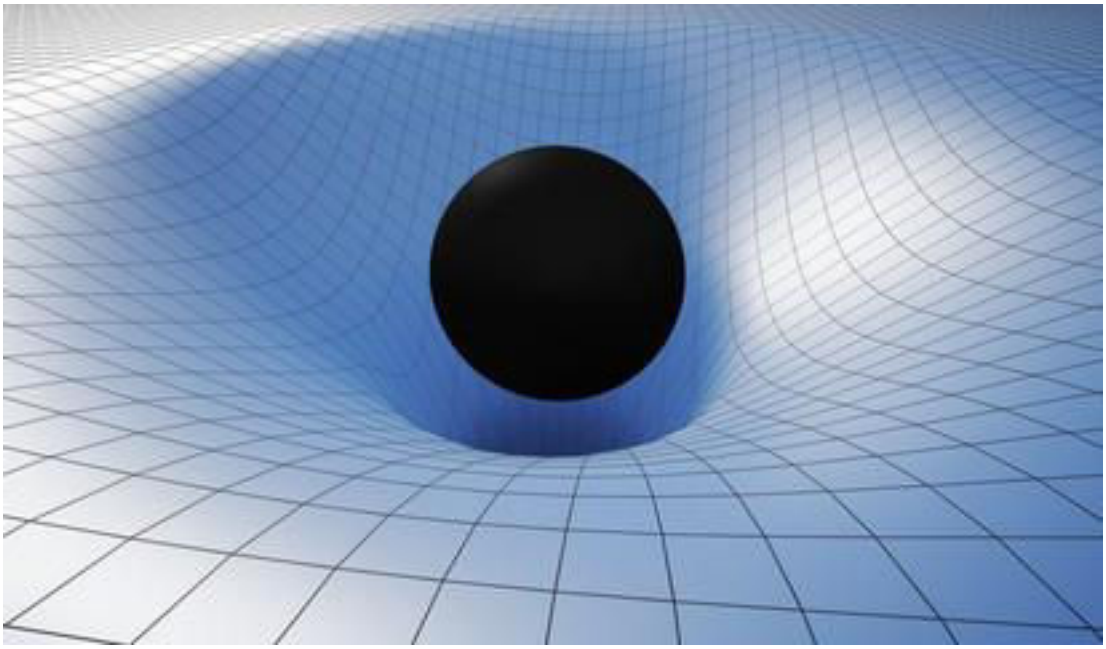
DNA storage system looks very appealing because it is having high data density, high stability and is very easy to store but it obviously has many challenges before it can be universally adopted. Few factors are time and labour-intensive decoding of the DNA (the sequencing) and also synthesis of DNA. The technique does require more accuracy and broader coverage. Even though advances have been made in this area, the exact format in which data will be stored in the long-term as DNA is still evolving. Microsoft has vowed to improve the production of synthetic DNA and address the various challenges to design a fully operational DNA storage system by 2020.

Source

1. Yaniv Erlich and Dina Zielinski. DNA Fountain enables a robust and efficient storage architecture. *Science*, 2017; 355 (6328): 950 DOI: 10.1126/science.aaj2038
2. Lee Organick et al., 2018, 'Random access in large-scale DNA data storage', *Nature Biotechnology*, vol. 36, pp.242–248, DOI:10.1038/nbt.4079

Remembering Stephen Hawking

"However difficult life may seem, there is always something you can do and succeed at "
– Stephen Hawking



Stephen W. Hawking (1942-2018) will be remembered not just for being an accomplished theoretical physicist with a brilliant mind but also for symbolising the ability of the human spirit to rise and triumph above severe physical disability of the body and achieve what is presumed to be the unthinkable. Prof Hawking was diagnosed with a debilitating condition when he was barely 21 years old, but he showed resilience over his adversities and continued to engage his mind in an attempt to theorize some of the intriguing scientific mysteries of the universe.

The idea of black holes emerged from Albert Einstein's general theory of relativity. The cosmic objects *black holes* - thought to be the biggest enigmas of the known universe - are extremely dense, so dense that nothing escapes their huge gravity, not even the light. Everything gets sucked into it. This is the reason black holes are called black holes because nothing can escape its clutches and also its impossible to see a black hole. Because black holes do not emit light or energy in any form unlike all other cosmic objects, they would never undergo explosion. This meant black holes would be immortal.

Stephen Hawking questioned the immortality of the black holes.

In his letter titled ''*Black holes explosions?*'', published in *Nature* in 1974[1], Hawking came up with the theoretical conclusion that not everything is sucked into a black hole and black holes emit an electromagnetic radiation called *Hawking radiation*, detailing that radiation *can* escape from a black hole, because of the laws of quantum mechanics. Thus, black holes too would explode and convert to gamma rays. He showed that any black hole will create and emit particles such as neutrinos or photons. As a black hole emits radiation one would expect it to lose mass. This in turn would increase the surface gravity and so increase the rate of emission. The black hole would therefore have a finite life and eventually disappear into nothing. This stuck down the long-held idea by the theoretical physicists that black holes are immortal.

The *Hawking radiation* was thought to contain no useful information about what the black hole engulfed because the information swallowed up by the black hole would have been lost forever. In a recent study published in 2016 in *Physical Review Letters*, Hawking showed that black holes have a halo of 'soft hair' (technically, low-energy quantum excitations) around them which might store the information. More research on this could perhaps lead to an understanding and an eventual resolution of the black hole information problem.

Any proof of Hawking's theory? No observational confirmation yet seen in the cosmos. Black holes are too long-lived to be observed today at their end.

Source:

1. Hawking S., 1974. Black hole explosions? *Nature*, vol. 248, pp.30–31, DOI:10.1038/248030a0
2. Hawking S. et al., 2016, 'Soft Hair on Black Holes', *Phys. Rev. Lett.*, vol. 116, 231301, DOI:10.1103/PhysRevLett.116.231301

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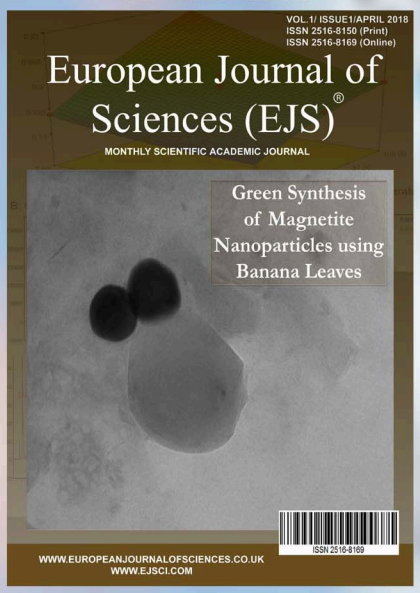

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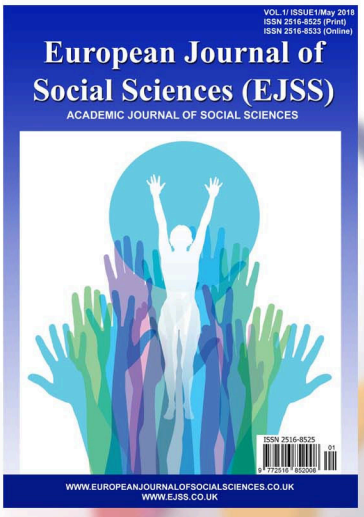

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