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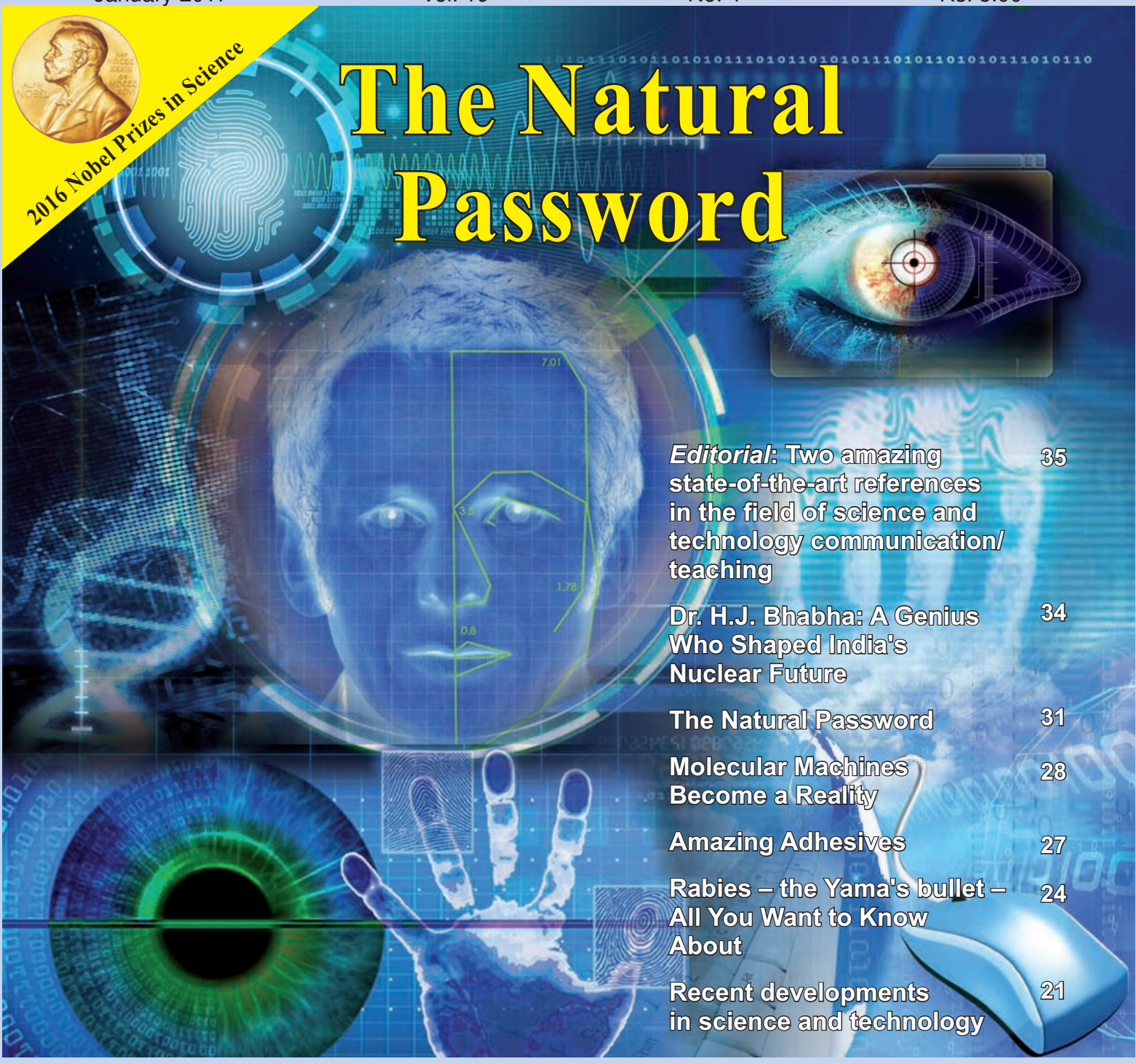

... think scientifically, act scientifically... think scientifically, act scientifically... think scientifically, act...

Two amazing state-of–the-art references in the field of science and technology communication/teaching

Dr. R. Gopichandran

The first of the two refer to is titled International *Science and Technology Education: Exploring Culture, Economy and Social Perceptions* edited by Ortwin Renn *et al.* 2015, is published by Routledge Oxon, New York. The second publication is of three volumes edited by Michael R. Matthews; titled *International Handbook of Search in History, Philosophy and Science Teaching*. The most unique aspect about both these publications is the opportunity to learn about the landscape of science teaching across the world. Importantly, people interested in networking should be able to connect with experts listed in the volumes. The latter publication deals with teaching approaches in physics, chemistry, biology, ecology, earth science, astronomy, cosmology and mathematics in a comprehensive manner along with insights about the interface of science, culture and society.

Sundar Sarukkai has authored the chapter titled 'Challenges for STEM Education in India'. I had the opportunity of interacting closely with him on the framework of science as a window of opportunity to pursue truth. An interesting take-away from the discussion was about need to consciously adhere to the agenda of science and not tweak it with any personal philosophical agenda. The book has another interesting chapter from the Indian context by Chelluri and Avvari titled 'Corporate Social Responsibility Programme for STEM Education: Cases from the Indian Technology Cluster City of Hyderabad'.

The chapter by Arthur Eisenkraft titled 'The NRC Framework and the Next Generation Science Standards: An Opportunity to Improve Science Education in the USA', is interesting because it lists eight science and engineering practices and seven cross-cutting concepts. These are applicable across countries and all levels of learning seamlessly. I often am asked about the pervasiveness of the science and technology in the lives of citizens in all walks of life, especially with reference to the indicators of scientific temper that can be identified or perceived. I have no hesitation in saying that a porter on a railway station balancing heavy weights on his/her head has enough scientific temper to balance it appropriately. They ensure, the contents did not fall off and yet move swiftly with minimal strain. An auto rickshaw driver is able to plough his/her way through heavy traffic without causing any accidents; yet abide by the laws of traffic. The ability to balance weight and drive through the maze are exciting manifestations of scientific temper. This ability to stay focussed and deliver the best is true also of cooks, who build on their abilities to deliver the best, without losing their own identity. These capabilities to stay focussed and mix and match for optimal benefits can be interesting entry points for dialogues/engagement with people who pursue their own innate abilities. In this process, it is essential for the communicator to remain absolutely credible in so far as the agenda and the objectives are concerned. It gravitates to one simple human value and that is to respect others points of view and inclusiveness.

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Dr. H.J. Bhabha:
A Genius Who Shaped India's Nuclear Future

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A genius was born on 30 October 1909 in a very wealthy and prominent Parsi family of Bombay (now Mumbai). His name was Homi Jehangir (meaning "conqueror of the world") Bhabha. The family had a long tradition of learning and service in the field of education. His father Jehangir Hormusji Bhabha was educated at Oxford and later qualified as a lawyer, mother Meheren also hailed from a great family; she was the grand-daughter of Sir Dinshaw Maneckji Petit who was widely respected in Bombay for his philanthropic endowments. Bhabha's paternal aunt Meherbai married Sir Dorab J. Tata, the eldest son of Jamshetji Nusserwanji Tata, the renowned Industrialist, social worker of India and founder of the powerful Tata group.

Homi J. Bhabha

Education

Bhabha received his early education at Bombay's Cathedral and John Connon School. From there, at the age of 15 he completed his Senior Cambridge Examination with Honours. He entered Elphinstone College in Bombay and later the Royal Institute of Science, in the same town. In 1927 at the age of 18, he left for England to pursue higher studies at Cambridge. There he joined the Gonville and Caius College, the same college where his uncle Sir Dorab J. Tata had studied and had made a donation of twenty-five thousand pounds to the college in 1920. His father and his uncle Dorab Tata had sent him to Cambridge for higher studies, knowing that he was brilliant and if trained in engineering he could build a great career in Tata Industries.

But at Cambridge Bhabha's interests gradually shifted to theoretical physics. He felt an urge for physics and only physics. So, in 1928 in a letter to his father he wrote: "I seriously say to you that business or job as an engineer is not the thing for me. It is totally foreign to my nature and radically opposed to my temperament and opinions. Physics is my line. I know I shall do great things here. …. I am burning with a desire to do physics. I will and must do it sometime. It is my only ambition. I have no desire to be a 'successful' man or the head of a big firm. There are intelligent people who like that and let them do it... It is no use saying to Beethoven 'You must be a scientist for it is great thing' when he did not care two hoots for science; or to Socrates 'Be an engineer; it is work of intelligent man'. It is not in the nature of things. I therefore earnestly implore you to let me do physics."

Family Picture, with father, mother and brother

For doing physics Bhabha opted the Mathematical Tripos. When his father had to yield to his son's firm determination he put a condition. He told Homi that in case he could complete the Mechanical Tripos successfully he would allow him to stay in Cambridge to take up the Mathematical Tripos. Bhabha passed the Mechanical Tripos with a first class. At that time (1931-32) he got the Salomons Studentship in Engineering. Now his father allowed him to fulfill his wishes. Again he passed the Mechanical Tripos with a first class. He obtained Rouse Ball Travelling Studentship in Mathematics. This helped him to travel in Europe and work with Wolfgang Pauli in Zurich and Enrico Fermi in Rome. In January 1933, Bhabha published his first scientific paper, "The Absorption of Cosmic radiation". In the paper, he offered an explanation of the absorption features and electron shower production in cosmic rays. The paper helped him win the Isaac Newton Studentship in 1934, which he held for the next three years. It enabled him to complete his PhD under R. H. Fowler, who was also the PhD thesis advisor for the famous astrophysicist Subrahmanyan Chandrasekhar.

The Cambridge years

Bhabha was mainly a theoretical physicist and distinguished himself in the emerging areas of elementary particles, high-

energy physics and cosmic rays during his stay in Cambridge. After completion of his PhD he devoted himself to physics. While working at Cambridge with R.H. Fowler he also worked with Niels Bohr in Copenhagen. In 1935, Bhabha published his second paper in the *Proceedings of the Royal Society, Series A*, in which he performed the first calculation to determine the cross-section of electron-positron scattering. Electron-positron scattering was later named Bhabha scattering, in honour of his contributions in the field.

Bhabha scattering

In quantum electrodynamics (a quantum field theory of the electromagnetic force), Bhabha scattering is an annihilation process where the electron and positron briefly become a photon on collision and then exit as an electron-positron pair. It is used as a luminosity monitor in electron-positron collider physics experiments. The accurate measurement of luminosity is necessary for accurate measurement of collision cross sections. Bhabha scattering is usually pictorially represented by what are known as 'Feynman diagrams' invented by Richard Feynman in the late 1940's.

Cosmic rays

In 1936, Bhabha published another paper in the *Proceedings of the Royal Society, Series"* titled "The Passage of Fast Electrons and the Theory of Cosmic Showers". In this paper he described how primary cosmic rays from outer space interact with the upper atmosphere to produce particles observed at the ground level. Bhabha made numerical estimates of the number of electrons in the cascade process at different altitudes for different electron initiation energies. He concluded that observations of the properties of such particles would lead to the straightforward experimental verification of Albert Einstein's theory of relativity. In 1937, Bhabha was awarded the Senior Studentship of the 1851 exhibition, which helped him continue his work at Cambridge until the outbreak of World War II in 1939.

The postal bag recently discovered
Source:- http://interestingnewsfromallover.blogspot.in/2010/05/mystery-death-of-two-indian-nuclear.html

At IISc, Bangalore

Bhabha was in India on his annual vacation during September 1939 but had to stay back as the Second World War broke out and the subsequent war condition made it almost impossible to return to England. So, Bhabha decided not to return to England for the time being. In early 1940, he accepted an offer to serve as Reader in the Physics Department of the Indian Institute of Science in Bangalore (now Bengaluru) headed by Nobel laureate physicist Sir C.V. Raman. Here he started some work to generalise Dirac's work on spinning particles which he had started with H.C. Corben at Cambridge. After the completion of the work he sent a note to the journal *Nature* on 17 March 1940. This was his first work at IISc, Bangalore and became famous as "Bhabha-Corben Equation." He received a special research grant from the Sir Dorab Tata Trust, which he used to establish the Cosmic Ray Research Unit at the Institute. He then started his research work working with some students including Harish-Chandra, to work with him. "He also started experimental studies of the secondary component of cosmic radiation at several altitudes between 5,000 and 30,000 feet (1,500 and 9,000 metres). The high-altitude studies were made using a B-29 bomber aircraft belonging to the US Air Force, making them the first studies made at equatorial latitudes. Bhabha also constructed a 12-inch cloud chamber identical to the one operating in Manchester. Later, on 20 March 1941, he was elected a Fellow of the Royal Society.

Bhabha in IISc, Bangalore
Source:- https://www.google.co.in

Birth of TIFR

When Bhabha was working at the Indian Institute of Science, it was the best research Institute in India of the time, but it did not have the necessary facilities for original work in nuclear physics, cosmic rays, high-energy physics, and other frontier areas of physics. Bhabha realized the importance of a modern institute for carrying out research in these frontier areas. This prompted him to send a proposal in March 1944 to the Sir Dorabji Tata Trust to extend its hand for establishing 'a vigorous school of research in fundamental physics'.

In his proposal he wrote

"There is at the moment in India no big school of research in the fundamental problems of physics, both theoretical and experimental. There are, however, scattered all over India competent workers who are not doing as good work as they would do if brought together in one place under proper direction. ... If much of the applied research done in India today is disappointing or of very inferior quality it is entirely due to the absence of sufficient number of outstanding pure research workers who would set the standard

of good research and act on the directing boards in an advisory capacity ... Moreover, when nuclear energy has been successfully applied for power production in say a couple of decades from now, India will not have to look abroad for its experts but will find them ready at hand. ... The subjects on which research and advanced teaching would be done would be theoretical physics, especially on fundamental problems and with special reference to cosmic rays and nuclear physics, and experimental research on cosmic rays. It is neither possible nor desirable to separate nuclear physics from cosmic rays since the two are closely connected theoretically."

The trustees decided to accept Bhabha's proposal and took financial responsibility for starting the Institute in April 1944. Bombay was chosen as the location and Maharashtra state government came forward and became a joint founder of the proposed institute. The institute, named Tata Institute of Fundamental Research, was inaugurated in 1945 in a hired building. In 1948 the Institute was moved to the Royal Yacht Club. Foundation stone of the present building was laid by Prime Minister Jawaharlal Nehru in 1954. It was inaugurated him in 1962.

Atomic Energy Commission

Bhabha is generally acknowledged as the father of Indian nuclear energy programme. His principal philosophy was the large-scale development of science in India. He was convinced that for a developing country it is really difficult to establish modern science research centres and building its economy on modern science and technology. So, to solve India's energy crisis he advocated nuclear energy. When Bhabha realised that technology development for the atomic energy programme could no longer be carried out within TIFR he proposed to the government to build a new centre entirely devoted to this purpose. Bhabha had met Nehru on a voyage in 1939 and after that gradually they had developed a close personal relationship. Naturally the proposal was accepted by Prime Minister Nehru.

For the new centre, 1,200 acres (484 hectares) of land was acquired at Trombay from the Bombay Government. Here the Atomic Energy Establishment Trombay (AEET) started functioning in 1954. The same year the Department of Atomic Energy (DAE) was also established. Bhabha also planned to exploit nuclear energy to its fullest capacity. Raja Ramanna confirms that Bhabha planned from the very outset to establish an Indian nuclear weapons capability. Bhabha is said to have told Ramanna, "We must have the capability. We should first prove ourselves and then talk of Gandhi, non-violence and a world without nuclear weapons." After the tragic death of Bhabha in an air crash on 24 January 1966, Prime Minister Indira Gandhi renamed the

Bhaba with Lalbahadur Shastriji
Source:- https://www.google.co.in

Atomic Energy Establishment Trombay as the Bhabha Atomic Research Centre (BARC) on 12 January 1967 in honour of the great scientist.

India's three-stage nuclear energy programme

India has only about 2% of the global uranium reserves, but 25% of the world's thorium reserves. Bhabha being a great visionary formulated a new strategy focussing on extracting power from the country's vast thorium reserves rather than depending on its meagre uranium reserves. He planned a three-stage nuclear energy programme aimed at utilising the country's large thorium reserve to the maximum. This thorium-focussed strategy was in marked contrast to all other countries in the world.

The three proposed three stages were to be:

1. Natural uranium fuelled Pressurised Heavy Water Reactors (PWHR)
2. Fast Breeder Reactors (FBRs) utilising plutonium based fuel
3. Advanced nuclear power systems for utilisation of thorium

Calling for more research into thorium as an energy source for of the country's indigenous three-stage programme, Srikumar Banerjee, Chairman of India's Atomic Energy Commission (2009-2012) said, "The world always felt there would be a miracle. Unfortunately, we have not seen any miracle for the last 40 years. Unless we wake up, humans won't be able to exist beyond this century. We are optimist enough that present scientists of India will take active role to fulfill Bhabha's dream and that will a real tribute to this great visionary".

Bhabha died in a plane crash near Mont Blanc on 24 January 1966 while on way to Vienna, Austria, to attend a meeting of the International Atomic Energy Agency's Scientific Advisory Committee.

His legacy

Bhabha left us 50 years ago, but his legacy still guides the nation. With his pioneering scientific ideas and brilliant administration he served India for more than two decades. He was the founder of, the Tata Institute of Fundamental Research (TIFR) and the Atomic Energy Establishment Trmbay (now known as BARC) – the two institutions that stand out as leading centres of scientific research in the country. Remember that these were built soon after Independence when we had minimum facilities in the universities and colleges to even hold classes. Note also the emphasis on fundamental research that Bhabha placed on the character of research.

His virtuous philanthropy and clear actions changed the scene of Indian science. He sacrificed his personal scientific career to devote most of his time to plan India's scientific development. It is our duty to remember him for his contributions because we owe him an immense debt of gratitude for what he did to India's science, technology and education.

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The Natural Password

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Many of us often find it difficult to memorise different passwords and PINs that are essential in today's digital world. The solution may lie in a natural password that is possessed by everyone, is unique to every individual, and no one needs to memorise it. It is called biometrics. The word "biometrics" comes from the Greek language and is derived from the words "bio" meaning life and "metric" meaning to measure. Biometric characteristics are certain personal characteristics (both physiological and behavioural) that can uniquely identify a person. The physiological biometric characteristic include fingerprint, face pattern**,** iris pattern, retina, hand geometry, palm geometry and the behavioural characteristic include voice, gait, signature, etc. All these characteristics can uniquely identify an individual. These characteristics are unique; i.e., strongly connected to an individual and cannot be shared, forgotten, stolen, copied or easily hacked.

A biometric system is basically a pattern recognition system. It operates by acquiring biometric data from an individual then extracting a feature set from the acquired data. Finally, the feature set is compared against a template set stored in the database. Based on the application, a biometric system may operate either in verification mode or identification mode.

'Verification' occurs when the user is already enrolled in the system (presents an ID card or login name); in this case the verification biometric data obtained from the user is compared to the user's data already stored in the database. Verification involves one-to-one comparisons and therefore the cost of computation is independent of the number of records (templates) stored in the system database.

'Identification' (also called search) occurs when the identity of the user is *a priori* unknown. In this case the user's biometric data is matched against all the records (templates) in the database as there is possibility that the user can be anywhere in the database or not at all there in the database. Identification is technically more challenging and costly. Identification accuracy generally decreases as the size of the database grows. Identification involves one-to-many comparisons and therefore the cost of computation is proportional to the number of records (templates) stored in the system database.

'Enrolment module' is responsible for enrolling individuals into the biometric system database. Here the live samples (fingerprint, retina, iris from individuals) are scanned; processed and distinguishing features are extracted to form templates that are stored in the system database for recognition purpose.

In this technologically advanced world everything is becoming digitised. On-line applications are gaining popularity and internet is emerging as a "natural resource". On one hand this has vast advantages, but on the other hand security threats are increasing. Now, the basic objectives of e-security are: authentication, authorisation (access control), privacy (data confidentiality), data integrity and non-repudiation. Biometrics is a technique that can fulfil all of these requirements with greater reliability. Biometric systems provide a strong degree of security: It provides a three-tire secured system.

In any biometric-based secured system at first a reader/sensor is used. It is an electronic device that is used to capture or scan the biometric sample (live scan) from an individual during verification or identification phase.

During the enrolment phase, the biometric characteristic (fingerprints, iris, retina, etc.) of an individual is first scanned by a biometric reader to produce a digital representation of the characteristic. In order to facilitate matching, the input digital representation is further processed by a 'feature extractor' in which the acquired biometric data is processed to extract a set of salient or discriminatory features that can uniquely identify an individual (e.g., the position and orientation of minutiae points, ridge and valley in a fingerprint or pattern of blood vessels in a retina scan based biometric system). Then it generates a compact but expressive representation called a 'template' that can be easily and efficiently stored in the database.

Fig. 1. Biometrics enhances the security aspects of a system (Credit: google Images).

'System database module' is used by the biometric system to store the biometric templates of the enrolled users. In a biometric system, the database needs to be accessed several times since in both verification and identification, the system has to match the input biometric characteristics with the template(s).

Then comes the 'matcher module', in which the features extracted during recognition are compared against the stored templates to generate matching scores. Based on this matching score and a particular threshold value the biometric matching algorithm (which is actually based on statistics) takes the decision whether the individual is genuine or an imposter. It gives a Boolean output either 'TRUE: *access granted*' (if individual is genuine) or 'FALSE: *access denied*' (if individual is an imposter). If the 'matching score' is greater than or equal to threshold value then access is granted Otherwise access is denied.

For every biometric-based access control system, a database or storage is required that keeps the templates to which the biometric samples are matched during verification or identification as the case may be.

Fingerprint

All fingerprints have unique characteristics and patterns. A normal fingerprint pattern is made up of lines (ridges) and

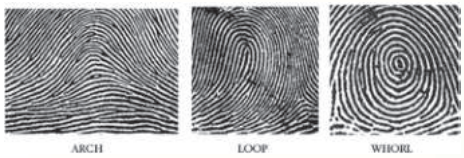

Fig. 2. Major fingerprint pattern with typical orientation of friction ridges on a finger (Credit: Google Images)

spaces (valleys). Generally fingerprints are made by the impression of the ridges of a human finger. These eatures have certain characteristics that make them very special. These impressions have specific patterns and they can be broadly classified into three categories: arch, loop and whorl. Fingerprints are unique to all humans; even twins have different fingerprints. They do not change in an individual's life time, even aging have no effect on fingerprint. For these two major qualities of uniqueness and permanence, fingerprints are considered as one of the highly accepted biometric characteristics in the world. Another interesting feature that helps in distinguishing among different fingerprints is the minutiae features. The major minutiae features of fingerprint ridges are ridge ending, bifurcation, and short ridge (or dot).

In fingerprint recognition, firstly the fingerprint of an individual is taken through a fingerprint scanner or sensor, then this input sample is processed and crucial points or features are extracted, these features are matched with the template stored in the database.

Today fingerprints are extensively used in different fields for verification as well as identification. In offices, government organisations, laboratories and research institutions, the entry-checking systems use fingerprint verification technology to allow the right person to get entry. In forensic science, fingerprints help identify a suspect or a criminal. Actually fingerprints get easily deposited on suitable surfaces such as glass or metal or polished stone by the natural secretions of sweat from the sweat glands that are present in epidermal ridges.

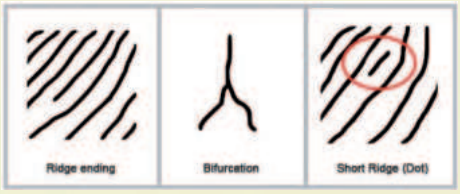

Fig. 3. Minutiae features (Credit: Wikipedia)

Retina

A retina scan is a biometric technique that involves analysing the layer and pattern of blood vessels situated at the back end of the eye. Retina is rich in bold vessels and because of the complex structure of the capillaries that supply the retina with blood, each person's retina pattern is unique. A low intensity light is used to scan the pattern of blood capillaries present in the retina. The unique pattern of blood vessels can be processed to form templates that can be easily stored in a database and can be used in verification/identification procedures. But today, retinal scanning is rarely used because

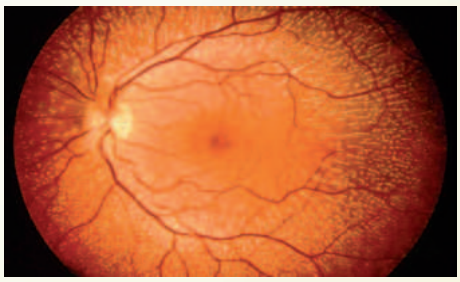

Fig. 4: The retina (Credit: Wikipedia).

it is not user-friendly and the technology is very expensive, even the collection of samples is quite difficult. It is only suitable for applications where high security is required. For these reasons this technology is not widely accepted by users even though its accuracy rate is moderately high.

Face

Face recognition is a physiological characteristic recognition of humans that identify by predefined matching algorithms and computer programs thereby analysing human faces for the purpose of identifying them. The distinct geometrical distinguishing features in face recognition are position, shape, and size of the eyes, nose, cheekbones and jaw line. Again, distance between the eyes, nose, mouth, and jaw edges; upper outlines of the eye sockets, the sides of the mouth, the location of the nose and eyes, the area surrounding the cheekbones are also calculated. The biometric system based on facial recognition is used to decide if the "face" is of someone known or unknown. Distinguishing features are digitally stored in the database which serves as the template to which the input face is matched and decisions are taken based on the algorithms. Generally, most of the biometric face recognition systems consist of face detector

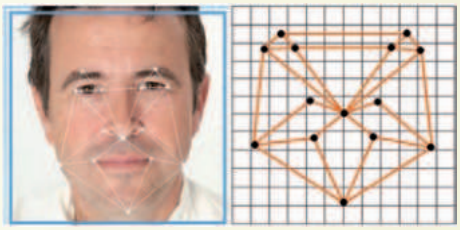

Fig. 5. Face recognition technology (Left), Feature extraction with data point collection (Right) (Credit: Google Images)

modules that have the capacity to capture a face from an input image or video clip.

Iris

The iris is the pigmented, connective tissue that regulates the size of the pupil, controlling the amount of light that enters the eye. It develops during prenatal growth through a process of complex forming and folding of the tissue membrane and once fully formed, its texture and pattern remains stable throughout life. The iris pattern of the eye is unique to an individual. Iris recognition is the process of recognising a person by analysing the random pattern of the iris. Iris scanning analyses more than 200 points of the iris and compares it with a previously-stored image template. This method is very secure (even contact lenses, and eye surgery cannot change the iris pattern) and almost error-free. But this process requires very high-resolution cameras

Fig. 6. Iris pattern and texture (Left), White outline indicates the localization of the iris and eyelid boundaries (Right) (Credit: Wikipedia).

for capturing the iris image and patterns. Iris scanners are very strong and accurate and therefore they cannot be deceived or duped. They can easily distinguish between a photo (of an iris) from a "live" one because while capturing the iris pattern, the iris-scanning systems vary the light and check if the pupil is dilating or contracting as it should in response to the light.

Hand geometry

Hand geometry recognition is one of the oldest biometric recognition systems based on a number of measurements taken from the human hand, such as its shape, curvature,

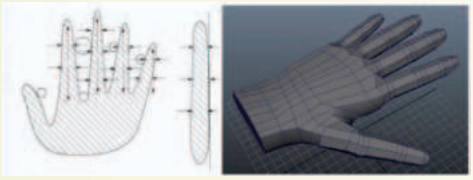

Fig. 7. Hand geometry recognition including feature extraction, edge detection and various measurement calculations (Credit: Google Images).

size of palm, and lengths and widths of the fingers.

Signature

Signatures are a behavioural biometrics that change over a period of time and are influenced by physical and emotional conditions of the signatories, but the way in which an individual signs is more or less unique. In biometric domain signatures are not verified only by their resemblance to one another but by the way in which the signatories do the signature. Biometric

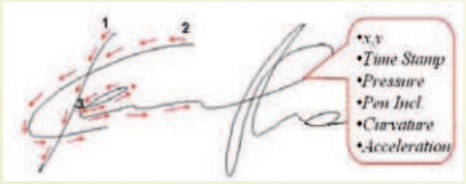

Fig. 8. Dynamic signature depiction. When an individual signs in a contact-sensitive pressure pad, various measurements are observed and processed for comparisons (Credit: Google Images).

signature recognition systems measure and analyse the physical activity of signing, such as the stroke order, the stroke sequence, the pressure applied and the speed while signing. This method is easy and very straight forward, but not at all secure because signature can be copied and people may not always sign in a consistent manner. Actual signature recognition is carried out by writing on a pressure sensitive pad with a pen or stylus.

There are various kinds of biometric recognition systems. Currently, different countries are trying to build their own biometric database for easy identification and verification purpose. Some of the famous biometric system and databases are:

IAFIS: The 'Integrated Automated Fingerprint Identification System' (IAFIS) is a national automated fingerprint identification and criminal history system maintained by the US Federal Bureau of Investigation (FBI). The IAFIS includes fingerprints, along with corresponding criminal histories, mug shots, scars, tattoo photos, associated gang name, physical characteristics like height, weight, hair and eye colour; and aliases of some most wanted and dangerous criminals. This database provides a great help to the police, investigation bureau and several federal organisations to solve, prevent crime, and catch criminals or terrorists. IAFIS is the largest criminal fingerprint database in the world, having a record of fingerprints and criminal histories for more than 70 million subjects in the criminal master file, along with millions of other related information. In September 2014, FBI announced that its 'Next Generation Identification' system (NGI) is in full-fledged operation and will effectively replace the Bureau's traditional fingerprint repository IAFIS.

AADHAAR: The Unique Identification Authority of India (UIDAI) is a Central Government agency of India. It has recently been shifted to the administrative control of the Ministry of Communication and Information Technology from NITI Aayog (National Institution for Transforming India), from the erstwhile Planning Commission of India. Its objective is to collect the biometric and demographic data (Name, DOB, age, address, mobile no., email id) of residents, store them in a centralised database and to issue a 12-digit unique identify number called Aadhaar to each citizen. It is going to be the world's largest national identification number project.

Risks associated with biometric systems

False rejection: (Type I error) – A genuine (valid) user is rejected by the biometric system (because the system does not find the user's current biometric data similar enough to the master template stored in the database). The main risk in this error is that, if the valid user has a great need to enter a system then he will not be allowed despite being the right person.

False acceptance: (Type II error) – An imposter is accepted as a legitimate user (because the system finds the imposter's biometric data similar enough to the master template of a legitimate user, who has an enrolment in the system). This is a very dangerous error because the imposter can manipulate things in the system or can take valuable information from the system. The consequences of insecure authentication and false acceptance in a banking or corporate environment can be catastrophic, with loss of confidential information, money, and compromised data integrity.

Every system has both its advantages and disadvantages. Moreover, all the giant systems have some amount of risk associated with them. If anyone says that "Biometric systems are completely risk-proof" then it is not true. But in the "big picture" biometric systems are highly advantageous and almost risk-proof. The risks of false acceptance and rejection are almost negligible and to a great extent they can be eliminated, if the system is maintained in proper conditions, samples are collected distinctly and properly during the enrolment phase and biometric samples (live scans) are fetched in perfect condition using high-quality reader or scanners.

Biometrics can be used as one of the most effective tools for protecting individual privacy. It ensures privacy by safeguarding identity and integrity. There is need to create awareness for exploring and advancing the use of new and enhanced biometric technologies and capabilities for integration into operation, thereby turning them into effective tools for the law enforcement and intelligence communities. Use of biometrics technology in entry-checking systems, access-control systems, banking, and passport can be of great importance. In India, schemes like Direct Benefit Transfer and Aadhaar-enabled biometric attendance system is gaining popularity. Direct Benefit Transfer (DBT) programme is an ambitious and revolutionary project launched by the Government of India in January 2013. Its objective is to transform service delivery in India by transferring government benefits and subsidies directly into the hands of citizens through the biometric-based identification system (Aadhaar), thereby speeding up payments, removing loopholes, and enhancing financial inclusion.

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Molecular Machines Become a Reality

Biman Basu E-mail: bimanbasu@gmail.com

Ever since the Nobel Laureate Richard Feynman stated in a lecture that it was possible to build machines with dimensions on the nanometre scale, scientists have been trying to build machines that can be seen only under a microscope. Nanometre-sized machines are also known as molecular machines where molecules are interlocked without the atoms interacting directly with each other and can move freely like components of a machine. The 2016 Nobel Prize in Chemistry has been awarded jointly to three scientists – Jean-Pierre Sauvage of the University of Strasbourg, France, Sir J. Fraser Stoddart of Northwestern University, Evanston, USA, and Bernard L. Feringa of the University of Groningen, the Netherlands – "for the design and synthesis of molecular machines". The three scientists have built molecular knots, shuttles, rotors, chains, pumps, axles, switches, memory devices, and even a rudimentary nano-car with four "wheels." – all at the scale of molecules. According to the scientists, future applications of nano-scale machines could range from delivering drugs to enhancing computer memory.

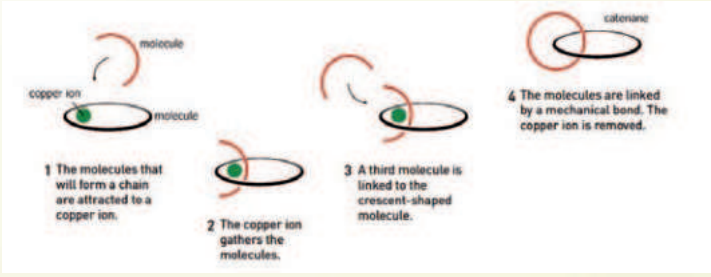
Jean-Pierre Sauvage

J. Fraser Stoddart

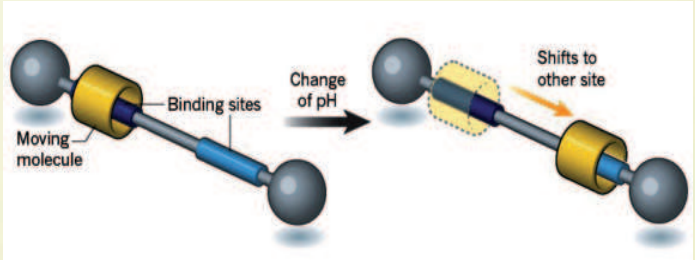
Bernard Feringa

Molecules we come across in everyday life such as water molecules, oxygen and hydrogen molecule, common salt, and most others are held together by chemical bonds. There are two main types of chemical bonds, namely covalent and ionic bonds. In covalent bonds electrons are shared between the linked atoms whereas in a compound formed by ionic bonding such as common salt (NaCl), electrons are transferred from one atom to the other to form the bond. Such chemically bonded molecules might move around or some groups of atoms may be able to rotate, but the atoms remain linked unless the bonds are broken.

Success to build molecular machines came after many years of struggle. In the mid-20th century, as part of efforts to build increasingly advanced molecules, scientists sought to create a different kind of bond: a mechanical bond, a connection such as that between a free-spinning wheel and an axle that would allow for motion within a nanoscale contraption. To do that, they had to create a molecule with at least two separate, semi-independently mobile parts. One of the first things they tried to do was connect two molecular rings, like links in a chain. The idea was to create mechanical bonds, where molecules are interlocked without the atoms interacting directly with each other.



Steps that Sauvage used to form a molecular chain link (catenane).



A rotaxane in which the ring-shaped molecule can move forwards and backwards on the axle like a tiny shuttle.

The first step towards a molecular machine was taken by Jean-Pierre Sauvage in 1983, when he succeeded in linking two ring-shaped molecules together to form a chain, called a 'catenane' (from the Latin word for chain, *catena*) – a molecule which consists of two or more connected rings like links in a chain. Sauvage was working with photochemistry, in which chemists develop molecular complexes that can capture the energy of the Sun's rays and utilise it to drive chemical reactions. When Sauvage built a model of one of these photochemically active complexes, he suddenly saw its similarity to a molecular chain: two molecules were intertwined around a central copper ion. "Minus the ion, it looked remarkably like a chain".

Based on that complex, Sauvage built a system where he placed a molecular ring around a copper ion, and then looped a C-shaped molecule through the ring. The copper ion provided a kind of cohesive force that held the molecules together. In a second step, chemistry was used to weld together the crescent-shaped molecule with a third molecule so a new ring was formed, thereby creating the first link in a chain. The researchers could then remove the copper ion, which had served its purpose.

Sauvage soon realised that "molecular chains were not only a new class of molecule, but that he had also taken the first step towards creating a molecular machine". It is well-known that in order for a machine to perform a task, it must consist of several parts that can move in relation to each other. The two interlocking rings that Sauvage and his team had made fulfilled this requirement. In 1994, Sauvage's research group succeeded in producing a catenane in which one ring rotated, in a controlled manner, one revolution around the other

Continued on page 22

Amazing Adhesives

Chaganty Krishnakumari
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In everyday life we undertake small repair jobs using adhesives, like reattaching a handle that has broken off a cup or a lost tail of child's play horse. If tiles in the kitchen are leaky we get them repaired by using silicone sealant adhesive. We are able to seal and fix stamps on envelopes only because of a pre-coated layer of adhesive on flap of the envelopes and back of the stamps. Today we find adhesive tapes in every home. These tapes consist of an adhesive layer coated on the back of paper, cloth, rubber, plastic or some other material. Different types of adhesive tapes are available such as Scotch tape, carpet tape, masking tape, duct tape, and sealing tape – each serving a definite purpose. We find labels on every packed material we purchase. School children stick labels to their new textbooks and notebooks with great enthusiasm. We can go on citing innumerable examples from our daily life and industries wherein adhesives are being used as a routine.

Natural adhesives

Natural adhesives such as gum, resin, and bitumen have been used since earliest times. Ancient Egyptians used flour paste in the making of papyrus and glue made from animal skin and bones for woodworking. Monks of the middle Ages (400–1450) used egg white to glue gold leaf to their decorated manuscripts. Adamantine glue was used by ancient Indians. It was a processed natural adhesive – a mixture of substances, such as Shrivasaka, Raktabola (myrrh), Guggulu (*Commiphora roxburghii*), Bhallataka (*Semecarpus anacardium*), Kunduruka, extraction of Deodar tree resin Atasi (*Linum usikatissimum*), and Bilva (*Aegle marmelos*) fruit. The resulting paste is termed as adamantine glue. This glue was heated and then used in construction of temple, mansions, windows, walls and wells as well as for fixing idols of gods. It was expected to last for a million years

Synthetic adhesives

Synthetic adhesives are compounds invented in research laboratories by chemists. These adhesives bond two or more materials at their surfaces. They may be used for bonding metal-to-metal, metal-to-plastic, and metal-to-composite. When different materials have to be joined to make components which retain their individual beneficial properties in the composite product, bonding technology uses synthetic adhesives.

Animal glue

There are many disadvantages in traditional joining techniques. In thermal techniques such as welding, the specific properties of the material alter within the heat-affected zone. Mechanical techniques such as or bolting, riveting or the use of screws allow force transfer only at points; moreover it is necessary to drill holes in the work pieces that are being joined. This operation weakens the materials. Adhesive bonding technique involves glues, epoxies, or various plastic agents that bond by evaporation of a solvent or by curing a bonding agent with heat, pressure, or time. Compared to welding and soldering/brazing, the bonding process requires relatively little heat input. It distributes stress load evenly over a broad area, reducing stress joints. Adhesives can be used join irregularly shaped surfaces easily. As they are applied on the inside surfaces of joints, adhesives are invisible within the assembly. They can also serve other purposes, such as sealing of leaking pipes or other items that require sealing a screw fixation in order to eliminate the effect of self-loosening caused by dynamic loads, sealing of areas where prevention of oxidation and corrosion, waterproofing, acoustic and electric, etc., are essential.

A large fraction of modern glues are carbon-based petrochemical derivatives. These can be used to bond almost any combination of surfaces, either by direct contact or by fastening both surfaces to a third, as with adhesive tapes. Aluminium does not readily weld to steel but can be glued. Carbon fibre and other composite materials lend themselves to glues than to screws. Thus due to the many advantages provided by the use of adhesives and glues in joining, protection and sealing processes, a wide range of industries use adhesives in the areas of construction, manufacturing and maintenance.

Types of adhesives

There are a large number of adhesive types for various applications. They may be classified in a variety of ways. Depending on their chemistries (e.g., epoxies, polyurethanes, polyimide); their form (e.g., paste, liquid, film, pellets, tape); their type (e.g., hot melt, reactive hot melt, thermosetting, pressure sensitive, contact, etc.); or their load-carrying capability (structural, semi-structural, or non-structural).

Structural adhesives

Structural adhesives are relatively strong adhesives. Epoxies, cyanoacrylates, and certain urethanes and acrylic adhesives come under this category. They can carry significant stresses, and lend themselves to structural applications. Structural adhesives are available as pastes, liquids, films, and supported films.

Semi-structural adhesives

Semi-structural adhesives are used in applications where failure would be less critical. Pressure-sensitive adhesives that come as double-sided foam tapes can be used in semi-structural applications.

Non-structural adhesives

Non-structural adhesives provide cost-effective means required for assembly of finished products. These include contact adhesives where a solution or emulsion containing an elastomeric adhesive is coated onto both adherents, the solvent is allowed to evaporate, and then the two adherents are brought into contact. Examples include rubber cement and adhesives used to bond laminates to countertops, facades, etc., for aesthetic purposes.

Pressure-sensitive adhesives are normally purchased as tapes or labels for non-structural applications. These are very low-modulus elastomers which deform easily under small pressures, permitting them to wet surfaces. When the substrate and adhesive are brought into intimate contact, Van der Waals forces are sufficient to maintain the contact and can provide relatively durable bonds for lightly loaded applications.

Thermosetting structural adhesives

Thermosetting structural adhesives are normally available in two-part forms. These two parts are mixed in proper ratio and applied to the surface of the adherent. Pot life refers to the time after a two-part adhesive is mixed during which it is workable and will still make a satisfactory bond. Materials with too short a pot life will harden too fast and do not give the workers sufficient time to assemble the product. An excessively long pot life may delay the cure time and slow the assembly process.

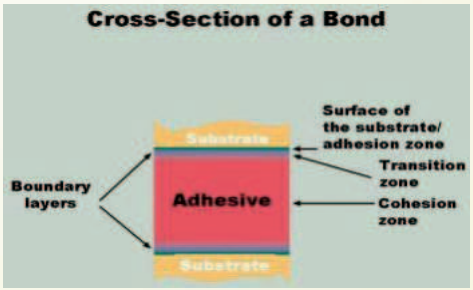
One-part forms are also available in which the resin and hardener are already mixed together. One-part thermosetting adhesives often have limited shelf life, and often must be stored at low temperatures, but do offer very high performance capabilities.

Hot melts

Hot melts are formulations based on thermoplastic polymers tailored to meet handling, performance, and application methods required for specific use. These adhesives are solids at room temperature, become liquid when heated, wetting the surfaces and then cooling into a solid polymer. Hot melts are used in printing industry for bonding the spines of books, in the textile industry for bonding appliqué. The automotive industry also uses hot melts for bonding insulating and cushioning materials, bonding headlight covers into metal frames and wheel covers. While the electronic industry uses them for bonding coil windings and coil ends,

Reactive adhesives

When repairing a damaged heel of shoe the cobbler removes the old heel from the shoe, roughens the joining area, applies a medium-viscosity adhesive to the bonding



surfaces of the new heel and the damaged shoe. He then presses the heel against the shoe for a short time in a press. The bond is now intact and any spill around the edge can be cleaned up. The reactive adhesive that allows him to work so fast is a cyanoacrylate, also commonly called superglue.

Mechanism of adhesion

An adhesive is a non-metallic binder that acts via adhesion and cohesion. Cohesion is defined as the internal strength of an adhesive as a result of interactions between the adhesive molecules while adhesion is the bonding of the adhesive molecules with substrate molecules – mainly the materials being joined together.

The phenomenon of adhesion is caused by molecular interactions between the substrate surface and the adhesive. For interactions to occur, the two materials must be able to make intimate contact with each other (i.e., they must be able to approach within a nanometre). A distinction can be made here between weak intermolecular interactions and strong chemical bonds. Chemical bonds, however, only form for very few substrate/adhesive combinations, such as between silicone and glass, polyurethane and glass, and epoxy resin and aluminium.

Applications

The automotive industry

In recent years there has been a large increase in the use of adhesives in the manufacturing processes of the automotive industry. A host of adhesives are used for the construction and manufacture of ground, air and sea vehicles. Adhesives have entered what used to be the domain of welding in the automotive industry. Glued cars are safer, lighter and more economical. General Motor's Corvette now comes with a carbon fibre roof glued to a magnesium frame. The high speeds we now expect of a car can only be achieved using composites of different materials – and a car tire is nothing more than that. The automotive industry uses advanced high-performance adhesives for windshield so that it can face enormous loads, remains perfectly in place in the frame, guarantee perfect hold overall, even under extreme conditions including wind, rain or hailstorm, blistering heat in the summer or bitter frost in the winter. Directly-glued front and rear screens ensure lower air resistance, thereby reducing fuel consumption.

Weight reduction offered by adhesives is an economically advantageous aspect. Every kilogram that is saved reduces the operating costs of an aircraft; and savings in the production costs and, based on the overall life of the vehicle, extremely important for the auto and aviation industry. The application of bonding technology in aircraft manufacture allows extremely lightweight design due to the consequent use of light metal alloys, fibre-reinforced plastics and so-called sandwich components. Bonding is used for internal structures for manufacturing structures with lightweight honeycomb sheets. The Airbus vertical tail is composed of an aluminium lattice framework and veneers made of carbon-fibre reinforced epoxy resin adhesive.

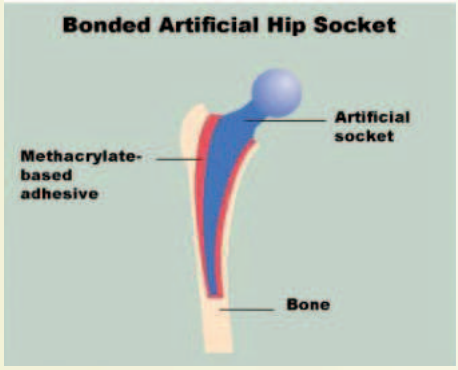
In railway coach manufacture, new components such as those made from glass-fibre reinforced plastic have resulted in enormous weight reduction and have transformed the production process.

Sandwich panels are widely used for constructing containers and refrigerated containers. These panels are made by bonding core materials such as plastic foams, sheets made of mineral materials or honeycomb sheets to cover plates made of aluminium or glass-fibre reinforced plastic. Low- and

medium-viscosity epoxy resin adhesives are used for this purpose and decorative panels also being bonded using such adhesives

Medical field

Adhesives are employed in diverse areas of medical practice, especially in surgery. Stitches can be avoided by applying special cyanoacrylate adhesives to quickly close skin wounds. An advantage here is that the whole wound can be covered, so largely suppressing secondary bleeding and the risk of infection.



One of the newest bio-adhesives on the market enables drugs to be delivered through the inside of the mouth, nasal passages and other mucus membranes instead of just through skin. It adheres extremely well to the soft, wet mucus membranes of the body because of adhesives made from starch-polyacrylic acid blends, which then completely erode and disappear. Drug makers are able to put their medicine into tablet, film or powder form, and the patient is able to attach the product directly to a mucus membrane, providing a means for controlled delivery of drugs to specific areas of the body or systemically throughout the body. The use of methacrylate-based adhesives has been a great success in orthopaedics for anchoring hip socket implants to the bone.

In dentistry, fillings based on UV curing acrylates have largely replaced traditional filling materials such as amalgam and bond in just a minute or so when exposed to UV light.

Electric motors

Electrical devices like CD-players and video cameras, kitchen appliances etc., contain electric motors. Adhesives play an important role in motor assembly, for example, for connecting the armature and shaft, for connecting the commutator and shaft, for attaching ball-bearings and for securing screws in position. Acrylate is used generally for this purpose. This is an anaerobic adhesive that cures when oxygen is excluded.

Electronic circuits

The continuing miniaturisation in the area of electronics has not only resulted in smaller components but also components that are more sensitive to heat. Adhesives have taken over many tasks in the assembly of electronic circuits. Besides being used for mechanical attachment, adhesives also function as electrical conductors and insulators. Today, many electronic components are fixed in their intended positions with adhesives, prior to soldering. Electrically conducting adhesives are normally epoxy resin adhesives containing a very small amount of ionic contaminants. To a lesser extent special polyimide adhesives are also used. In both cases these adhesives contain 70 to 80 weight percent of very fine silver powder.

Mobile phones

Just because of the adhesive films used in their production mobile phones are getting cheaper, better and smaller. What modern adhesive films, composed of epoxy resin, silicone or polyurethane, can accomplish is amazing. One can produce electrical connections between two or more contact points or replace small screws and solder joints. The bond is flatter, less complex and cost-intensive. In comparison to solder joints, adhesive film is lead-free and less vulnerable to heat, thereby reducing the risk of thermal damage. Further, adhesive film in mobile phones protects against shock and prevents the permeation of moisture, protects the screen from unpleasant scratches, ensuring untarnished communication.

Packaging

Most packaging materials used today are in fact different materials laminated together. Adhesives based on starch, dextrin, gluten, and also polyvinyl acetate dispersions, are used for laminating cardboard with high-gloss paper to put product information on the cardboard. Dispersion adhesives and hot melts are used to seal packaging (e.g., folding cartons, packets). Adhesives are used in a wide variety of paper-bonding applications as in the construction of corrugated box, composite containers and tubes, bags, envelopes, foil laminates, flexible packaging, labels, signs, decals, etc.

Furniture-making industry

Polyvinyl acetate dispersion adhesives have long superseded the carpentry adhesives based on animal proteins that were used till a few decades ago. Condensation resins (urea, melamine, and resorcinol-formaldehyde resins) have made possible the development of new wood-based materials such as plywood, chipboard and laminated composites (resorcinol/ phenol-formaldehyde resins) for building construction

The significance of adhesives has been shown and proven through the millennia – from papyrus of the ancient Egyptians and the magnificent temples of ancient Indians to the navigation system, laptop and plasma screen TV of today.

Dr. Chaganty Krishnakumari is a Telugu Popular Science writer well-known for her unique creative presentation of complex scientific subjects in a captivating narrative style. She retired as reader & head of the Department from Singareni Collieries Women's' college.

Rabies – the Yama's bullet
All You Want to Know About

Dr. Yatish Agarwal
E-mail: dryatish@yahoo.com

Call it a bullet-shaped single-stranded RNA virus, or more poetically, the God of Death Yama's emissary, rabies is one of the oldest documented viral diseases to affect human beings, and the most lethal, causing a certain death once the disease sets in. The earliest records of it stretch back to Ancient Egypt around 2300 BCE; it has been recognised since the Vedic period, and finds a detailed description in the ancient Indian scripture *Atharvaveda*. The irony is that despite a range of effective vaccines, of which the first was formulated in 1885 by the French bacteriologist Louis Pasteur, the disease still rings in more than 25,000 human deaths in the country each year.

Rabies is present on all continents with the exception of Antarctica, but more than 95 per cent of human deaths occur in Asia and Africa. Many countries have, however, become rabies-free by employing robust and effective public health policies.

In the midst of an epidemic

The landscape in India, however, requires a big change. With a person being bitten by a dog every 2 seconds, and someone dying from rabies every 30 minutes, India currently accounts for more than 35 per cent of the global rabies deaths. Just as more and more countries across the world declare themselves rabies-free, these numbers spin a terrible tale, and should form a ground for lawmakers to reframe the current public health policy.

With more than 99 per cent of all rabies transmissions taking place through dog bites, the disease is largely preventable, and can, indeed, be eliminated if the World Health Organization (WHO) goals were to be met. That shall not be, given that both the arms of the preventive strategy – one, of keeping the population of stray dogs under check; and two, of vaccinating all the dogs against rabies – remain grossly unmet.

The problem relates to the monstrously large stray canine population in the country. Be it towns, villages or cities, millions of stray dogs populate public spaces, protected under a law that prohibits impounding and euthanising unclaimed dogs. Until 1998, that was not the case, and the population of stray dogs in India was kept under check by the civic authorities. Under pressure from animal welfare activists, the country decided to embrace the strategy of animal birth control, rather than culling the strays, as is the policy in large parts of the civilised world. Under the current rabies control national policy, stray dogs are impounded, surgically sterilised and released back into the area from where they were picked up. The success of this programme hinges on the castration of 70 per cent of the strays in a given geographic area within 6 months, before the next reproductive cycle begins, otherwise the entire effort is negated. This target is difficult to achieve, given the over 30 million estimated strays in the country on one hand, and the considerable resources and commitment that it requires on the other.

The testing spectre is further confounded by a number of stark facts. Strays – be they family dogs (partially restricted, wholly dependent); community dogs (unrestricted, partially dependent); or feral dogs (unrestricted, independent) – outnumber pet dogs (restricted and supervised) in a 80:20 ratio. The majority of people who die of rabies are people of poor or low-income socioeconomic status. Since rabies is not a notifiable disease in India, the country doesn't even know the true extent of the disease. There is no requirement for doctors to report human infections, and no information exists on how widespread the disease might be among animals. Experts believe the actual number of deaths due to rabies may in fact be much higher than the current estimates.

This is, however, just one part of the story. Considering that some 18 million people are bitten by dogs in the country every year, if only the number of person-days lost to canine bites and the cost of post-bite anti-rabies treatment is tallied, it adds up into a huge cost for the community.

The government has been planning to set up a national rabies control programme since 2014. However, till date, only a pilot project has been launched in the northern state of Haryana. Until the national programme takes wings, the local civic authorities stand saddled with the responsibility of vaccinating the strays on the street. On a present estimate, fewer than 15 per cent of the dogs have been vaccinated. These vaccinations are simply not enough. If 70 per cent of the dog population was vaccinated, and a larger population was to be castrated, it would make sure that new animals – potential reservoirs for the virus – aren't introduced into the community.

At the time of writing, India has no national or state-wide plans in effect to make this happen. Most civic authorities deal with the problem by hiring non-governmental organisations like *Compassion Unlimited Plus Action*. That leaves rural areas, where rabies strikes hardest, all but ignored.

With little being done to rein-in the damage, the number of dog bite cases and post-exposure vaccination continue to rise, and India continues to be in the midst of an epidemic of rabies. As a result, the goal of the World Health Organization of eliminating

rabies from the South-East Asia region by the year 2020 must remain no more than a pipe dream.

A disease of warm-blooded mammals

Rabies is primarily a disease of terrestrial and airborne mammals. A vicious killer, rabies virus is transmitted through saliva. Any warm-blooded mammal — including dogs, wolves, foxes, coyotes, jackals, cats, bobcats, lions, mongooses, skunks, badgers, bats, monkeys and humans – is susceptible. The dog has been, and still is, the main reservoir of rabies in large parts of the world, including India. Dogs can become infected through a bite by a rabid wild animal or fellow canine; in turn, a bite from an infected dog is the most common method of human infection.

Other animals, such as monkeys, jackals, horses, cattle and rodents, seem to bite incidentally on provocation, and the fear of rabies leads the victim to seek post exposure prophylaxis. The number of cases involving monkey bites has been increasing in the last few years. Monkeys are susceptible to rabies, and their bites necessitate post exposure prophylaxis.

The rabies virus

A member of the rhabdovirus family, the rabies virus is bullet shaped and has a single stranded RNA genome. From the wound of entry, the rabies virus travels quickly along the neural pathways of the peripheral nervous system. The retrograde axonal transport (the transport of materials from axon to cell body of the rabies virus to the central nervous system is the key step of pathogenesis during natural infection. From the nervous system, the virus further spreads to other organs.

The salivary glands located in the tissues of the mouth and cheeks receive high concentrations of the virus, thus allowing it to be further transmitted due to projectile salivation.

Transmission

People are usually infected following a deep bite or scratch by an infected animal. Dogs are the main host, transmitter, and the cause of human rabies deaths in Asia and Africa.

Bats are the source of most human rabies deaths in the Americas. Bat rabies has also recently emerged as a public health threat in Australia and Western Europe. Human deaths following exposure to foxes, raccoons, skunks, jackals, mongooses and other wild carnivore host species are very rare.

Transmission can also occur when infectious material – usually saliva – comes into direct contact with human mucosa or fresh skin wounds. Human-to-human transmission by bite is theoretically possible but has never been confirmed.

Rarely, rabies may be contracted by inhalation of virus containing aerosol or via transplantation of an infected organ. Ingestion of raw meat or other tissues from animals infected with rabies is not a confirmed source of human infection.

Recognising the symptoms

Rabies is an infectious viral disease that is almost always fatal following the onset of clinical signs. The time between the animal bite and the occurrence of rabies, or the incubation period of the disease, is typically 1–3 months, but it may vary from less than 1 week to more than 1 year, dependent upon factors such as the wound of entry and the viral load.

The first symptoms of rabies are fever and often pain or an unusual or unexplained tingling, pricking or burning sensation at the wound site. As the virus spreads through the central nervous system, progressive, fatal inflammation of the brain and spinal cord develops.

Two forms of the disease can follow:

The furious rabies

'Furious' rabies – so called because of victims' hyperactivity, excited behaviour, and agitation – is far more common. Victims become aggressive, start hallucinating and develop a marked fear of water (hydrophobia), even shrinking from the sight of a glass filled with it. This is because rabies causes painful muscle spasms in the throat and larynx, and water can trigger the spasms. Others may exhibit fear of draft of fresh air (signs of aerophobia). Death results from blocked airways, seizures or widespread paralysis. Within three or four days, the victim is usually dead.

The paralytic rabies

Paralytic rabies accounts for about 30 per cent of the total number of human cases. This form of rabies runs a less dramatic and usually longer course than the furious form. The muscles gradually become paralysed, starting at the site of the bite or scratch. A coma slowly develops, and eventually death occurs. The paralytic form of rabies is often misdiagnosed, contributing to the under-reporting of the disease.

Diagnosis

No tests are available to diagnose rabies infection in humans before the onset of clinical disease. Unless the rabies-specific signs of hydrophobia or aerophobia are present, diagnosing a victim of rabies purely on the clinical basis is difficult.

The diagnosis can be confirmed while a victim is still alive and also in the post mortem phase by using specific diagnostic techniques. These techniques work by detecting the rabies virus, viral antigens or nucleic acids in infected tissues such as the brain or skin, or secretions like saliva.

Medical treatment

For a patient with an illness consistent with rabies, transfer to a tertiary care centre with intensive care support and capability of providing timely diagnostic workup is essential. Symptomatic rabies cannot be managed in the outpatient setting. Intensive heart and lung (cardiopulmonary) supportive care is the only treatment available for patients with symptomatic rabies. Rabies vaccination and administration of human rabies immunoglobulin (HRIG) is ineffective at this point.

In animal studies, rabies immunoglobulin has been associated with "early death"; it has been suggested that HRIG may also pose a risk of early death in humans and should be avoided.

Regardless of treatment, symptomatic rabies is almost invariably fatal, with autonomic dysfunction leading to loss of cardiac rhythm and drop in blood pressure. Some role for combination treatments including ribavirin, interferon, ketamine, and immunomodulatory therapies has been proposed and may be considered in future cases under investigational protocols.

The survival of a teenage girl from Wisconsin, United States received substantial attention in October 2004 as the first reported case of human survival of rabies in the absence of preceding vaccination or post-exposure prophylaxis. She received an investigational regimen of ribavirin, amantadine, and a ketamine-midazolam–induced coma; however, this therapy has not been validated and has not been reproducible. Further, the bat rabies virus isolated in this case may be less neurovirulent (capable of causing disease to the nervous system) than canine or other variants that are responsible for most human cases of rabies.

Trials with immunomodulatory therapies such as rabies immunoglobulin, rabies vaccine, and interferon have not benefited patients till date.

Steroids, which are usually indicated in the treatment of local vaccine reactions or brain swelling (cerebral oedema), are contraindicated because of increased mortality noted in animal studies.

(In the next issue 'Safeguarding against rabies: the 1-2-3 of post-exposure treatment')

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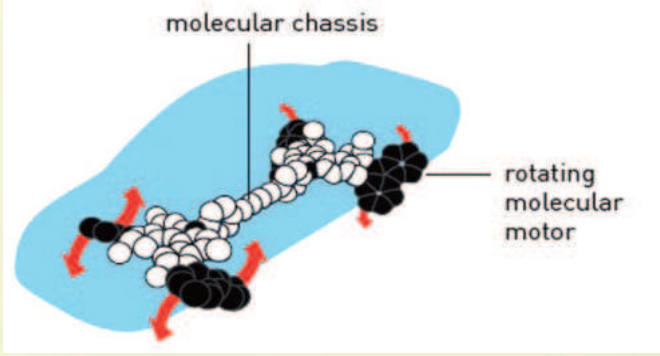
Molecular Machines Become a Reality (continued from page 28)

ring when energy was added. Molecular machines had become a reality.

According to the Nobel Foundation, Sauvage's pioneering work in the 1980s set the stage for modern molecular machinery. His great contribution was "to realise that the synthesis of such structures could be greatly facilitated by using the preferred coordination geometry of transition-metal ions to assemble and orientate the molecular building blocks".

The second step was taken by Fraser Stoddart in 1991, when his research group built an open ring that lacked electrons, and a long rod, or axle, that had electron-rich structures in two places. When the two molecules were placed in a solution, the electron-poor molecule was attracted to the electron-rich molecule, and the ring threaded onto the axle. In the next step, the research group closed the opening in the ring so that it remained on the molecular axle. Stoddart had thus created a rotaxane – a ring-shaped molecule that is mechanically attached to an axle. When heat was added or the pH changed, the ring jumped forwards and backwards – like a tiny shuttle – between the two electron-rich parts of the axle. Among his developments based on rotaxanes are a molecular lift, a molecular muscle and a rotaxane-based computer chip.

The first molecular motor was developed by Bernard Feringa; in 1999 he used a number of clever tricks to get a molecular rotor blade to spin continually in the same direction. The molecule was composed of something that can be likened to two small rotor blades – two flat chemical structures that were joined with a double bond between two carbon atoms. A methyl group was attached to each rotor blade; these, and parts of the rotor blade, worked like ratchets that forced the molecule to keep rotating in the same direction. When the molecule was exposed to a pulse of ultraviolet light, one rotor blade jumped 180 degrees around the central double bond. Then the ratchet moved into position. With the next light pulse, the rotor blade jumped another 180 degrees. And so it continued, round and round in the same direction. In 2011, Feringa's research group also built a four-wheel drive nanocar – a molecular chassis held together four motors that functioned as wheels. When the wheels rotated, the car moved forward over a surface.



A molecular nanocar with four wheels

Other researchers have connected molecular motors to long polymers, forming an intricate web. When the molecular motors are exposed to light, they wind the polymers up into a messy bundle. In this way, light energy is stored in the molecules and, if researchers find a technique for retrieving this energy, a new kind of storage battery could be developed. The material also shrinks when the motors tangle the polymers, which the researchers say could be used to develop sensors that react to light.

Incidentally, in terms of development, the molecular motor is currently at about the same stage as the electric motor was in the 1830s, when researchers proudly displayed various spinning cranks and wheels using rudimentary electric motors in their laboratories without having any idea that they would lead to washing machines, fans and food processors. Molecular motors may see similar transformation in the years to come!

Recent Developments in Science and Technology

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Trip to Mars may cause permanent brain damage in astronauts

Ever since Yuri Gagarin first ventured into space on 12 April 1961 on board a Soviet spaceship, more than 550 people have been to space. Twelve astronauts have already landed on Moon and returned back to Earth. Many have spent several months in the weightless condition of space stations, giving scientists an opportunity to learn a lot about how conditions in space affect human health. These studies have brought to light many damaging effects of zero-gravity and helped in designing means to counter the damaging effects of space environment. There are now plans to build colonies on Moon and travelling to Mars. But a recent finding about the long-term effects of cosmic radiation on rodent brain may force rethinking on such ambitious space missions.

Recent studies indicate that astronauts may suffer irreparable brain damage due to galactic cosmic rays during extended spaceflights such as those to Mars.

In a recent study, researchers at the University of California, Irvine have found that exposure to highly energetic charged particles – much like those found in the galactic cosmic rays that will bombard astronauts during extended spaceflights – causes significant long-term brain damage in test rodents, resulting in cognitive impairments and dementia. It is the second study the team has done to show that cosmic radiation causes permanent and likely untreatable, brain damage. While their experiments involve mice, according to the researchers the brain structures that are damaged are similar in humans (*Scientific Reports*, 10 October 2016 | DOI: 10.1038/srep34774).

The study further adds, "Exposure to these particles can lead to a range of potential central nervous system complications that can occur during and persist long after actual space travel – such as various performance decrements, memory deficits, anxiety, depression and impaired decision-making. Many of these adverse consequences to cognition may continue and progress throughout life."

According to the US space agency NASA, astronauts risk physical damage from the radiation encountered in space. Earth is enveloped in a large, protective sheath called the magnetosphere, which deflects a lot of the ionising radioactive particles that speed through space, significantly reducing the risk for astronauts staying in space stations in near-Earth orbit. Teams aboard the International Space Station are inside that protective envelope so unlikely to suffer any damage. But Moon travellers were not, and according to NASA, a study showed the cosmic radiation may have damaged the hearts of many of the Apollo program astronauts. According to Charles Limoli, who led the UCI study, "Our data provide additional evidence that deep space travel poses a real and unique threat to the integrity of neural circuits in the brain".

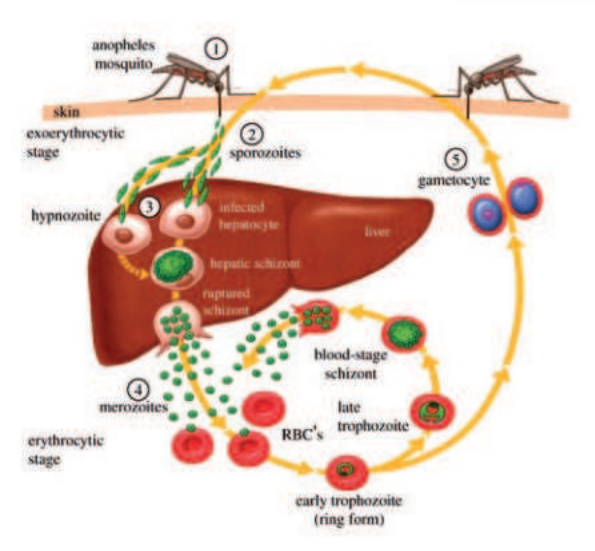
A trip to Mars would expose astronauts to even more radiation than during a trip to Moon – enough to cause cancer, for sure, and now this research suggests brain damage, as well. Limoli says, "Such conditions could clearly be problematic for astronauts and their capability to efficiently operate over the course of a deep space mission. Exposure to these particles can lead to a range of potential central nervous system complications that can occur during and persist long after actual space travel – such as various performance decrements, memory deficits, anxiety, depression and impaired decision-making. Many of these adverse consequences to cognition may continue and progress throughout life."

NASA is looking for light-weight and efficient shielding material to protect astronauts from the energetic particles during long space voyages. Conventional shielding materials would be too heavy and would enormously increase the cost of launch. In fact, NASA is currently investigating a handful of possibilities that could be used in anything from the spacecraft to the Martian habitat to space suits. Unless the right shielding material is found, a manned mission to Mars may turn out to be too risky to undertake.

New drug clears malaria from mice in a single dose

Malaria is a mosquito-borne killer disease caused by a parasite. Last year, there were over 200 million cases of malaria, and they resulted in nearly half a million deaths. The malaria parasite is carried by the female Anopheles mosquito, which acts as a vector. Between the mosquito and human hosts the parasite goes through several stages. In humans, the parasite grows and multiplies first in the liver cells and then in the red cells of the blood. In the blood, successive broods of parasites grow inside the red cells and destroy them, releasing daughter parasites called merozoites that continue the cycle by invading other red cells. It is the blood stage parasites that cause the symptoms of malaria.

When a female Anopheles mosquito bites a human malaria patient, it picks up certain forms of blood stage parasites called gametocytes and starts another, different cycle of growth and multiplication in the mosquito. After 10-18 days, the parasites are found as sporozoites in the mosquito's salivary glands. When the infected Anopheles mosquito bites



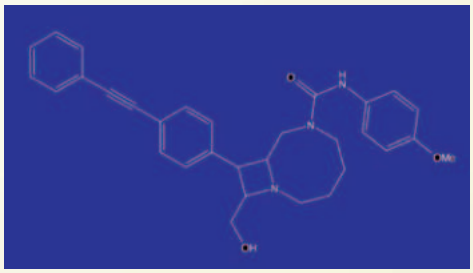
Life-cycle of the malaria parasite.

another human, the sporozoites are injected with the mosquito's saliva and start another human infection when they parasitise the liver cells. Unlike the human host, however, the mosquito vector does not suffer from the presence of the parasites.

Current treatments of malaria primarily target the blood stage parasites in humans, which often does not work because the parasite continues to persist in the liver. Recent research by an international team of scientists has led to identification of a novel class of antimalarial drugs that are highly effective against all the stages of the malaria parasite. The team includes four scientists from the Molecular Medicine Group, International Centre for Genetic Engineering and Biotechnology, New Delhi.

The team screened more than 100,000 molecules against a strain of *Plasmodium falciparum*, the most lethal malaria-causing parasite in humans. They focussed on compounds that would be effective against multiple life stages of *P. falciparum*, and found a group of compounds that blocked an enzyme that previous treatments did not target, which the researchers felt might make the parasite less susceptible to resistance. The compound they found targets an enzyme called phenylalanyl-tRNA synthetase and appears to wipe out parasites before they can multiply in the liver and be released into the bloodstream. When single dose of these compounds, called bicylic azetidines, were administered to mice infected with *P. falciparum* or another species, *P. berghei*, the animals remained parasite-free for 30 days. In tests on mice, a single dose of the drug was able to completely clear any sign of infection from the mice. It was also effective when ingested orally. The drug appeared to work against several different stages of the parasite's life cycle as well, clearing infections from both the blood and the liver. According to the researchers, bicyclic azetidines have the potential to cure and prevent transmission of the disease as well as protect at-risk populations with a single oral dose. (*Nature*, 7 September 2016 | doi:10.1038/nature19804).

The most exciting fact about the new discovery is that it works with a single dose, which will be of great help in covering populations in poorer countries where medical facilities are scarce. Getting people in those areas to successfully complete a course of treatment is a real challenge because it is known that failure to complete the course encourages the evolution of drug resistance. Being able to clear the parasite with a single dose could solve that problem. However, there is still a lot of human testing that will be needed, but the researchers hope the findings will lead to the discovery of better anti-malarials in coming years.



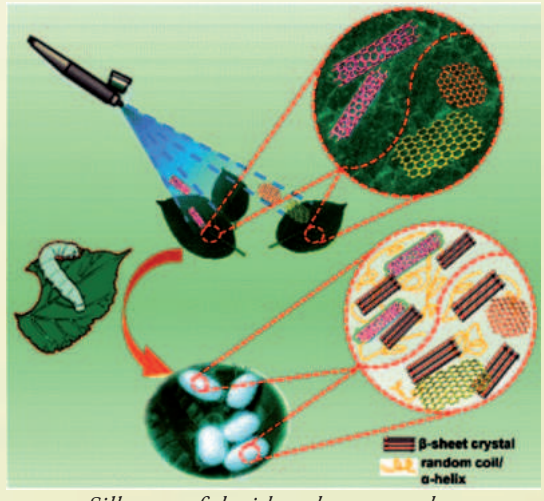
Compounds called bicylic azetidines have the potential to cure and prevent transmission of malaria with a single dose.

Silkworm fed with carbon nanotubes produce stronger silk

Silk is a natural protein fibre produced by caterpillars of certain moths that can be woven into fabrics. Most silk used for clothing comes from silkworms or moth caterpillars, the larvae of which produce silk to form cocoons. Many other types of insects, including spiders, also produce silk. Silk produced by silkworms is not as strong as spider silk, which is even stronger than steel. But now scientists have found a way to make silkworms produce stronger silk by feeding them carbon nanotubes and graphene (*Nano Letters*, 13 September 2016 | DOI: 10.1021/acs.nanolett.6b03597).

The study was done by Yingying Zhang and her colleagues at Tsinghua University in Beijing, China, who fed common silkworms *Bombyx mori* a diet of mulberry leaves sprayed with an aqueous solution that contained either 0.2 percent of carbon nanotubes or graphene. According to the researchers, the smaller, 1- to 2-nm-wide single-walled nanotubes they used "are more suitable for incorporation into the crystalline structures of silk protein". After feeding, the worms produced silk that was twice as strong as traditional silk and could withstand about 50 percent more stress before breaking. The higher strength of the modified silk was due to incorporation of part of the fed carbon nanomaterials. According to Zhang, treating already spun silk would require dissolving the nanomaterials in toxic chemical solvents and applying those to the silk; so the feeding method is simpler and more environmentally friendly. When the researchers heated the new fibres up to 1,050°C they were carbonised and could conduct electricity.

Although there is no doubt that feeding with carbon nanotubes produced stronger silk, the scientists are still not clear as to how the silkworms incorporate the nanomaterials in their silk. Another question that needs to be answered is what percentage of the nanomaterials eaten by the worms makes it into the silk instead of



Silkworms fed with carbon nanotubes produce stronger, reinforced silk.

being excreted or otherwise metabolised. According to Zhang, the carbon materials are not visible in the cross-sections of the silk threads, perhaps because the nanoparticle content is low. But Raman spectroscopy and electron microscopy imaging showed that the carbon-enhanced silk fibres had a more ordered crystal structure due to the incorporated nanomaterials. Looking ahead, the scientists hope to better understand the process of how the carbon materials are integrated into the silk thread in order to optimise the amount of supplement that ends up in the finished thread. According to the researchers, this work provides an "easy way to produce high-strength silk fibres on a large scale". The electrical conductivity of the carbon-reinforced silk might make it suitable for sensors embedded in smart textiles and to read nerve signals

Excessive exposure to digital media harmful for children

Technological innovations have transformed media and its role in our lives to such extent that even infants and young children take them for granted. Computers, TV, iPad and smartphone are commonplace things in almost every household today. More children, even in economically weaker households, are using newer digital technologies, such as interactive and mobile media, on a daily basis. Many parents are under the belief that technology and gadgets are essential for a child's development and they consider it normal to keep their kids busy watching cartoon channels on TV or handing them smartphones to keep them quiet. TV has been an easy "babysitter" for years now, aided even further with gadgets like the iPad and smartphone. The current generation of children in most Western societies, and even in many developing societies, spends more time in front of a screen than any before it.

Although there has been much hope for the educational potential of interactive media for young children, accompanied by fears about their overuse during this crucial period of rapid brain development, research in this area has remained limited. Some studies had shown that excessive screen exposure at early age have adverse effect on a child's health, behaviour and even education. In 2013 the US Department of Health recommended that children under 2 years of age should not be in front of a screen at all, and over that age the maximum

Paediatricians have warned against excessive exposure to visual electronic media on the health and development of children up to 5 years of age.

leisure screen time should be no more than two hours a day. The French government has even banned digital terrestrial TV aimed at all children under three, while Australia and Canada have similar recommendations and guidelines.

Recently, the American Academy of Paediatrics has come out with a policy statement and recommendations which outline the potential dangers of excessively exposing young children up to age of 5 years to television, videos, and mobile and interactive technologies. The policy statement addresses the influence of media on the health and development of children up to 5 years of age, "a time of critical brain development, building secure relationships, and establishing health behaviours" (*Pediatrics*, November 2016 | DOI: 10.1542/peds.2016-2591).

The recommendations are based on dozens of studies on screen time and its effect on the emotional and physical health of kids of all ages. They also incorporate evidence about whether young children really do learn from apps and TV shows.

Here is a gist of the recommendations:

- Children under the age of 2 should avoid all digital media use except for occasional video chatting.
- If you must introduce digital media to toddlers between the ages of 18 and 24 months, choose high-quality programming and sit with your child. Solo viewing should be avoided.
- Children ages 2 to 5 years should have no more than one hour exposure to screen a day.
- Keep bedrooms, mealtimes and parent-child playtime free of screens.
- Children of all ages should avoid exposure to devices and screens for one hour before bedtime.
- Keep smartphones, TVs and other devices out of the bedroom.

Biman Basu is a former editor of the popular science monthly Science Reporter, published by CSIR, He is a winner of the 1994 'NCSTC National Award for Science Popularisation'. He is the author of more than 45 popular science books.