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The riddle of the cosmic speed limit

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

Fight the fake news, tell your story



Dr. T. V. Venkateshwaran

In a recent blog, Jennifer Leigh Rohn, a British-American cell biologist and novelist lamented fake news and the emerging 'post-truth' media environment. Disheartened, she wrote "I think writers like me, who specialise in evidence-based communication, have been deluded as to the power of our pens in the face of this inexorable tide.... We convince ourselves we are doing good, that we are shining a light – no matter how dimly – on an accumulation of evil disinformation. We feel smug when we get a thousand retweets – until we notice that the anti-vaxxers, the racists and the nutters are getting hundreds of thousands more."

Fake news, in the wake of the digital era and the proliferation of social media, is the latest challenge to nurturing scientific temper. It weakens the public confidence in science and leads science-based decision making into a crisis of credibility. While some of the fake news content may be innocent, having hardly any impact, yet some such as anti-vaccination messages could result in epidemics causing perceptible danger to health, environment and well-being. The climate-change deniers, anti-vaccine evangelists, flat-earthers, shake the public trust in evidence-based public policies and the mistrust between public and scientists will have repercussions in the future of science, health and environment.

Discovery of vaccination is a watershed moment in the history of humans. It has made possible to consign smallpox to the dustbin of history and polio too is on its way to becoming history. The estimate of deaths globally due to measles was about

5,46,800 in 2000, which due to Measles & Rubella Initiative of WHO has decreased to just 89,780 deaths, mostly among children under the age of five. We can appreciate the magnitude of the impact of this vaccine on human well-being when we remind ourselves, before the introduction of measles vaccine in 1963, each year the estimated death due to measles was about 2.6 million. Between 2000-2016, one estimate pegs 20.4 million lives saved by this vaccination alone.

Yet, every twenty-second, one child somewhere in the globe dies due to diseases that could have been prevented by a vaccine. While lack of access to life-saving immunisations is the main reason for such preventable deaths, the spread of 'fake news' through social media is increasingly becoming a significant burden in the area of public health. Take the case of the recent incident of the Ebola outbreak. The quarantine measures advocated by the experts were misrepresented and questioned, due to widespread circulation of fake news in social media, resulting in the spread of the diseases and avoidable deaths in Guinea, Liberia and Sierra Leone. The false claim that self-medication with salt and bitter melon is adequate to treat Ebola in Nigeria resulted in many patients not seeking health care, resulting in deaths. The "anti-vax" sentiment, at times endorsed by celebrities, resulted in outbreaks of measles in the US and across Europe. Unfounded suspicion of vaccination has resulted in persisting polio in Pakistan and Afghanistan.

While the fake news dazzles our vision and numbs our reason, people are still keen

and interested in science. A recent National Youth Readership Survey by National Book Trust and National Council of Applied Economic Research says that "About 75 per cent literate youth evinced some amount of interest in science; 25 per cent being very much interested in science and 50 per cent being fairly interested." This is a proverbial light at the end of the tunnel for us, science communicators.

What do we do? Start locally. Tell your story. Share your research and passion with your relatives and friends. Communicate your work. Visit nearby school or college, give a talk. Understand what we have is not mainly an information gap, but the trust gap. Hence the primary objective is to build trust. We can build confidence only if we tell accurate stories that humanise science and scientists, and a tale that encompasses the entire scientific process and not just the final outcomes. In short, reason out why we trust as a scientist what we claim, rather than seek blind trust.

What more, if you are a PhD Scholar or a Post-Doctoral Fellow (PDF) in science and technology (S&T) streams from India, then you can even participate in the "Augmenting Writing Skills for Articulating Research" (AWSAR) initiative of DST and take part in a national competition.

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The Dangers of Diabetic Neuropathy



Richa Saxena

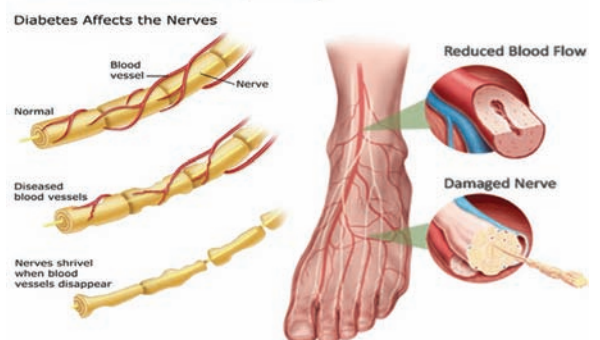
Diabetic neuropathy can be prevented or delayed if blood glucose is kept under control. If neuropathy has already developed, taking care of one's health should be the first priority before it gets too late, as nerve damage can seriously affect the quality of life. Moreover taking care of your feet should become a daily habit as your feet are as precious as your life. Take steps to control your diabetes before you lose control over your life!

If you lack motivation to control your diabetes, then you will surely get motivated to take charge, when you learn more about diabetes neuropathy! It is one of the most dreaded complications of diabetes which can be both disabling as well as life-threatening. Diabetes neuropathy develops as a result of uncontrolled blood sugars which damage nerves of the body. People who have difficulty maintaining normal blood sugar levels or those who do not pay heed to diabetes control may not be aware of how their food intake and irregularity of meals might be playing havoc with their blood glucose levels. Eating anything and anytime of the day, eating too much or too little may either send blood sugars skyrocketing or may make them plummet. Faulty diet coupled with stress and sedentary lifestyle can cause irreparable damage to vital organs of our body, which then manifests as diabetes complications. Wide fluctuations in blood glucose levels may precipitate nerve damage over a period of time. Development of neuropathy depends on many factors such as age, duration of diabetes, smoking and alcohol consumption. Nearly 60-70% patients develop some form of neuropathy during lifetime. Long-standing diabetes (people who have diabetes for more than 20-25 years) and old age increases the risk of developing neuropathy.

Neuropathy is divided into two categories mainly: Peripheral neuropathy,

which affects the limbs or extremities, and Autonomic neuropathy in which damage occurs to the nerves of internal organs. Nerve damage may not present any symptoms initially and remains undiagnosed till it significantly affects the daily activities. As it progresses, it can reduce one's ability to work and lead a normal life. Hence, it is best to nip the problem in the bud by getting treated early for diabetes neuropathy. Timely diagnosis and regular treatment helps prevent any disability by reducing the progression of neuropathy. The only way to prevent

Diabetic Neuropathy



neuropathy is by controlling the levels of blood glucose, blood fats (cholesterol and triglycerides) and blood pressure. Blood vessels which nourish the nerves with oxygen and nutrients may get damaged due to high blood pressure, increased lipid levels which are responsible for a reduced supply of blood carrying oxygen and nutrients and also due to persistently high blood glucose levels.

High blood glucose levels over a period of time can prove toxic to nerve cells. Damage

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affects the normal functioning of our nervous system, which can impair sensory as well as motor nerves. Sensory nerves assist in sensation and touch and in feeling pain, vibration and temperature changes. Motor nerves control the involuntary muscles which are present in every organ system of our body.

Symptoms of diabetic neuropathies

Some people may not have any symptoms at all while some may present with symptoms which vary depending upon the type of neuropathy and which nerves are affected. Initially, symptoms may be minor and may go unnoticed as nerve damage occurs over a period of several years. Only in some cases, sudden and severe pain may occur, as in focal neuropathy.

Peripheral neuropathy

This is the most common form of diabetic neuropathy. It affects mainly toes, feet and legs followed by arms, hands and fingers. Symptoms of peripheral neuropathy include:

1. Loss of protective sensation in arms, hands, legs and feet.
2. There may be sharp pain which may not be relieved by painkillers.
3. There is a feeling of numbness.
4. There may be tingling, burning or prickling sensation.
5. There is insensitivity to hot and cold temperatures, and no feeling of vibration.
6. Extreme sensitivity to touch. Even the slightest touch of a bed sheet may be unbearable.
7. Loss of co-ordination and balance due to reduced sensation may lead to gait deficits. The person with neuropathy may get disbalanced while walking which may lead to fall fractures.

These symptoms may get worse at night. Peripheral neuropathy may result in muscular weakness due to degeneration of muscles (*muscle atrophy*) in the lower limbs and feet. Along with this, loss of reflexes, especially near the ankles, may affect the way a person walks. Foot deformities like *hammertoes*, *bunions* and *claw toes* may affect the shape of feet and require special footwear. Any blisters and sores or even a minor injury

to the feet of a neuropathic patient may not be felt and ulcers may develop which, if left untreated, may cause foot infections and lead to gangrene. If the infection spreads to the bone, then amputation (surgical removal of limb) may become essential in order to save life! Each year many foot amputations are performed due to negligence and unawareness among diabetes patients. *Minor injuries or foot ulcers, if treated on time by qualified foot care specialists, can help save a diabetes patient's limb.*

Autonomic neuropathy

Autonomic neuropathy affects nerves that control the heart, regulate blood pressure and those that control blood glucose levels.



It also affects nerves of other organ systems like the digestive tract, genitourinary tract, eyes, sweat glands and respiratory tract. Symptoms depend upon which organ system is involved.

Hypoglycaemia unawareness

When the blood sugar drops below 70 mg/dl, hypoglycaemia may occur, resulting in various symptoms like sweating, trembling, dizziness or palpitations. These warning symptoms are not felt by patients who are suffering from autonomic neuropathy which may pose a danger for patient as he/she may not feel any symptoms, and if hypoglycaemia is left untreated, the patient may collapse and lose consciousness. Hypoglycaemia unawareness may occur due to other reasons as well.

Cardiovascular system

The heart and blood vessels that carry blood to and from the heart constitute our cardiovascular system. Damage to nerves of the cardiovascular system can cause difficulty in adjusting blood pressure and heart rate. The heart rate may remain high and may not rise or drop according to physical activity or normal bodily functions. Sometimes, this can also lead to *silent ischemia* or a silent heart attack wherein the person may not have any symptoms like chest pain or pressure felt in the chest during an attack. Blood pressure control may also get disturbed leading to *postural hypotension*. In this condition, the blood pressure may suddenly drop on standing up or sitting leading to fainting spells, light-headedness and dizziness. In order to avoid this condition, people with *postural hypotension*, should stand up or sit slowly.

Digestive system

Damage to the nerves of gastrointestinal tract can cause various symptoms depending upon which part of the digestive system is affected. If nerves in the oesophagus (food pipe) are damaged, it causes difficulty in swallowing food. Nerve damage in the stomach causes delayed gastric emptying leading to a condition called gastroparesis. In this condition, food is digested slowly and passes at a much slower rate into the intestines. Persistent nausea, vomiting, bloating sensation with loss of appetite may occur due to severe gastroparesis. This can affect the blood glucose levels adversely leading to wide fluctuations due to abnormal digestion process. Nerve damage in the intestines may lead to constipation alternating with frequent, uncontrolled diarrhoeal episodes, especially at night. Nerve damage in the digestive tract may lead to weight loss problems.

In mild cases of gastroparesis, patients are advised to eat small, frequent meals. As the digestion rate is slowed down, foods like fatty foods and too much fibre, which slow down digestion, must be avoided. In severe gastroparesis, the patient may be prescribed medications to speed up the digestion process.

Genito-urinary system

Nerve damage may also result in erectile dysfunction in men and vaginal dryness in

women. When nerves to the urinary bladder get damaged, the bladder may not empty completely, leading to bacterial growth in the urinary tract and kidneys. This may stimulate development of UTI (urinary tract infection). To prevent the recurrence of UTI, the patient must drink plenty of fluids. When nerves in the urinary bladder are damaged, the person may not sense when the bladder is full or lose control over the muscles that release urine and this may lead to urinary incontinence. In such a case, the individual suffering from this problem must empty the bladder frequently (every 3 hours) even when there is no urge to urinate.

Sweat glands

Nerve damage in the sweat glands may affect thermoregulation. Sweating helps to control the body temperature, but when neuropathy affects the sweat glands, then either the body does not sweat when required to bring down body temperature or the person may sweat profusely at night.

Eyes

Autonomic neuropathy may cause difficulty in visibility as the pupils fail to adjust to changes in light. A person with this condition may have difficulty in seeing when light is turned on in a dark room or he may have difficulty driving at night.

How to prevent or treat neuropathy?

The first step in the treatment of neuropathy revolves around bringing down the blood glucose levels close to normal range. This can be achieved by regular blood glucose monitoring, planning meals carefully with the help of a Registered Dietitian, maintaining regular physical activity along with insulin/medications for diabetes control. Your doctor may prescribe some medications for relieving painful neuropathy. Over-the-counter drugs are not so effective and should not be taken without your doctor's consent. In order to relieve pain, antidepressants may be prescribed by your doctor. Do not take any medicine without consulting a qualified physician as they can have serious side-effects. Tell the doctor about any pre-existing complication as some medications are not suitable for

heart patients or older people. Check for any side-effects of medications prescribed and discuss them with your doctor.

Good blood glucose control is the best way to control nerve damage. Initially, the symptoms may get worse when blood glucose is brought under control, but over a period of time maintaining blood glucose levels near normal range may help alleviate the symptoms. Discuss the target blood glucose range with your doctor as it varies depending upon the individual's condition. Very strict blood glucose control is not advisable for older people, people with a history of frequent episodes of hypoglycaemia, or those with multiple complications.



Foot care in neuropathy

Every year many diabetes patients lose limb and life due to foot complications. Neuropathy increases the risk for getting foot infections and ulcers as there is loss of feeling or any sensation in the feet which may leave any cut, bruise or injury undetected. Any non-healing ulcer must be brought to the notice of a podiatrist (foot-care specialist) to prevent foot amputation. The risk doubles when the patient with diabetes neuropathy also has PVD (peripheral vascular disease). PVD reduces blood supply to the feet which reduces the chances of healing any injury caused to the foot. When blood supply to the feet is diminished due to poor circulation, a wound does not heal properly as blood nourishes the cells in the feet with oxygen and nutrients required for repair and regeneration of worn out cells. *Every diabetes patient must therefore make it a ritual to inspect feet daily for any cuts, bruises, corn or callus formation.*

Tips for foot care

1. Smoking increases the risk of diabetic foot complications as it reduces blood supply to the feet leading to

circulatory problems. Hence, one must seek professional help in order to quit cigarette/tobacco smoke.

2. Check your feet daily for any cuts, bruises, corn or callus formation. Do not use any corn cap as it may cause infection. Corn or calluses should never be cut using blades, razors or callus removers. Consult a foot doctor for more advice.
3. Wash your feet daily with warm (not hot) water and a mild soap. Gently rub a pumice stone to smoothen corn or callus. Never rub it vigorously as it can tear out skin.
4. Do not soak your feet in warm/hot water. Do not add any antiseptic liquid to the water used for cleaning feet. Soaking feet for long can cause dryness of skin.
5. Inspect the bottom of your feet using a mirror. If you have poor vision, then ask your family members or friends to assist you in checking for any sores, cuts or injury to feet which may otherwise go unnoticed.
6. Check your feet, toenails and skin for any undesirable changes. Autonomic neuropathy is responsible for dryness of feet. Any redness or warmth felt on touching must be reported to the doctor. Dry, shiny and fragile skin with loss of hair indicates poor blood supply to the feet.
7. Fissures and cracks may develop in feet and legs due to dryness. These may further increase your risk for getting infections as dry skin is susceptible to bacterial invasion. Hence, after bathing or washing feet, dry skin gently with a soft towel and moisturise it using a good moisturising lotion. Keeping your legs and feet well-moisturised helps in reducing any chances of getting foot infection. Keeping feet moisturised doesn't mean keeping them wet or moist after washing as this will only favour fungal growth. Also do not use lotion between toes as it favours bacterial growth.
8. Fungal infections are common in people who have diabetes or poor blood circulation, especially in the

Continued on page 29

Solitary Waves and Solitons



Dr. Kaushik Roy, Prof. Prasanta Chatterjee

Solitary waves are waves which never crest nor dissipate; they propagate without changing shape. But soliton is a special type of solitary wave with the remarkable features that, when two or more of them collide, they do not scatter but emerge with the same shape and speed.

We all know that a wave is a disturbance that travels through a medium by transferring energy from one particle or point to another without any permanent displacement of the medium. Some waves do not need medium to be able to move.

Suppose an astronaut wants to send information from the Moon to Earth. There are two ways; either he could put the information in a rocket or he could send it in the form of a signal, like a radio or light wave. Information can be sent via matter or waves. If it is sent via waves, the information is transmitted from the sender to a receiver. If you talk to a friend, maybe on the phone, you are transmitting information via waves. Nothing is physically transported from you to your friend. But if you send him a letter, information is transported as a physical entity.

While speaking of universal wave functions, the German physicist Erwin Schrödinger had said, “The unity and continuity of the *Vedanta* are reflected in the unity and continuity of wave mechanics. This is entirely consistent with the *Vedanta* concept of All in One.”

Mathematically, the energy of a wave is proportional to the square of its amplitude. That is $E=CA^2$, where E , C , A are energy, a constant (depends on the medium), and amplitude of the wave, respectively.

Types of waves

If a wave propagates through a continuous medium it is called a mechanical wave. Here, the medium could be air, water, a spring, the Earth, or even people. Sound, water waves, a pulse travelling on a spring, and earthquakes are all mechanical waves. Also a “people wave” in a football stadium like the “Mexican wave” is mechanical wave. The particles in the medium can move in two different ways: either perpendicular or parallel to direction of the motion of the wave itself. A wave in which the medium oscillates at right angles to the direction of the wave is called a transverse wave and if the medium moves back and forth in the same direction, the wave is called a longitudinal wave. Sound is a longitudinal wave. A surface wave is often a combination of the two. But in all cases, the particles that constitute a wave do not actually move with the wave, but typically move in circular or elliptical paths within the surface of the medium.

If wave propagates without a medium, as with electromagnetic waves, the propagation occurs due to the oscillation of electromagnetic field. Light is an electromagnetic wave and hence light can travel without a medium.

Matter waves and gravity waves are important in present-day science. The term ‘matter wave’ is used to describe particles like

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electrons that display wave-like properties. These waves are important for studies in quantum mechanics. Gravity wave is a ripple in “spacetime” itself. They were predicted by Einstein’s general theory of relativity in 1916 and detected for the first time hundred years later in 2016.

Seismic waves are waves that travel either through the Earth’s interior or near the Earth’s surface. They arise as a result of an earthquake, underground explosion, or a volcano that gives out low-frequency acoustic energy. There may be many different kinds of seismic waves, but they are basically of four types: (i) Primary wave, (P-type) (ii) Secondary wave (S-type), (iii) Love wave, and (iv) Rayleigh wave.

History of solitary waves and solitons

The history of the discovery of soliton is both fascinating and remarkable. John Scott-Russell, a Scottish scientist and engineer in 1834 first observed the solitary water wave on the Edinburgh Glasgow Canal and reported his observations in 1844 to the British Association in his “Report on Waves”. He wrote “*I was observing the motion of a boat which was rapidly drawn along a narrow channel by a pair of horses, when the boat suddenly stopped not so the mass of water in the channel which it had put in motion; it accumulated round the prow of the vessel in a state of violent agitation, then suddenly leaving it behind, rolled forward with great velocity, assuming the form of a large solitary elevation, a rounded, smooth and well-defined heap of water, which continued its course along the channel apparently without change of form or diminution of speed. I followed it on horseback and overtook it still rolling on at a rate of some eight or nine miles an hour, preserving its original figure some thirty feet long and a foot to a foot and a half in height. Its height gradually diminished and after a chase of one or two miles I lost it in the windings of the channel. Such in the month of August 1834 was my first chance interview with that singular and beautiful phenomenon which I have called the Wave of Translation.*” The word ‘solitary wave’ was coined by Scott-Russell himself. The solitary wave is so called because it often occurs as a single entity and is localised.

After minute observations along with extensive wave-tank experiments, the

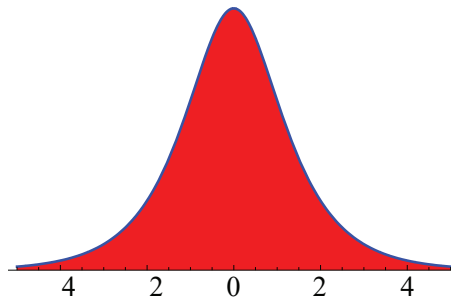


Figure 1. Solitary Wave

following significant properties of solitary waves were found:

These localised bell-shaped waves travel with enduring form and velocity. The speed of these waves are given by

$$c^2 = g(h+a)$$

where g , a , and h represent the acceleration due to gravity, amplitude of the wave, and the undisturbed depth of the water, respectively.

(b) Solitary waves can cross each other without any alteration.

John Scott-Russell’s observation made a sensation in the scientific community. It created a debate with the existing theories of waves. Russell’s observation also contradicted previous knowledge of waves, according to which a periodic wave of finite amplitude and permanent form is possible only in deep water while Russell had observed the permanent profile in shallow water. But ultimately the permanence of the form of solitary waves was accepted by the scientific community with the help of nonlinearity and dispersion. It was discovered that a perfect balance between nonlinearity and dispersion could create such waves.

In 1895, Dutch professor Diederik Johannes Korteweg and his doctoral student Gustav De Vries derived an equation from the basic equation of hydrodynamics. This equation describes shallow water waves,

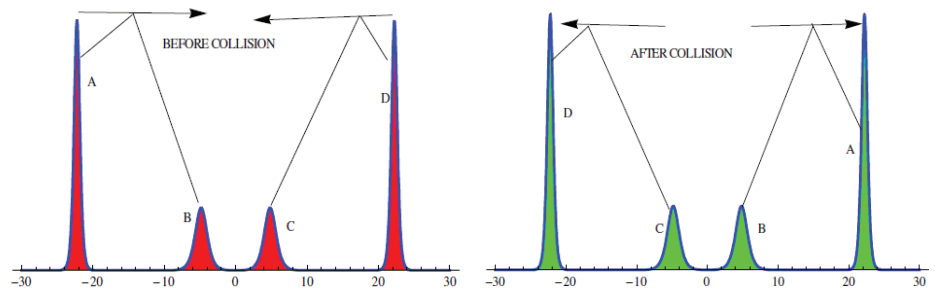


Figure 2. Two solitons seen on the left hand side are moving to the right side and the two solitons on the right hand side moving towards the left side.

where the existence of solitary waves was mathematically established. This equation is known as *Korteweg–de Vries equation*, or KdV equation. It is one of the famous equations of soliton theory. Its study leads to the understanding of the fundamental ideas that lie behind the soliton concept. In the year 1965, Martin Zabusky and Norman Kruskal solved the KdV equation numerically and observed that the localised waves preserve their shape and momentum in collisions. They called these waves “solitons” due to the particle-like behaviour of the pulses.

Solitary waves and solitons

A solitary wave is a localised wave which propagates with well-formed shape along one direction only. On the other hand, a soliton is a localised wave which propagates without changing its properties like shape, velocity, etc., and remains stable against mutual collision and retains its identity. Thus solitons are dynamic structures and they move with constant speed and shape.

Solitons are formed in a medium when the effects of dispersion and nonlinearity are balanced. In the absence of nonlinearity, dispersion can destroy a solitary wave as the various components of the wave propagate at different velocities. Introducing nonlinearity without dispersion rules out the possibility of the solitary waves, because the pulse energy is continuously injected into high-frequency mode. But with both dispersion and nonlinearity present, formation of soliton is possible.

Properties of soliton

Solitons are solitary waves with the remarkable property that they preserve the form asymptotically even when undergoing a collision. The interaction does not

change the soliton amplitudes. After the interaction, each soliton gets an additional phase shift. The total phase shift of a soliton acquired during a certain time interval can be calculated as a sum of the elementary phase shifts in pair-wise collisions with other solitons during this time interval.

An arbitrary initial profile will evolve into two waves which then move apart and progressively approach individual solitary waves as time tends to infinity. The larger soliton moves faster, approaches the smaller one and after the overtaking collision both resume their original shape and speed. These are nonlinear waves and they do not satisfy linear 'superposition principle'.

Different types of soliton structures

Solitons propagate with a regular speed and shape. Mathematically two types of solitons are defined – one topological and another non-topological. When two sides of the state of the medium of the soliton

are different, they are called topological soliton. On the other hand when both sides of the state of the medium of the soliton are the same, they are called non-topological soliton. Physically, topological solitons are a way of storing a localised lump of energy in a nonlinear system. They have applications in a range of areas in particle physics, condensed matter physics, nuclear physics and cosmology. There are technological applications in magnetic systems, where topological solitons are being used in the design of the next generation of data storage devices. A topological soliton can exist at rest whereas non-topological soliton never exist at rest. Non-topological solitons (KdV type) have many applications in plasma physics.

Application of solitons in fibre optics, optical computers, etc., creates a sensation even in today's scientific community. Traditional signal processing relies on linear systems and linear techniques. Since nonlinear systems produce more efficient algorithms, the properties of solitons are

useful in optical fibre communications systems.

Comparison between solitary waves and solitons

Solitary waves are waves which never crest nor dissipate, they propagate without changing shape. But soliton is a special type of solitary wave with the remarkable features that, when two or more of them collide, they do not scatter but emerge with the same shape and speed.

In the framework of the KdV equation and other similar equations, one soliton solution refers to "solitary wave" (probably such a wave was observed by Russell) but when more than one of them appears in a solution, they are called "multi-solitons". Some nonlinear systems have solitary waves but not solitons; whereas others like the KdV equation have solitary waves which are solitons. The soliton becomes a solitary wave when it is infinitely separated from any other soliton. ■

The Dangers of Diabetic Neuropathy *(continued from page 32)*

9. Dry feet well after a shower or cleaning. Make sure to dry skin between the toes using a soft towel and by dusting talcum powder to prevent any bacterial/fungal infection.
10. Avoid walking barefoot even in your home. While visiting temples avoid going barefoot. Wear thick socks atleast to avoid any injury to the feet. Diabetes patients should never walk barefoot, be it home, temples or swimming pools.
11. People with peripheral neuropathy should NOT use hot water bottle/heating pads in winters as the loss of protective sensation in the feet may make it difficult to feel any temperature changes and can cause burn.
12. Trim toenails straight across and smooth them with a nail filer or emery

- board. Never cut into the corners of toenails. If you have difficulty cutting nails due to vision problem or if the nails are thick or yellow, take help of a family member or caregiver.
13. Always wear thick cotton socks which absorb sweat when wearing shoes. Always check the inside of shoes for any stones or sharp objects before putting them on to avoid any injury.
14. For foot with deformities, choose shoes that fit well according to the shape of the feet.
15. Wear shoes that fit well and protect your feet.
16. Check your feet often in winters to prevent frostbite. Wear woollen socks at all times if feet remain cold.
17. Wear shoes which are comfortable and which allow your feet to "breathe". Never wear shoes with pointed ends or high heels, which put too much pressure on your toes.
18. For "high risk" feet or with foot deformities, special therapeutic footwear or diabetic footwear can be purchased from health stores or shops after consulting your foot care specialist.

19. Custom-moulded shoes, extra-depth shoes, shoe inserts or insoles maybe required to accommodate feet with serious complications.
 20. Consult a podiatrist if any cut, bruise, blister or sore does not heal in a day.
 21. When blood supply to the feet is reduced, make sure circulation is not obstructed. For this keep your feet up resting on a stool while sitting.
 22. Do not cross your legs for a long time. Do not wear tight socks or elastic bands around your legs which may obstruct blood flow.
 23. Wiggle your toes and move your ankles up and down to improve blood flow to the feet. Do this atleast 2-3 times in a day.
- Diabetic neuropathy can be prevented or delayed if blood glucose is kept under control. If neuropathy has already developed, taking care of one's health should be the first priority before it gets too late, as nerve damage can seriously affect the quality of life. Moreover taking care of your feet should become a daily habit as your feet are as precious as your life. *Take steps to control your diabetes before you lose control over your life!* ■

The riddle of the cosmic speed limit



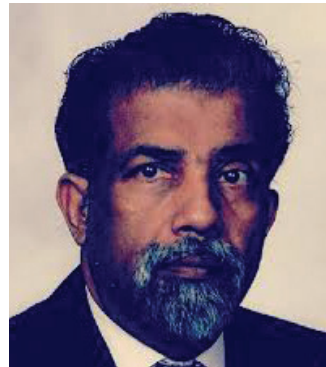
Dr. P. K. Mukherjee

Nothing can move faster than light. If it happens, fundamental laws of physics will need modifications. The physicists, however, opine that if some day we are able to discover particles travelling faster than light, they could be called tachyonic particles. Sending signal at a speed faster than light would still remain a remote possibility, and that is the bottom line, say the physicists. Who knows the riddle of the cosmic speed limit may have much to unfold. We will have to wait and see.

The velocity of light in a vacuum (known as “c” to physicists and mathematicians and which is equal to 3,00,000 kilometres per second) is a universal constant that makes its appearance in many areas of physics. It relates space with time and matter with energy (through Einstein’s famous mass-energy relation $E= mc^2$). It also figures in all kinds of astrophysical calculations, from estimate about the size and age of the universe to the radius of the black hole.

As is known to anybody acquainted with a bit of physics, in order to explain the results of the Michelson-Morley experiment (which was performed to detect the presence of the hypothetical medium dubbed aether), Einstein had postulated that the velocity of light in a vacuum is constant. This postulate is the cornerstone of the Einstein’s Special Theory of Relativity, which was propounded by him in 1905 and is now considered a pillar of modern physics. According to Einstein, it is impossible for a material particle to be accelerated up to or beyond the speed of light as the mass

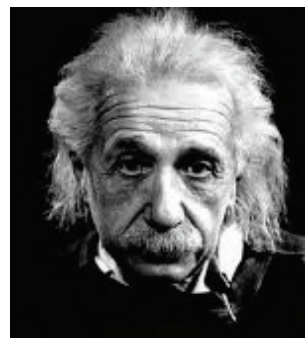
becomes infinity and infinite energy would be required to move it. Thus, velocity of light, said Einstein, is the maximum speed limit. This means that it is the maximum speed at which matter and energy can travel in space.



E.C.G. Sudarshan

Breaking the speed barrier: implications

If the speed of light in a vacuum is the ultimate speed limit set out by Einstein, what would be the possible implications if this speed limit were broken? In the first place, it would wreck the long-standing notion of cause and effect. For instance, if a person knocks on the table, the sound of the knock would follow the act of knocking, which means the knock would be followed by the sound of the knocking. Here knocking is a cause and the sound of knocking the effect. However, if the cause-effect principle is violated the sound would come first and the knock would come later, which is not possible. Therefore, breaking the speed limit would lead to bizarre scenarios where effect would precede the cause. As an implication of this,



Albert Einstein

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the backward flow of time would become possible. Explaining this, Einstein said if you send a message faster than the speed of light in a vacuum “you could send a telegram to the past.” You could set out from your home on a faster-than-light journey one fine morning and return back home the previous evening. Thus, breaking the speed barrier could open up the possibility of time travel. But, time travel, according to Einstein, is not possible; only mental time travel into the past can take place. Stephen Hawking, the noted British physicist (who died in March 2018) was also in full agreement with Einstein.

There are other implications, too. All present-day standards of distance, time and weight would have to be jettisoned. All estimates about the size and age of the universe and quantities such as the radius of black holes would need revision.

Case of neutrinos breaking the speed barrier

Neutrinos are electrically neutral subatomic particles which are all around us. They are passing through our bodies without interacting. You will be surprised to know that about 65 million neutrinos pass through your thumb every second. Neutrinos are known to rarely interact with matter; therefore, they cannot be detected directly. However, in rarest of rare occasions when neutrinos interact with matter, they produce tiny flashes of light which can be detected using sensitive photon detectors.

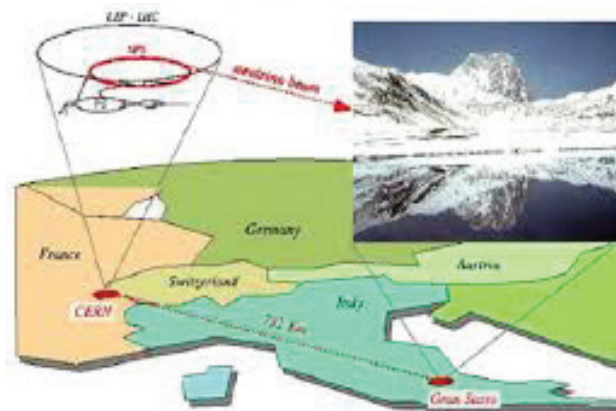
In September 2011, the physics world was startled with the news of detection of neutrinos travelling faster than the speed of light. A beam of neutrinos was created by a super proton synchrotron accelerator at CERN, the European Centre for Nuclear Research, near Geneva, Switzerland. The neutrino beam was sent from Geneva to Gran Sasso National Laboratory in Italy, the largest underground laboratory in the world, travelling a distance of 730 km. About 1,500 neutrino beams were sent from CERN to Gran Sasso over a period of three years.

A particle detector called OPERA (Oscillation Project with Emulsion-tRacking Apparatus) kept in Gran Sasso Lab was used to detect the neutrinos. The



The ICARUS detector

results were announced on 23 September 2011 by the OPERA team. The researchers installed atomic clocks at both ends to determine exactly when the neutrinos were created and detected; and used GPS-based measurements to precisely measure the length of the baseline. The velocity of the neutrinos was obtained by dividing the baseline by the time of flight. The researchers claimed to have measured the trip between CERN and Gran Sasso to within 20 cm and the time of flight within 20 nanoseconds (ns). They found that the neutrinos from CERN reached the detector at Gran Sasso



CERN to Gran Sasso Neutrino Beam

60 ns faster than it would have reached travelling with the speed of light. Thus, neutrinos were found to possess a speed that was greater than the speed of light by about

6 km per second. Although it was not a big difference but still a difference that called for further scrutiny by the researchers. So, they checked and rechecked their results. There could be some sources of experimental errors as well. However, when in spite of their best efforts the results remained unchanged, they decided to share their results with the scientific world.

In November 2011, the researchers at Italian institute of Nuclear Physics repeated the experiment performed by the OPERA group. Their result offered to provide further evidence that neutrinos were indeed travelling faster than the speed of light.

Doubts cast on OPERA results

In the meantime, the Nobel Prize winning physicist Sheldon Glashow and his colleague Andrew Cohen published their critique of the results obtained by the OPERA team in the journal *Physical Review Letters*. The physicists wrote that when a particle travels faster than light, it keeps on losing its energy by emitting other particles. The process continues till the speed of the particle becomes equal to the speed of light. Therefore, said Glashow and Cohen, to ascertain whether the particle was moving faster than light one needed to measure their energy spectrum.

A research team led by Carlo Rubia (who was jointly awarded Nobel Prize in physics in 1984 with van der Meer Simon for their discovery of W and Z bosons, the subatomic particles mediating the weak interaction) decided to carry out the experiment to record the energy spectrum of neutrinos. Rubia’s team fired neutrinos from CERN to a detector, called ICARUS, 730 km away in an underground cavern situated at Gran Sasso. The team could not find any change in the energy of the neutrinos travelling from CERN to Gran Sasso. Going by the reasoning of Glashow and Cohen, the team concluded that the neutrinos do not travel faster than the speed of light. Commenting on the results of his group, Rubia said, “The results are very convincing and they tell us essentially that there was something not quite right with the results of OPERA.”

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Master Ramchandra: A Nearly Forgotten Mathematician



Dr. Utpal Mukhopadhyay

Ramchandra bridged the mathematical legacy of India with modern mathematical ideas.

Ramchandra was an open-minded person and realising the importance of Western education he tried to enlighten Indian people by informing them about latest developments of European science. On the other hand he had great respect for ancient Indian mathematics.

For this reason, he solved problems of maxima and minima through indigenous method. This nearly forgotten mathematician can be regarded as a torchbearer of modern Indian mathematics.

Ramchandra Lal (1821-1880), popularly known as Master Ramchandra, was a contemporary of Radhanath Sikdar (1813-1870), well-known for being the first to calculate the height of Mount Everest, the tallest peak of the world. Ramchandra carried the mathematical legacy of India till the arrival of many talented mathematicians in our country in the last quarter of the nineteenth century, including the pioneer Sir Asutosh Mukhopadhyay (1864-1924) and the legendary S. Ramanujan (1887-1920). Ramchandra not only showed his excellence in mathematical creativity through his book, *Treatise on Problems of Maxima and Minima, Solved by Algebra*, but he was also a free thinker. He vehemently opposed all kinds of superstitions and religious dogma. But, unfortunately, today he is a nearly forgotten name in the history of mathematics.

Ramchandra, son of Sundarlal Mathur, was born in 1821 at Panipat in Haryana. In fact, Sundarlal, an employee of revenue department of East India Company, was a resident of Delhi. But at the time of birth of Ramchandra, Sundarlal was posted as a *Tehsilder* at Panipat. Primary education of Ramchandra started in a *Maktab* (elementary school) at the age of six. When his family returned again

to Delhi, Ramchandra took admission in Delhi English School (later upgraded to Delhi College). But unfortunately Sunderlal expired in 1831.

One year after his father's demise, at the tender age of 11, Ramchandra was married to the daughter of a wealthy family. Although monetary support gained through this marriage helped to improve the financial condition of Ramchandra's family to certain extent, his wife turned out to be deaf and dumb. Discontinuing his formal education, Ramchandra had to work as a clerk for about three years to support his family. Then in 1841 he entered Delhi College securing a scholarship of Rs. 30 per month through a competition. All along a very attentive and talented student, Ramchandra completed his study in the year 1844. Then he joined the *Madrasa* section



Ramchandra Lal

of Delhi College as a teacher of science and mathematics. It may be mentioned here that at that time Delhi College had two separate wings – one was the *Madrasa* section in which the curriculum was based on Oriental ideas while the other section was based on European curriculum. However, medium of instruction was Urdu in both wings. Ramchandra taught algebra, trigonometry and other branches of mathematics in Urdu.

As a part of his teaching duty, Ramchandra was involved with the activities

of Delhi Vernacular Translation Society. Felix Boutros, the Principal of Delhi College established this society in 1940 for the purpose of translating English text books into different Indian languages. At that time an important duty of the Education Department was to translate science books (written in English language) into Sanskrit, Arabic, Persian and other languages. For instance, Radhanath Sikdar, on advice from Professor Tytler, started translating English scientific books into Sanskrit. However, due to his joining the Survey Department his work didn't materialise.

Ramchandra translated several books on mathematics into Urdu language including *Analytical Geometry* by Simmons, and Hutton's *Trigonometry*. He had two-fold motivation for translating the books. One was linguistic and the other educational. Since at that time most Indians did not know English, he translated books on various topics into Urdu to deliver European science to people of India and simultaneously made an effort to explain different topics on science and mathematics to his students. Regarding the purpose of translating text books in Urdu, Ramchandra had written: "*These translations were introduced into the Oriental departments as class-books; so that in two or three years many students in the Arabic and Persian departments were, to certain extent, acquainted with English science and the doctrines of the ancient philosophy, taught through the medium of Arabic, were cast into the shade before the more reasonable and experimental theories of modern science.*"

Apart from his teaching duties, Ramchandra edited the fortnightly magazine *Favaidu'n-Nazrin* and science and literary monthly *Muhibb-e Hind* published by Delhi College. Ramchandra utilised these two publications to inform the elite of North India about the recent discoveries in Europe in the field of science and technology. In these magazines he described the earthquake at Constantinople and the construction of rail route from Calcutta towards Howrah district. Moreover, various articles (such as *Tarbiyat-e Ahl-e Hind ka Bayan*) of Ramchandra published in them reflected his pedagogical views. Ramchandra wrote articles on various topics, viz., astronomy, scientific contribution of Isaac Newton, the relationship of human body and mind, etc. In spite of his important contributions in academic affairs, translation of text books,

science popularisation, propagating free rationalistic views, etc., Ramchandra has gone into oblivion. One of the possible reasons might have been the destruction of Delhi College during the mutiny of 1857. Although it was revived again, it could never attain its glorious past.

Ramchandra was a believer in rationality and had an unbiased view on science. He strongly opposed irrational religious rites. In order to spread the virtue of knowledge among the Indians, Ramchandra created a society with his students of higher classes of Delhi College and brought out a bi-monthly magazine *Fawaedanna-zireen* (meaning 'useful for readers'). In that magazine, various news of Western science was published regularly and the dogmas prevailing in both the Hindu and the Muslim communities were severely criticised. As a result, conservative Hindus and Muslims both were aggrieved. Except some British Government officials of higher rank, such as Sir John Lawrence, Mr. A. A. Roberts, Dr. A. Ross, Mr. J. F. Gubbins, etc., the magazine did not receive support of Indians. Consequently, its publication ceased after five years. Incidentally, one of the favourite students of Ramchandra in Delhi College was Munsijakaulah.

On 11 May 1852, Ramchandra was baptised by Rev. Jennings at St. James Church near his college. As a result, during the Great Mutiny of 1857, Christian Ramchandra had to save his life by hiding in a jungle and then taking shelter in a British army camp. He had to stay there till the recapture of Delhi by the British forces on 20 September 1857. In January 1858, Ramchandra was appointed as Headmaster in Thomason College (at present Roorkee I.I.T.) at Roorkee. In September 1858 he joined as Headmaster in a school in Delhi.

Ramchandra's Magnum Opus

However, Ramchandra's most memorable work was his book *A Treatise on Problems of Maxima and Minima, Solved by Algebra*, written in English. Ramchandra published this book from Calcutta in 1850 at his own cost. P.S. Rozario & Co. of Calcutta printed the book. In the preface of the book the author stated that for last four to five years he had a desire to solve mathematical problems related to maxima and minima using principles of algebra without applying

the method of differential calculus. In the book, solutions of 130 mathematical problems have been discussed. The problems were taken from various books viz., *Fluxions* by Simpson, *Differential Calculus* by Hall, *Gregory's Examples*, *Differential Calculus* by Connel, *Differential Calculus* by Walton, *Differential Calculus* by Ritchie, *Differential Calculus* by Young, *Geometry* by Hirsch, *Encyclopaedia Britannica*, etc.

The book contains four chapters excluding the preface and appendix at the beginning and the end of the book, respectively. In the first chapter, those problems of maxima and minima are discussed which can be solved using simple and quadratic equations. The second chapter deals with problems involving cubic equations while problems involving fourth, fifth, sixth and even seventh degree equations for obtaining solutions have been placed in chapter three. Problems which require more than one variable are highlighted in chapter four. According to Ramchandra's version, he devised the techniques of solving all types of algebraic equations related to the problems of the book. In the preface, Ramchandra provides the definitions, formulae and propositions necessary for understanding the problems and their solutions. Besides, the equations of parabola, ellipse, hyperbola, sphere, ellipsoid, and area of ellipse are also there in the preface. All the necessary diagrams are kept together in the appendix of the book.

While on a vacation in 1851, Ramchandra came to Calcutta and noticed adverse reviews of his book in local newspapers. Ramchandra commented in this regard – "*When I composed my work on 'Problems of Maxima and Minima', I built many castles in the air; but Calcutta reviewers, &c. destroyed these empty phantasms of my brain*". Moreover, he had to bear criticism of his friends for writing the book in English. However, on being advised by some of his well-wishers, Ramchandra sent his reply to the newspapers and fortunately the *Englishman* published it.

On the other hand, "Court of Directors" of East India Company honoured Ramchandra for his book and the British Government handed him over five honorary robes and Rs. 2,000 through Robert McClagan. Not only that, Dr. Aloys Sprenger (1813-1893), Ex-Principal of Delhi College, introduced Ramchandra to J.E.

Drinkwater Bethune (1801-1851). Bethune collected 36 copies of the book from Ramchandra and in return donated him Rs. 200. Perhaps the honour and respect Ramchandra received from the British prompted him to convert to Christianity.

Introduction with Bethune came as a boon to Ramchandra because Bethune despatched a number of copies of the book to his friend as well as a renowned mathematician

Augustas De Morgan and advised him to present these copies as gift to different persons in England. It may be mentioned here that De Morgan was born on 27 June 1806 at Madurai in India. His father was in defence service of East India Company.

It may be mentioned here that in the book Ramchandra had solved problems of maxima and minima by algebra without using differential calculus. For this reason, some mathematicians did not accept the book properly. However, on reading the book, De Morgan, Professor of Mathematics at London University, praised it wholeheartedly and mentioned about the strength of ancient Indian mathematicians in the field of algebra. One may say that this work of Ramchandra resurrected the works



Augustus De Morgan

of Bhaskaracharya II (1114-1185) and other Indian mathematicians of the antiquity. De Morgan expressed his reaction thus: "On examining this work I saw in it, not merely merit worthy of encouragement, but merit of a peculiar kind, the encouragement of which, as it appeared to me, was likely to promote native effort towards the restoration of the native mind in India".

Being overwhelmed by the work of Ramchandra, De Morgan drew the attention of the "Court of Directors" of East India Company through letters regarding the book. "Court of Directors" also agreed about circulation of the book. As a result, they consented in favour of the publication of Ramchandra's book under the supervision of De Morgan for circulation in Europe and India. The book was published from London by W.H. Allen & Co.

in 1859 in accordance with the instructions of the "Court of Directors". In the title page of the book was written: "Reprinted by order of the honourable Court of Directors of the East-India Company for circulation in Europe and in India, in acknowledgement of the merit of the author, and in testimony of the sense entertained of the importance of

independent speculation as an instrument of national progress in India". A long introduction of the book was written by De Morgan. That writing clearly reflects great respect of De Morgan to the mathematical legacy of ancient India. Along with that he highly praised Ramchandra for reviving that mathematical tradition of India.

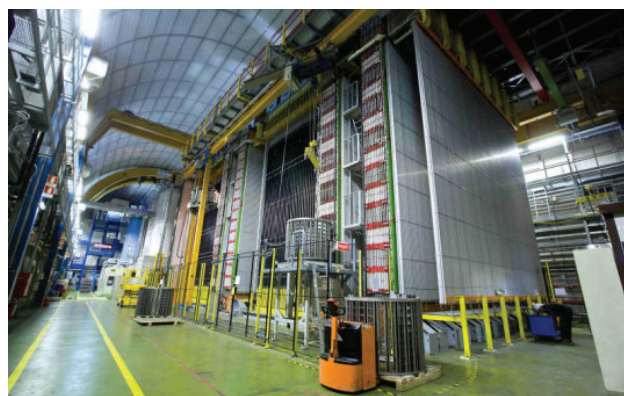
Those who are acquainted with higher mathematics, are well aware of the fact that it is not easy to solve cubic and bi-quadratic equations whereas for solving problems of maxima and minima, Ramchandra faced the challenge of solving even seven degree equations. This clearly reveals the proficiency of Ramchandra as a mathematician. So, it is sad and surprising that the name of Ramchandra has gone into oblivion. For this reason, Charles Muses in his article 'De Morgan's Ramanujan, an Incident in Recovering Our Endangered Cultural Memory of Mathematics', published in *Mathematical Intelligencer* in 1998, remarked that in spite of De Morgan's earnest effort Ramchandra's name has not entered in most of the books on algebra. However, Ramchandra's life and work had been discussed in July, 1929 issue of *Indian Scientists* magazine. Recently, in 2007, The Association of Mathematics Teachers of

Continued on page 22

The riddle of the cosmic speed limit *(continued from page 27)*

OPERA result revisited

In February 2012, James Gillies, a spokesman of the OPERA team, said that a flaw in the Global Positioning System (GPS) was behind the startling result of neutrinos travelling faster than light. According to Gillies, a loose fibre optic cable linking a GPS satellite receiver to a computer led to the erroneous result. So, Einstein's theory was vindicated once again.



OPERA detector

Tachyonic particles

It may be remarked that it was not the first time that Einstein's theory

was challenged. In the past too, many a time doubts were raised on the validity of Einstein's theory. But, so far none could be backed with experimental evidence. In this

context, it may be noted that more than five-and-a-half decades ago, the Indian physicist E. C. G. Sudarshan (who died recently) had theoretically proposed in 1962 the existence of particles travelling faster than light, called tachyons. However, so far the existence of tachyons has not been confirmed experimentally.

The physicists opine that if some day we are able to discover particles travelling faster than light, they could be called tachyonic particles. However, sending signal at a speed faster than light would still remain a remote possibility; and, that is the bottom line, say the physicists. Who knows the riddle of the cosmic speed limit may have much to unfold. We will have to wait and see. ■

CRISPR – Cas9: The latest tool for genetic enhancement of crop plants



C.R. Bhatia

Genetic enhancement depends on the availability of new genetic variability and rapid selection of the desired types. Earlier, the sources of new variability were the collections made from different places. With the advancement of knowledge and development of new cellular and molecular techniques, scientists have applied them to create new variability, and for improving the selection efficacy.

Contemporary knowledge, tools and techniques for genetic enhancement of crop plants have been used by humans in the past ten thousand years since they domesticated crop plants and started cultivating them. The resulting plants cultivated today look very different from their wild ancestors. Prior to domestication of crop plants, humans survived as hunters and food gatherers. They collected grains from stands of wild ancestors of currently grown crops that grew naturally in the neighbourhood. The earlier selections were based at the plant (organism) level. The best plants with large grain that were easy to harvest and separate from chaff were selected.

With advances in knowledge of pollination biology and genetics, the cellular methods became the tool of choice. Pollen grains from the desired parents were used to hybridise with the other plants of the same species having the preferred traits to obtain plants combining the desired characters of the two parents. High-yielding plants were hybridised with the ones having disease/insect resistance to obtain plants combining high yield and insect/disease resistance. Desired selections were based on single plants. Hybridisation and selection of the desired types have been the main tools in plant breeding, and will remain so, for utilising the newly created variability. Hybrid vigour was utilised for enhancing cross-pollinated crops such as Maize.

Genetic enhancement essentially depends on the availability of new genetic

variability and rapid selection of the desired types. Earlier, the sources of new variability were the collections made from different places. With the advancement of knowledge and development of new cellular and molecular techniques, scientists have applied them to create new variability, and for improving the selection efficacy. Toward this, several cellular and molecular techniques have been developed, starting from hybridisation mentioned earlier to doubling of the number of chromosomes (polyploidy), induced chromosomal translocations, induced mutations, somaclonal variation generated in tissue culture, identifying markers linked to the desired agronomic traits, marker-assisted selection, genomic selection, and use of haploids and doubled haploids. Gene editing is the latest, new tool.

Cellular methods for doubling the number of chromosomes, using colchicine and similar alkaloids to produce auto polyploids (cells or nuclei containing more than two homologous sets of chromosomes) were extensively developed and evaluated in the 1940s and 1950s. During the same period, doubling the number of chromosomes in hybrids between two species, with the objective of obtaining fertile amphiploids (organisms having at least one diploid set of chromosomes from each parent species) were used. *Triticale*, amphidiploid hybrids with 56 chromosomes between wheat (*Triticumaestivum*, 42 chromosomes)

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and rye (*Secale cereale*, with 14 chromosomes) were widely evaluated. However, they were found suitable only as animal feed. Subsequently, hybrids between tetraploid *durum* wheat with 28 chromosomes and rye were developed. They are grown in some countries to feed animals and are being explored as a bio-fuel crop. Some induced polyploid cultivars of ornamental plants are grown for their large flower size.

In 1927, H. J. Muller discovered that mutation rates can be enhanced in fruit flies by exposing them to ionising radiations. A year later, L.J. Stadler demonstrated that the mutation rate in plants can be enhanced by exposing seeds to X-rays and radium. This led to widespread use of different types of radiations, stimulated by the Atoms for Peace program, after the Second World War. Subsequently, chemical mutagens to enhance mutation rates were discovered and have been widely used due to their easy availability compared to radiation sources. Swedish scientists developed several new cultivars of barley using the mutation technique. This led to extensive use of induced mutations for genetic enhancement of crop plants, commonly known as mutation breeding. Joint FAO-IAEA Division maintains database of the cultivars developed using the induced mutations. More than 35,000 new crop cultivars have been developed all over the world and over 300 in India.

In India, mutation technique for improving crop plants was pioneered by M.S. Swaminathan at the Indian Agricultural Research Institute, New Delhi, soon to be followed by the then Biology Division of newly created Atomic Energy Establishment at Trombay (now Bhabha Atomic Research Centre or BARC). More than thirty new cultivars have been developed at BARC. Department of Atomic Energy has supported such investigations at the agricultural

universities and research institutes. Genetic variation that comes up when plant cells are cultured *in vitro* is known as somaclonal variation. Such variation has been used at the Indian Agricultural Research Institute to develop a new cultivar (*Pusa Jaikisan*) of mustard.

In the 1960s, with the discovery that restriction enzymes can precisely cut DNA at specific sites, and the cut pieces can be cloned and rejoined with heterologous DNA isolated from any other organism, recombinant DNA techniques came to the forefront. This led to development of genetic engineering and several new crop cultivars or hybrids are currently grown in many countries, erroneously referred as GMOs (In fact, all crops are genetically modified). The most recent one, from the end user view point, is the non-browning Arctic apples in USA that are now under commercial production and on the market shelf. In India, Bt cotton was approved for large-scale cultivation in 2002, and currently occupies almost 95 per cent of the cotton area in the country. Subsequently, Bt brinjal (eggplant), after extensive field trials all over the country, was not approved by the Government. Recently, commercial cultivation of hybrid mustard had a similar fate. Besides, nutritionally enhanced golden rice was not even evaluated.

After recombinant DNA techniques, genome or gene editing technologies using nucleases followed for modifying DNA sequences. DNA-binding proteins like Zinc Finger Nucleases (ZFNs) and transcription activator-like effect or nucleases (TALEN) and clustered regulatory interspersed short palindromic repeats (CRISPR) have been developed. Out of these, CRISPR is the easiest and cheaper to use. It was identified as a breakthrough of the year by *Science* magazine in 2015. CRISPR Cas 9 is the

easiest and most widely used technique for gene editing. It was discovered at the University of California, Berkeley, USA by Jennifer Doudna and colleagues and further developed at Berkeley and by Feng Zhang and associates at Broad Institute of Massachusetts Institute of Technology and Harvard University. CRISPR-Cas9 is the latest technique for gene editing in any living organism. Further improvements in CRISPR technology are being made currently in many laboratories. CRISPR-Cas9 has been applied to delete, activate, and suppress targeted genes in human, animal, and plants cells. Over 22 species of plants including *Arabidopsis*, sorghum, rice, wheat, barley, maize, tomato, orange, populus, cucumber, cotton, and cassava (*Manihot esculenta* Crantz) have been altered by CRISPR/Cas9 technology.

Borlaug Dialog, coinciding with the award of World Food Prize, for 2017 was organised by the International Maize and Wheat Improvement Centre (CIMMYT), at Des Moines, Iowa, USA to address how small farmers can benefit from CRISPR-Cas9. Besides experts from CIMMYT, participants included from private seed companies such as Dupont Pioneer, and from Donald Danforth Plant Science Center. Feng Zhang from Harvard-MIT was the main promoter for CRISPR. Concluding statement that emerged stated: "There's a lot of exciting opportunity to apply this technology both in human health and in agriculture." Nigel Taylor, director of the Institute for International Crop Improvement at Donald Danforth Plant Science Center in St. Louis, Missouri, USA said that the technology will also benefit the orphan crops. Kevin Pixley, who heads the Genetic Resources Program at CIMMYT, reminded that though gene editing is very fast, benefits to reach the farmers would take time. ■

Master Ramchandra: A Nearly Forgotten Mathematician *(continued from page 24)*

Chennai has republished Ramchandra's book. Relying on the 1859 edition, Dr. M.S. Rangachari has written an introduction of the book.

Epilogue

Ramchandra was an open-minded person and realising the importance of

Western education he tried to enlighten Indian people by informing them about latest developments of European science. On the other hand he had great respect for ancient Indian mathematics. For this reason, he solved problems of maxima and minima through indigenous method without using calculus. Use of algebra may have made the solutions of the problems

lengthy and laborious, yet as alternative method, Ramchandra's effort demands due credit. In fact, he bridged the mathematical legacy of India with modern mathematical ideas. That's why this nearly forgotten mathematician can be regarded as a torch bearer of modern Indian mathematics. ■

Recent Developments in Science and Technology

Biman Basu

The possibility that life could exist on Mars has captured the imagination of researchers, scientists, and writers for over a century. Ever since the Italian astronomer Giovanni Schiaparelli looked at Mars with a telescope and spotted what he believed were “Martian Canals” in 1877, the legend of life on Mars was born. According to a new study, Mars may have enough oxygen gas locked away beneath its surface to support aerobic organisms, suggesting that life could still exist under the Martian terrain. This finding, however, runs contrary to the current, accepted view of Mars and its potential for hosting habitable environments. The existence of liquid water on Mars is still not confirmed.

The dire warnings of the latest IPCC report

Climate change due to global warming caused by increasing levels of greenhouse gases in the atmosphere is now an established fact. There has been growing concern over the changing pattern of global climate over the past few decades, which is manifested by weather extremes such as heat waves and cold waves and extreme events of rain and drought. In tropical countries like India, summer now brings spells of scorching heat with temperatures exceeding 46° or 47°C that lasts for days or weeks, often taking a heavy toll of life.

The latest report of the Intergovernmental Panel on Climate Change, or IPCC, released on 8 October 2018 in Incheon, South Korea, spells out the grim consequences of the climate change, which is certainly a cause of concern, especially for developing countries like India. The report warns that no one is immune to the impact of climate change, which is fuelling war, hastening natural disasters, causing the extinction of species, and threatens to drag societies back into poverty. It predicts more extreme weather in the coming years if global temperatures continue to rise at the current rate.

The projected target for reduction in greenhouse gas emission has undergone many changes during the past decade. Since the 2009 United Nations climate talks in Copenhagen, Denmark, the consensus

among scientists and policymakers has been that 2°C should be the limit; any further temperature increase would be catastrophic. But, for the citizens of small island countries like the Maldives and other vulnerable places in the tropics and the Arctic, even a warming of 2°C would be a death sentence. Their communities would be inundated, and eventually destroyed.

In 2015, the final Paris Agreement on Climate Change declared that, while warming shall not surpass 2°C above pre-industrial levels (the target now commonly cited), countries should pursue “efforts to limit the temperature increase to 1.5°C”. The Alliance of Small Island States also asked the International Panel on Climate Change (IPCC) – the scientific body that informs the climate policies of the United Nations’ member states – to prepare a special report on the specific impacts of global warming of 1.5°C, along with ways the world could feasibly keep the temperature from rising



One of the most visible effects of climate change has been the rapid melting of Arctic ice. Some experts say the Arctic could be totally ice-free by the summer of 2035. (Credit: www.independent.co.uk)

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further. The present IPCC report is a sequel to that. The report draws on research conducted since nations unveiled the 2015 Paris climate agreement, which seeks to curb greenhouse-gas emissions and limit global temperature increase to between 1.5 and 2°C.

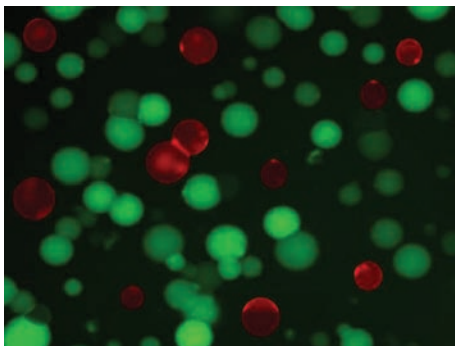
According to the latest report, ten million more people would be exposed to permanent inundation, and several hundred million more to “climate-related risks and susceptible to poverty”. Malaria and dengue fever will be more widespread, and crops like maize, rice, and wheat will have smaller and smaller yields -particularly in sub-Saharan Africa, Southeast Asia, and Central and South America. Security and economic growth will be that much more imperilled. It warns that the planet could pass the 1.5°C threshold as early as 2030 if greenhouse gas emissions continue at the current rate.

The report says, “To keep warming at 1.5°C, governments and private businesses must make unprecedented changes – on a sweeping global scale – in energy systems, land management, building efficiency, industrial operations, shipping and aviation, and city-wide design. Within the next decade, human-caused carbon-dioxide emissions need to fall 45 per cent below 2010 levels. By 2050, net carbon-dioxide emissions must equal zero.”

The good news is, as daunting as the task may sound, the IPCC report says scientists already have the technical wherewithal to limit temperature rise to the target 1.5°C. “Limiting warming to 1.5°C is not impossible but will require unprecedented transitions in all aspects of society,” it adds. Among other things, the list of solutions suggested includes energy efficiency, electrifying transport and pulling carbon dioxide out of the atmosphere by reforesting regions and using carbon capture technology. To keep temperatures at the target, renewable energy will need to provide at least 70% of global electricity in 2050, while coal use will essentially need to disappear.

Artificial bacteria-killing cells created

Cells are the basic building blocks of all living organisms. Living cells consist of cytoplasm enclosed within a membrane, which contains many biomolecules such as



The artificial cells mimic some of the properties of living cells although they do not grow and divide, but they could detect and destroy bacteria in a lab dish. (Credit: Cheemeng Tan, UC Davis)

proteins and nucleic acids – DNA and RNA. When placed in a nutrient medium, living cells divide and multiply to grow. Recently, biomedical engineers at University of California Davis have created artificial cells that mimic some of the properties of living cells. Although the artificial cells do not grow and divide, they have a unique ability to detect and destroy bacteria in a lab dish.

The researchers, led by Cheemeng Tan of UC Davis, created the artificial cell from the ‘bottom up’, like building structures with ‘Lego blocks’ piece by piece, by putting together purified components of all cells, namely DNA, proteins and metabolites. The cell wall was built using liposomes, which are small, spherical structures made from molecules of fat that enclose a drop of water within a fatty membrane. Liposomes are now a commonly used tool to deliver drugs, nutrients or DNA therapies into cells.

According to Tan, the artificial cells created by them mimic the essential features of live cells but are short-lived and cannot divide to reproduce themselves. He said the cells were designed to respond to a unique chemical signature on *E. coli* bacteria. When tested in laboratory experiments, these artificial cells were able to detect, attack and destroy bacterial cells (*Applied Materials & Interfaces*, 12 September 2018; DOI: 10.1021/acami.8b10029).

A unique feature of the artificial cells created by Tan and his team is that they can tolerate a wide range of environments. Artificial cells developed earlier could function only in nutrient-rich environments, Tan said. But, by optimising the

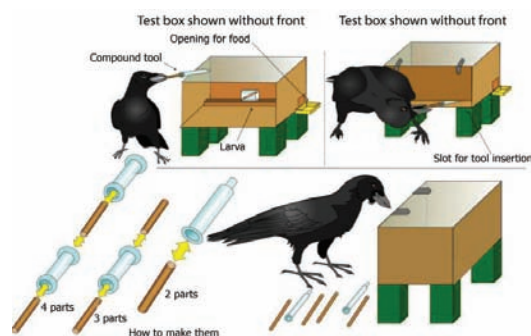
engineered cells membranes, cell plasma and genetic circuits, the researchers could reduce the dependence of these artificial cells on water and stable environmental conditions. “As these cells are much more robust and self-sufficient than previous ‘models’, they can be employed even in less-than-ideal or changing conditions”, says Tan. This enables them to have a much broader scope of potential applications compared to any other artificial cells currently at our disposal. These improvements, he says, significantly broaden the overall potential application of artificial cells.

According to the researchers, “Antibacterial artificial cells might one day be injected into patients to tackle infections resistant to conventional treatments. They might also be used for targeted delivery of drugs at the specific location and time, or as biosensors”.

Crows can assemble tools like humans

Crows have been known to be intelligent and clever creatures, but little was known about their tool-making ability. Recently, an international team of scientists from the Max Planck Institute for Ornithology in Seewiesen, Germany, and the University of Oxford, UK, have revealed that New Caledonian crows (*Corvus moneduloides*) are able to create tools by combining two or more otherwise non-functional elements, an ability so far observed only in humans and great apes. The New Caledonian crow is an all-black, medium-sized member of the family Corvidae, native to New Caledonia – a French colony in the South Pacific.

The researchers designed a very clever experiment to test the birds’ tool-making skills. First, they designed a “puzzle box” that



Scientists designed the puzzle box specifically to test the crows’ tool-making skills (Credit: Alice Auersperg)

the crows had never encountered before, containing a small food container behind a door that left a narrow gap along the bottom. Initially, the eight crows participating in the study were provided with long sticks capable of reaching and prodding the food (larva) kept in the box out of an opening in the box's side. All the birds soon learned how to get the larva out of the box using the long sticks. The researchers then moved on to a more difficult scenario, replacing the long sticks with an assortment of short cylindrical sticks, none of which was long enough to grab the larva on its own. Some of the sticks were hollow and some solid, with slightly different diameters so that they could be joined together to make longer sticks.

To their utter surprise, the researchers found that four of the eight birds could find the key to solving the puzzle within just five minutes. Without any help or demonstration, four of the crows partially inserted one piece into another and used the resulting longer compound stick to reach the food and push it out of an opening at the other end of the box. At the end of the five-step investigation, the researchers made the task more difficult by supplying even shorter combinable parts, and found that one bird named 'Mango', was able to make compound tools out of three and even four parts, offering "the first evidence of compound-tool construction with more than two elements in any non-human animal."

According to Alex Kacelnik, a behavioural ecologist at Oxford and one of the study's lead researchers, the crows, which received no demonstration or aid throughout the experiment, were able to predict the properties of a tool not yet in existence. "So, they could predict what something that does not yet exist would do if they made it; then they can make it and can use it", Kacelnik explains (*Scientific Reports*, 24 October 2018 | DOI: 10.1038/s41598-018-33458-z).

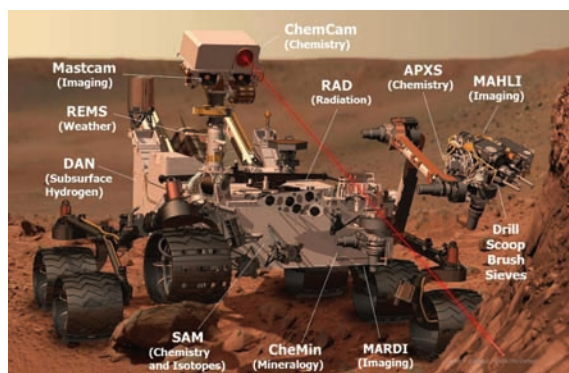
According to the researchers, three of the four successful crows "managed to replicate their crafty compound tool-making in three subsequent trials". Mango, the New Caledonian crow who built three- and four-part tools, reportedly exhibited "fluctuating motivation," refusing to participate in two follow-up trials but succeeding in later test runs. The researchers assert that Mango's

actions appear to represent a deliberate and conscious tool-making process rather than an accidental discovery.

According to the authors, the mental processes by which the birds achieve their goals have not yet been fully established, but the ability to invent a tool is interesting in itself. Few animals are capable of making and using tools, and in humans, the capacity only emerges late. "While children start using tools reliably when they are about 18 months old, they only invent novel tools suited to solve a given problem reliably when they are at least five years old".

Oxygen-rich, life-supporting liquid water may be present under Martian surface

The possibility that life could exist on Mars has captured the imagination of researchers, scientists and writers for over a century. Ever since the Italian astronomers



The new research on oxygen-rich water on Mars was made possible by the discovery by NASA's Curiosity rover of manganese oxides in Martian rocks.

Giovanni Schiaparelli looked at Mars with a telescope and spotted what he believed were "Martian Canals" in 1877, the legend of life on Mars was born. Schiaparelli's observation was later corroborated by the American astronomer Percival Lowell. Since the dawn of the Space Age in mid-20th century, dozens of space missions have been sent to the Red Planet to look for evidence of life, but without success.

Over the years, evidence has been found of the existence of water on Mars in the distant past from space observation and recently, the possible existence liquid water under the planet's south polar ice cap has been suggested. However, till recently it was presumed that the water on Mars is devoid of oxygen, which is essential for the existence of

any life form. But according to a new study, Mars may have enough oxygen gas locked away beneath its surface to support aerobic organisms, suggesting that life could still exist under the Martian terrain. The study was led by Vlada Stamenkovi, an Earth and planetary scientist and a theoretical physicist from NASA's Jet Propulsion Laboratory. Scientists of the JPL and the Division of Geological and Planetary Sciences of the California Institute of Technology (Caltech) were also involved.

The researchers arrived at the conclusion based on two pieces of evidence. The first was chemical evidence from NASA's *Curiosity* rover's Chemistry and Mineralogy (CheMin) instrument, which confirmed the high-levels of manganese oxides in samples of Martian rock. Second, they consulted evidence obtained by European Space Agency's *Mars Express*' Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) instrument, which indicated the

possible presence of briny water beneath Mars' southern polar region (*Dream 2047*, September 2018). Using this data, the team was able to calculate how much oxygen could exist in subsurface briny deposits, and whether this would be enough to sustain aerobic life. From their calculations, they found that most of the subsurface environments on Mars exceeded the oxygen levels required for aerobic respiration by up to a million times. This is equivalent to oxygen levels in Earth's oceans today and enough to support oxygen-breathing microbes and even more complex organisms such as sponges (*Nature Geoscience*, 22 October 2018 | DOI: 10.1038/s41561-018-0243-0).

This finding, however, runs contrary to the current, accepted view of Mars and its potential for hosting habitable environments. The existence of liquid water on Mars is still not confirmed. Even if it is there, researchers have long dismissed the idea that it might be oxygenated, given that Mars's atmosphere is about 160 times thinner than that of Earth and is mostly carbon dioxide.

From their calculations, the researchers have also identified which regions of Mars are most likely to contain brines with the greatest amounts of dissolved oxygen. This could help NASA and other space agencies plan where to send landers on future missions, and maybe, come up with evidence of life on Mars.