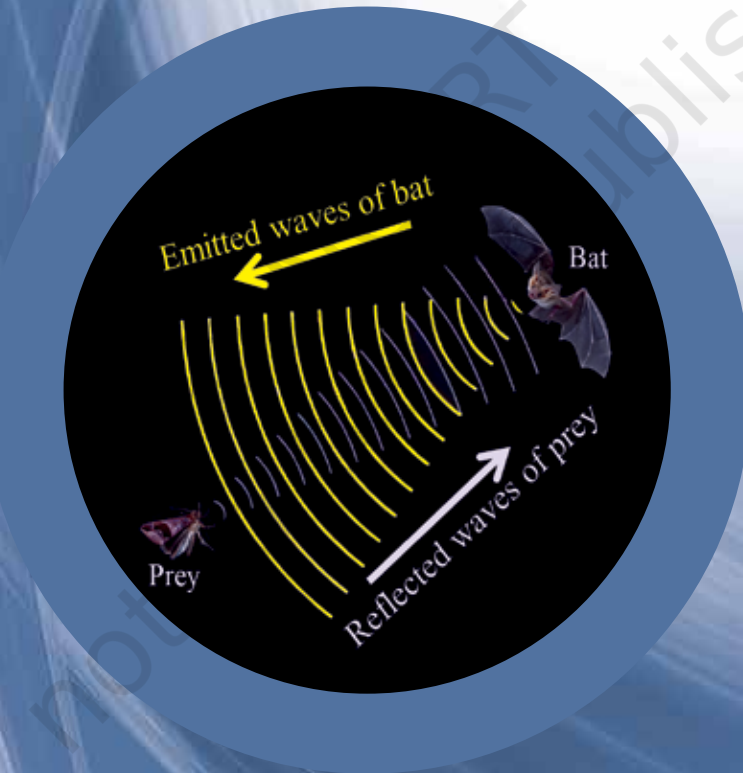


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# School Science

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Emission of sound by animal to environment bounces back as echo after striking off objects

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## EDITORIAL

This issue of *School Science* includes articles and research papers from various disciplines of science. In the article entitled 'Interlinking High School Science with Environment: Some Pedagogical Connections', the author discusses about how the environmental education is an integral part of education at all levels of schooling. In this article, the author points out gaps reflected in the attitude of students with regard to environmental awareness and sensitivity. To fulfil these gaps the author suggests that environmental education may be taught through infusion approach with other subjects rather than a separate discipline at school level. The author further elaborates that the environmental awareness is linked with science concepts and it may be taught through infusion with science concepts.

The article 'Echolocation in Bats: A Fascinating Array' is an interesting article that sequentially elaborates how the echolocation, despite of the weak vision in bats and in many blind species of animals, provides a better means to navigate in dark, to predate upon nocturnal insects and also to escape predators. The article also discusses how the echolocation mechanism was evolved with the loss of vision in bats. The article 'Physics Education Research and Teaching Strategies' explains the importance of the Information and Communication Technology (ICT) in education system.

The issue also includes the article 'Problem-based Learning in Basic Physics – X', which

is a sequel to the ninth article in the series published in the September 2015 issue. In this article, the author considers various problems from different areas of physics including mechanics, optical instruments and electrostatics. All these have a system in which one of the parameters varies continuously and to estimate any effect, differential element has to be taken and integration should be performed separately.

The research paper titled *Facilitating Teaching-learning Practices in Science* is an action research study, where researchers have discussed their experiences in real classroom situation using an example of the concept of 'Reversible and non reversible changes'. Through this example, the authors have pointed out that the learning becomes easy when students are involved in activities. Authors also found out that when the classroom environment is learner centric, where students not only learn through their own experiences but also through peer learning, in which the teaching-learning becomes more interesting.

This issue also has its regular features including *Science News* and *Web Watch* for our readers.

We welcome comments and suggestions to enhance the quality of the journal. We also wish our readers a happy and joyous reading with the hope that the reading material will further add in enhancing the interest in the area of Science and Mathematics.



# Interlinking High School Science with Environment: Some Pedagogical Connections

**Rashmi Sharma**

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Environmental consciousness is a major theme of almost all global and local deliberations and discussions in today's time. Environmental education is also an integral part of education at all levels of schooling. As per the guidelines of the Honourable Supreme Court of India, environmental education is a compulsory subject in schools. Apart from this, some topics pertaining to environmental education are a part and parcel of every discipline at school level. However, there are still some gaps reflected in the attitude of our students in regard to environmental awareness and sensitivity.

**KEY WORDS:** Pedagogy of Infusion, NCF-2005

## Introduction

Environmental consciousness is a major theme of almost all global and local deliberations and discussions in today's time. Environmental education is also an integral part of the syllabus at all levels of schooling. As per the guidelines of the Honourable Supreme Court of India, environmental education is a compulsory subject in schools. Apart from this, some topics pertaining to environmental education are a part and parcel of every discipline at school level. However, there are still some gaps reflected in the attitude of our students in regard to environmental awareness and sensitivity.

NCF-2005 recommends that environmental education should be taught through infusion approach with other school subjects rather than a separate discipline at the school level. For this purpose almost all textbooks reflect the concern for environmental education wherever possible. Science textbooks also incorporate the chapters which generate

the awareness and attitude towards the environment and environmental conservation. The NCERT Science textbooks for Classes IX and X includes chapters which are directly related with environment. There are many other chapters in these books where the environmental concerns are reflected along with the science concepts.

In spite of all these inclusions, there is still a lot which needs to be reflected in the practices of our students for a healthy and happy life. The efforts of bringing environmental concerns in practice seems to be insufficient. The present scenario of the sensitivity and attitude towards environment needs to be changed. School teachers are expected to take the lead for this purpose, as teacher's personality always positively affects the behaviour and personality of the students.

The infusion method suggests that the interlinking of environmental awareness, attitude, skills etc., with the text of any discipline (in this case with science), whatever and whenever possible. For this, teachers

are required to be imparted training in such a way that they can easily relate the topics / concepts of science with environment. The teachers should be able to generate the required awareness related to environment amongst the students. In turn students can reflect environmental sensitivity and can relate the local/global environmental issues with the text being taught. Pedagogically also, it is essential because excitement in learning comes only where the importance of the subject to real life problems is pointed out during teaching. Learning becomes joyful for the students and they feel motivated to learn if teaching is made in a context which shows the relevance of the subject. When a student is able to recognise the connections between environmental issues/problems and the concepts of science, the teaching is expected to be enhanced and applied for the betterment of the environment.

**Pedagogy of Infusion:** Some guidelines are suggested hereby for ready reference of high school science teachers for infusion of environmental concerns with science concepts.

1. While emphasising the close relationship between science and environment, it is necessary to highlight the distinct nature of science. (set the priorities)
2. Teach a topic from science textbook while giving it main focus. (knowledge)
3. Try to recognise the linkage between the topic and the environmental concern and generate the awareness about it amongst the learners.

(identification of environmental components)

4. Once, when the topic is within the cognitive reach of the learners, immediately focus on the environmental concern. (interlinking with environmental problem)
5. Make learners understand that how a particular science concept is related with the environmental issue. (strengthening the links)
6. Make them realise that how an environmental problem would be rectified or how its ill effects can be minimised. Learners should be able to realise about their contribution as an individual with reference to a particular problem. (skill development)

For example, a chapter from Class X Science textbook of NCERT '*Carbon and Its Compounds*' is illustrated here. Three concepts from the chapter have been interlinked here with the environmental concerns/issues.

## Carbon and its Compounds

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### Concepts

1. Carbon is everywhere
2. Compounds of carbon
3. Combustion reactions of carbon

### Carbon is Everywhere

Many of the things we use in our daily life are made up of carbon. All living structures are based on carbon in spite of its small amount available in the nature (0.02% in the earth crust and 0.03% in the atmosphere)



Once the concept is understood by the students, teacher may initiate the discussion that carbon does have ill effects on the environment and human beings. An activity for further understanding of the related environmental issues may also be given to the students.

**Environmental Concerns:** Ill effects of carbon black and carbon-14 on human health—

- Elemental carbon is of very low toxicity.
- Exposure to carbon black (a material produced by the incomplete combustion of heavy petroleum products as tar coal, even a small amount from vegetable oil) may result in damage to lungs and heart and leads to various skin problems. Carbon black has been reported as carcinogenic by International Agency for Research on Cancer.
- Carbon - 14 (a radioactive isotope of carbon) is one of the long lived radionuclide which has been involved in the testing of nuclear weapons. This carbon -14 increases the cancer risks and can endanger fetuses as it can cross the placenta and become organically bound in developing cells.

**Activity:** List out the situations where the exposure of carbon black to the humans is very high. Discuss about the measures through which the exposure to the carbon black may be minimised.

### Compounds of Carbon

Among many of the carbon compounds, carbon dioxide and carbon monoxide have adverse effects on the environment. Along

with the other compounds of carbon, CO and CO<sub>2</sub>, their effects on environment and ways to reduce CO<sub>2</sub> emissions may also be discussed.

### Environmental Concerns

- Carbon dioxide (CO<sub>2</sub>) is not normally considered as a pollutant because it is a normal constituent of air. However, excess of carbon dioxide is considered a pollutant because it leads to adverse effects on the environment. Higher concentration of carbon dioxide in the atmosphere is likely to increase the temperature of the atmosphere. Carbon dioxide permits the short wavelength visible radiations to pass through it but traps the longer wavelength infra-red radiations (heat waves) reflected by the earth's surface. This trapping of heat waves causes excessive heating of earth's atmosphere. This heating effect on the earth produced in this way is called the green house effect. The excessive heating of earth and its atmosphere can have adverse effect on our climate, which will affect all the living beings. The climate will become gradually hot. According to an estimate, the average temperature of the earth has increased by 10<sup>0</sup> C in the last 50 years. It is predicted that if the global temperature rises by 3.6<sup>0</sup> C, the polar ice caps and glaciers would melt. This would increase the water level of oceans by about 100 m and hence lead to the flooding of low-lying coastal areas of the earth.
- Carbon monoxide (CO) can cause harmful health effects by reducing

oxygen delivery to the body's organs (like the heart and brain) and tissues. At extremely high levels, CO can cause death. Exposure to CO can reduce the oxygen-carrying capacity of the blood. For people having heart disease, short-term CO exposure can cause chest pain, as they already have a reduced capacity for pumping oxygenated blood to the heart.

- If a person is exposed to very high levels of carbon monoxide gas in a poorly ventilated room, one can develop headache, shortness of breath, nausea and vomiting, rapid breathing, chest pain, a rapid or irregular heartbeat, fatigue, dizziness, clumsiness or difficulty in walking, vision problems, confusion and impaired judgement, etc.
- Hydrocarbons cause smog and are important in the formation of ozone, a pollutant. Methane ( $\text{CH}_4$ ) which is a principal component of natural gas is a major contributor of global warming.
- Volatile organic compounds include many substances that are suspected to cause cancer. For example, polycyclic aromatic compounds.

### Combustion Reactions of Carbon

Combustion is discussed when the other chemical reactions of carbon are discussed. Students may be made aware about the ill effects of incomplete combustion on environment and human health.

**Environmental Concerns:** Incomplete combustion of carbon gives a sooty flame. One of the negative effects of the combustion on the environment (particularly greenhouse gas (GHG) emissions released to the

atmosphere) contributes to global warming. Climate change resulting from global warming is one of the greatest challenges before the world.

### Environmental Impacts of Combustion

Incomplete combustion of carbon in fuel emits  $\text{CO}_2$  (carbon dioxide) which is the main culprit for global warming whereas incomplete combustion of carbon in fuel emits CO (carbon monoxide) which produces smog. Combustion of sulphur in fuel is  $\text{SO}_2$  (sulphur dioxide) which too leads to smog and causes acid rain. By-products of most combustion processes are NOX (oxides of nitrogen) which are contributors of acid rain and by-products of some combustion processes are  $\text{N}_2\text{O}$  (nitrous oxide), the contributors in global warming process. Combustion of hydrogen in fuel results in  $\text{H}_2\text{O}$  (water vapors) which is a cause of localised fog. Unburned or partially burned carbon and hydrocarbons, also ash and dirt in fuel are the source of particulates (dust, soot, fumes) which lead to smog. Combustion of air containing halogens (Cl, F, Br, I) are the source of halogenated compounds emission. Those are potential carcinogens and leads to global warming also.

**Activity:** List out the activities through which you produce the green house gases. How can this be minimised?

### Conclusion

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Though the task of interlinking is difficult but it is not impossible. The overcrowded curriculum is also a big hurdle. The lack of appropriate information which can be related with science concepts also may be a problem for practicing teachers. But for sure,

if teachers decide to take this responsibility all problems can be easily overcome. It is high time to join the hands together to develop our students as the responsible environmentally

literate citizens. The people who are sensible and sensitive towards the environment will only lead the future. Inclusion will help us to achieve our objectives of this category.

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# Echolocation in Bats: A Fascinating Array

Saptabarna Mukherjee and Animesh K. Mohapatra

The paper discusses the process of use of sound to distinguish the objects present in our environment known as echolocation. It can also be defined as the process of visualizing with the aid of sound, which is remarkably utilized by those organisms lacking efficient vision power. It is very astonishing that the diverse range of vertebrates uses sound to acquire their food and shelter supplemented with the aim to escape from their enemies to ensure the continuity of their race. These include the bats (Chiropterans), dolphins, whales (Odontocetes), birds, shrews, swift lets, porpoises, etc.

**Key Words:** Morphological modifications, Echo call

## Introduction

The process of use of sound to distinguish the objects present in our environment is known as echolocation. It can also be defined as the process of visualising with the aid of sound, which is remarkably utilised by those organisms lacking efficient vision power. It is very astonishing that the diverse range of vertebrates uses sound to acquire their food and shelter supplemented with the aim to escape from their enemies to ensure the continuity of their race. These include the bats (Chiropterans), dolphins, whales (Odontocetes), birds, shrews, swift lets, porpoises, etc.



Fig. 1: Examples of echolocating birds and mammals

## Basic principle behind echolocation

Echolocation, also referred to as biosonar, is a biological process employed which involves

the emission of sound by the concerned animal into the environment which after striking the obstacles gets bounced back as echoes.

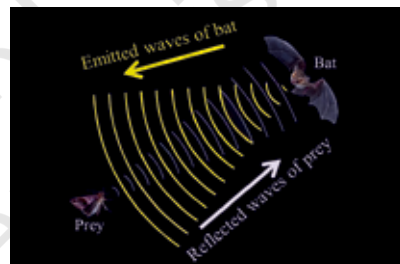


Fig. 2: Basic principle of echolocation

These echoes created by the surrounding objects are received by the animal to acquire an accurate representation of the surroundings. The range and the horizontal angle (azimuth) of the objects can be calculated to a high degree of accuracy by utilising the time delays and sound intensity of the received echoes thereby facilitating efficient communication, orientation, navigation and foraging of the respective animal. There are significant differences in the method of production, reception and interpretation of sound processing from animal to animal. In a nutshell, echolocation is a process conducted by the auditory brain circuit where the ascending brain pathways in the brain stem

allow the brain to calculate the differences between the receptions of two ears even to a level of small fractions of a second. The approximate echo level (EL) returning to the echolocating animal can be estimated using the active SONAR equation, i.e.  $EL = SL + TS - 2 \times TL$ , where TS denotes the target strength, SL denotes the source level of the emitted sound pulse, and TL represents the transmission loss. Appropriate detection of the returning echoes is possible when the EL is higher than the hearing threshold of the echolocating animal or higher than the ambient clutter levels.

## Echolocation in Bats

The unique wing structure and the specialised muscular coordination of bats facilitate appreciable flight manoeuvrability – crucial to their survival due to their extraordinary dependency on the small, quick moving insects. The task of hunting their prey becomes increasingly difficult for them due to their restricted activities at night, dusk and dawn. Their adaptation to this — against the clock — lifestyle is attributed to their tendency to escape the capture of their fierce flying predators who are exceptionally active during the day time. Hence, bats utilise the advantage of the abundant nocturnal insects to which they get access by their remarkably astonishing navigation system, i.e. echolocation.



Fig. 3: Morphological features of a bat

## Morphological Modifications

Bats have specialised larynx (voice box), the contraction of which produces sound. The vibrations of the vocal cords within the larynx which is tensed by cryco-thyroid muscle leads to sound production. The clicking of tongue by certain species invariably accomplishes sound production. In a few species, a basal fleshy horseshoe or leaf like structure is adhered to



Fig. 4: Head of a bat

the base of the nostrils which too aid in the emission of echo calls. Hence, bats can be regarded as mouth emitters or nostril emitters. The ears and the brain cells of the bats which are attuned to the sound emitted and the echo produced; contain dense concentration of the receptor cells within, which in turn make it tremendously sensitive by aiding it to detect even minute frequency variations, 0.0001 kHz. The ears of the bats are especially designed to get adapted to endure high frequency calls without getting any damage. To prevent deafening, the middle ear muscle called stapedius dampens the sound and contracts to separate three bones (ossicles), i.e. malleus, incus and stapes which normally conduct the received sound waves between eardrum and cochlea, thus

reducing the hearing sensitivity. This contraction of muscle occurs about 6 ms before the larynx muscle contract to commence the process of sound production. The middle ear muscle relaxes 2- 8 ms later, at an instant, when the ear is ready to receive the echoes of the surrounding objects. The reception and funneling of the echoes bounced back by the obstacles is perfectly accomplished by the bats due to the presence of large variations in sizes, shapes, folds and wrinkles in their external ears.

## Nature of Echolocation Calls

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Extensive research in the branch of chiropterology confirms that the source filter theory is applicable in bats. According to it, the vibration of tissue masses lead to sound production where certain frequencies are attenuated while the rest are left for propagation. As voice is considered a distinguishing feature of a particular person, similarly the echolocation calls also have certain variations in terms of frequency, intensity, harmonics, pitch, pulse interval, call duration, etc.

The echo calls generally have a frequency range from 9 – 200 kHz, majority of the range encompassing the human audible range which extends up to 20 kHz. In terms of loudness, bats exhibit significant variations ranging from 50 dB to 120 dB. Though some of the squeaks and squawks produced by the bats can be heard by the humans, but these are not echo calls. An echolocation call can be composed of FM or CF. FM or frequency modulation sweep is a broadband signal consisting of a range of frequencies, which allows for better resolution of time delay

between call and returning echo thereby improving the cross-correlation of the two. Additional imposition of harmonic frequencies enhances the precision of localisation. The distribution of energy of the call over a wide range of frequencies decreases the operational range of the FM call. Any echo returning at a particular frequency can be evaluated for a minute fraction of second due to fast downward sweep of the call which doesn't remain at a particular frequency for a considerable interval. CF or constant frequency is a narrow band signal composed of a constant frequency throughout the call duration and consequently has extended operational range as the summation of the echoes returning from within the narrow frequency band over the entire length of the call remains consistent for a considerable time. CF signals have adaptive structures that allow these bats to detect both the velocity and fluttering of the target. Hence FM and CF components are suitably used to prey in cluttered environment and open sky respectively due to their characteristic features without calls overlap.

A single echo call can persist from 0.2 to 100 milliseconds in duration depending on the stage of the prey catching behaviour in which the bat is engaged in. The call duration decreases in the final stages of prey capture which enables the bats to emit calls more rapidly with simultaneous reception of echoes without overlap.

The pulse, i.e. the time interval between successive echo calls is an important aspect to be controlled. Bats increase the repetition rate of their calls, i.e. decrease the pulse interval as they locate a target in order to get updated information about the target's location. Hence, the approach of the bat towards the prey

transforms their echo calls into a terminal buzz or train of clicks. The pulse interval also determines the maximum range of bat's detection capacity as the bats can keep a track of the echoes from one call at a time which then gets expunged after the reception of subsequent echoes from the next calls.

## Structures involved in Echo Call Reception

The process of accurate orientation of the objects in the brain is accomplished by the bats with the aid of specialised neuro-auditory circuits and capable of interpreting the calls generated by its own species. Although the bats exhibit remarkable structural similarities in their auditory organs with those of the mammals, however certain bats have specialised modifications of the inner ear to amplify its responsiveness to a particular ultrasonic frequency. The bats with CF component have a narrow frequency tuning corresponding to that of the predominant frequency and harmonic of CF vocalisation supplemented with an especially large area responding to the frequency of bat's returning echoes. All these specialisations are concentrated within the basilar membrane in cochlea. A large membranous section is present in the brain of bats which is extraordinarily sensitive to the frequency of the returning echoes called the *acoustic fovea* that possess dense aggregation of the primary auditory neurons. The stimulated basilar membrane which is connected to the auditory pathways transmits the signals to the primary auditory neurons and results in elicitation of considerable degree of response.

The process of conduction of the integrated signals received from the auditory processing

pathway to the auditory cortex is performed by the inferior colliculus present in the bat's midbrain. As the collicular neurons maintain high time accuracy hence the interneuron localised in that region are highly sensitive to the time delay which provides an idea about the distance. This extraordinary degree of responsiveness is attributed to their low threshold of activation. Besides, after getting activated, they respond with one or two action potentials. This short duration of response ensures extreme precision in the calculation of time delays.

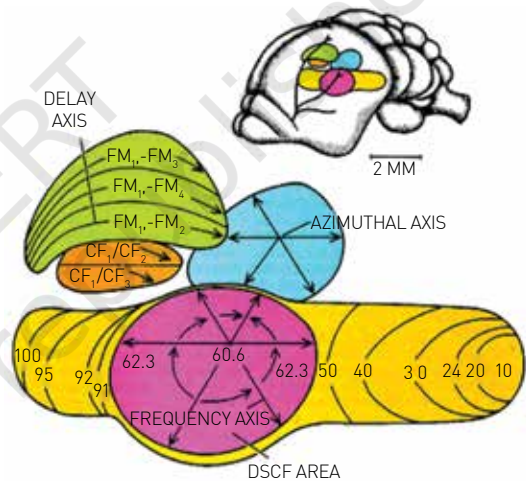


Fig. 5: FM, CF and DSCF areas in the brain of bat

A large space is occupied by the auditory cortex which being composed of a series of maps organised systematically based on acoustic functions, houses the response sites of different signals. A dense aggregation of neurons are localised there which responds to those specific frequency-timing (sound echo delay) and hence known as combination-sensitive neurons. The elicitation of a response requires the exposure of neurons to at least two specific



stimuli. The maps are basically of three types: FM-FM, CF-CF, and DSCF (Doppler shifted constant frequency). FM area is FM sensitive combination neurons arranged in columns which respond to the two FM sweeps: a call and its causes possessing sensitivity for one harmonic in the original call and a different in the returning echo. CF area consists of neurons sensitive to specific CF calls. The DSCF area is a large section of the cortex constituting a map of acoustic fovea which is organised into radially arranged columns containing neurons responding to specific combination of frequency and amplitude. Neurons in this region respond to Doppler shifted CF signals (only echoes) which lies within the same narrow frequency range of response of acoustic fovea and hence play a vital role in frequency discrimination.

### Bat's Perception and Sensing

Bats emit their echolocation calls due to passage of air through the vocal cords which gets vibrated and produces sound. This sound when emitted causes fluctuations in the rushing air and generates a longitudinal sound wave which requires a medium for propagation. The transmission of sound wave in the air is accomplished by the conduction of vibration to the surrounding air particles thereby generating a series of compressions and rarefactions. When the wave propagates, the energy of the disturbed particle is



Fig. 6: Location of prey by signals

transmitted to the adjacent particle thereby disturbing the latter from its equilibrium position. This particle soon displaces its adjacent particle on striking with it. The restorations of the disturbed particles occur with the wave continuously striving forwards. These waves however can get reflected, refracted or attenuated by the medium. The waves when strike a solid, preferably a

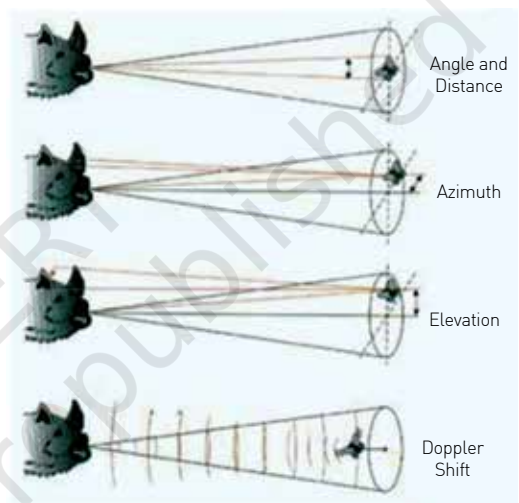


Fig. 7: Discrimination using echolocation

large obstacle, get bounced back as echoes which can again be perceived by the emitter provided the time of reflection and distance of obstacle are coherent. For example, in case of humans, the audible sound persists for one-tenth of a second and speed of the sound in air is 340.29 m/s and hence the object from which echoes can be received should be located at least at a distance greater than 17 m otherwise the echoes will be received too early and cannot be distinguished from the originally emitted sound. The distance varies from organism to organism depending on



the characteristic persistence of successive sounds.

By minutely listening to the echoes, bats can very accurately determine the position, shape, size and direction of motion of the objects. The bat can have the idea whether the insect is to the right or left by comparing the relative moment of the sound reaching the left and right ear. If the sound reaches the right ear prior to the left ear, then the insect is definitely present on the right side. The intricately designed ear folds perform the task of determination of an insect's vertical position. Echoes escalating from beneath will strike the outer ear folds at a different point than those descending from an elevated obstacle, which in turn produce different sounds after propagating into bat's inner ear. The estimation of elevation of obstacle detected is done by the interpretation of the interference patterns caused by the echoes getting reflected from the flap of skin on the external ear, the tragus. The idea about the size of the insect can be obtained by the analysis of the echo intensity. A smaller object will reflect less of the original sound wave thereby producing a less intense echo. The determination of the pitch of the echo can pave the way to sense the direction of movement of the prey. A prey moving away from the bat will result in the production of the echo with a pitch lower than the original sound while those originating from the insect moving towards the bat will have a higher pitch. This difference is distinct due to the phenomenon of Doppler Effect— a popular concept of acoustics. This information received is processed unconsciously in their brain, as we process the visual and aural information, by forming an echolocation image in its head.

## **Defense Mechanism of the Prey**

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Evolutionary studies of certain animals reveal a significant advancement in the cultivation of certain characters aimed to escape from their predators by hoodwinking them. The target prey exhibit strategies to impede its detection, one of which is associated with the increment in noise levels in the environment thereby minimising the echo/clutter ratio. The moths flying close to vegetation escape from the bats by auditory camouflage. In other words they hide themselves acoustically in certain environments where the echoes originating from them are predominated by other echoes. The small muscular mass and size of prey lower the target strength. If the prey gets aware of the fact that it has already been detected by the bat using its inherent aural and vibration sensing qualities, it starts exhibiting secondary defense mechanisms. The insects that are capable of tracing the bat's echolocation calls possess evasive manoeuvres. Some insects, such as, tiger moths emit anti-bat signals which are species-specific in function. These signals serve as a mode of advertisement of moth's toxicity in some species while startling the bats in other species. The anti-bat signals can also jam the bat's biosonar. Hence, the insects which evolve features to respond to ultrasonic frequency remain mostly undetected leaving their contemporaries encounter considerable selection pressures.

The bats can also detect their predators and enemies like cats, snakes, etc., by minutely analyzing the characteristics of the approaching organism by getting reference from the echoes received. It is probably the size of the organism which helps the bat

procure an idea about the presence of a predator or prey approaching it.

## Echolocation Jamming

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Bats hunt by echolocation which refers to the phenomenon where they listen to the bouncing back echoes generated by the high-frequency ultrasonic sound emitted by them. The universal system of competition prevalent in our ecosystem transforms the predator-prey interactions into amazing aerial dogfights. In order to sustain in the increasingly shrewd environment, bats of a few species have evolved strategies to emit certain typical calls quite distinguishable from normal echolocation calls. A close observation has revealed that the emission of those special calls occur on the occasions of approach of another bat towards their prey. It is hence concluded that these bats emit the calls to interfere with other's echolocation calls and the echoes, thereby causing jamming and confining the located prey within its own dish. Recent study on the habits of Mexican free-tailed bats (*Tadarida brasiliensis*) has confirmed the use of this jamming technique which is prominently observable while another bat emits the distinct feeding buzz.

## Evolutionary Deductions

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While a few bat species lack the power of vision but it cannot be negated that echolocation is often used in conjunction to vision. These abilities are not disjoint sets. Paleontology of bats provides evidences indicating the inability of bats to exhibit the echolocation powers approximately 52 million years ago. This makes us believe that the process has evolved in them to enable them

to thrive in their habitats. Two hypotheses have been proposed regarding the evolution of echolocation in bats. The first suggests that the evolution of laryngeal echolocation has occurred twice in Chiroptera, once in Yangochiroptera and once in the Horseshoe bats, i.e. Rhinolophidae. The second proposes single origin of it in Chiroptera, which was subsequently lost in the family Pteropodidae (all megabats) and later evolved as a system of tongue-clicking in the genus *Rousettus*. The possession of echolocation ability has enabled the Microchiropterans to occupy a diverse set of ecological conditions and simultaneously get adapted to the specific environments. These processes which are linked together so as to be carried out in a coordinated way promote the process of decent with modification escalating diversity of Microchiropterans as is visible today.

## Conclusion

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The advancement of science and technology in the present century is creating countless ways to conserve non-renewable natural resources often turning an ignorant attitude towards its negative impacts on the ecosystem. The construction of windmills to guarantee uninterrupted power supply has aggravated enormous problems for the bats, thus disturbing the natural ecosystem and obstructing the food chain and in turn the food web. Though the God gifted creatures are blessed with features to protect themselves from these stresses but the rampant and reckless expansion of the modernisation strategies is posing a genuine threat by disturbing the natural ratios. As human beings, we should take an oath to respect the wildlife resources of earth. We should be focused

enough to undertake determined endeavors to conserve wildlife. Our motto should be to satisfy our needs and not our greed and we should strictly abide by this path until it is too

late where the situation becomes irreparable. We have only one mother earth to live in and hence we should not leave a single stone unturned to transform it into a golden planet.

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# Physics Education Research and Teaching Strategies

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Because of globalisation, Information and Communication Technology (ICT) and knowledge advancement, the whole educational framework has changed. Learners now have access to information from the internet whenever and wherever required. It is evident that learning in 21st century is different in terms of skill and perceptions. The urgent question is what type of new pedagogy is required to better enhance learning? Pedagogy— a term derived from the Greek term 'PAID' (meaning child) and 'AGOGOS' (meaning learning). So pedagogy means the art and science of teaching children. In colleges and other institutions of higher learning, the learners are adults and thus mature and experienced. The adult learning is different from the traditional pedagogical approach. There is an emerging theory of adult learning, Andragogy — the word again derived from the Greek word 'ANDRA' (meaning man). Andragogy is therefore the art and science of helping and teaching adults. A further aspect of teaching related to pedagogy is called Cybergogy — principles and practice of teaching through the internet. The call of our time is to test the effectiveness of teaching strategies to enhance learning. In this direction physics education research is contributing and has brought many changes in physics teaching.

The emerging Physics Education Research (PER) is an interdisciplinary field which uses teaching approach of education for enhancing the learning of physics. It has potential to yield significant benefits for students, teachers and society by training the skilled science professional in this direction.

### Physics Education Research

Physics Education Research (PER) has become recognised as a legitimate research subfield of physics and recently emerged as a new field of research and physicists have begun to treat the teaching and learning of physics as a research problem similar to any applied science. It is based on the learning theory with the aim of introducing well defined learning outcomes or objectives for approving methodology of teaching and learning assessment. Today education is treated as topic worthy of scientific study. PER is a scientific approach to innovation in teaching-learning and involves—

- systematic observation made of students thinking and interpretation of concepts and then data collection; and
- in-depth probing and analysis of student's thinking by theories or models constructed to interpret the observation.

Based upon these theories and models, teaching instructional strategies are developed, implemented and finally assessed.

The main focus of PER is to find the gap between what is taught and what is learnt and looking for research based strategies to bridge that gap [Mc Dermott, 1991]. In other words PER is trying to identify students' misconceptions of core concept of physics, both before and after the completion of a traditional course of physics. There are a number of studies focusing on the pre-conceptions of student in physics [Trowbridge, 1980]. Physicists have found in their research that students even after completing their physics courses were unsuccessful at the answering question on mechanics (a most elementary sub field of physics), known as Force Concept Inventory FCI, (Hestenes, 1992).

Traditional lectures (teacher-focused, with passive students) still reign as the instructional strategy of choice in many science courses (Hurtado et al. 2012). The continued prevalence of this approach is surprising given the dramatic gains achieved by research-based instructional strategies: improved conceptual understanding, increased retention in enrolment, and reduction of well-documented minority gaps (e.g., gender, ethnic). These improvements are becoming increasingly important as we face a shortfall of skilled workers in science related disciplines.

### Instructional Design

The sequence of teaching acts that a teacher plans, organises and carries out to create

learning environment for the students is called instructional design. It is concerned with the structuring of the contents to create a suitable learning environment, selection of teaching strategies and assessments of performance level of students. Instructional designs are classified into objective based, skill based, competency based, model based and learning style based.

- (i) **Objective based:** For formulating objective based instructional design, understanding of clear concept of instructional objectives in terms of learner behaviour is the pre-requisite. Bloom has classified objectives in to three categories: **Cognitive domain** (Thinking process), **Affective domain** (Feeling), **Psychomotor domain** (Practical/doing).
- (ii) **Skill based:** A teacher performs many activities in the classroom which are interrelated; observable, measurable and controlled, thereby help in attaining the instructional objectives.
- (iii) **Competency based:** Here the focus is on acquisition of specific competencies by students. Depending upon the need and capabilities of the learner, he is allowed to attain competencies at his own rate and space.

### Assessments

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- Blooms taxonomy is useful in designing questions, lessons, and tasks for students.
- Higher level thinking allows a student's memory to be used effectively.

Competency	Skills Demonstrated
Knowledge	Recognising and recalling facts; remembering; observation and recall of information; listing; locating; naming
Comprehension	Explaining ideas, understanding information; grasp meaning; making sense of what you have learnt, interpret fact, compare, contrast
Application	Using and applying the knowledge; use methods, concepts and theories in new situations use information; problem solving using required skill or knowledge.
Analysis	Breaking down information into components or parts; identification of components; recognition of hidden meaning. organisation of parts.
Evaluating	Justify, judging the value of information or idea; compare and discriminate between ideas; verify value of evidences.
Creating/synthesis	Predict, draw conclusion; design; formulate; generalise from given facts; relate knowledge from several areas; create. develop, integrate

*To assess specific levels of student mastery of course content needs taxonomy for describing those levels. Bloom's taxonomy is one such framework to improve testing precision by categorising cognitive functioning into distinct levels.*

### Teaching Strategies

For transacting information and knowledge to students in large groups strategies like lecture, seminar, symposium, panel discussion, workshop, etc., are adopted. In small groups group discussion, simulation, brainstorming, case discussions, assignments etc., are useful. In individualised teaching tutorials, mastery learning, programmed instruction, etc., are effective. In PER, following Research Based Instructional or Teaching Strategies are used to enhance learning.

**(a) Peer Instructions or Interactive learning:** In this strategy, traditional lecture is stopped after seven to ten minutes and then a multiple choice question is posed to students. Small group discussion of conceptual questions is interspersed with lectures, thereby increasing engagement and providing formative feedback on student thinking. Students first answer

questions individually with classroom response system, then discuss with their neighbours. Peer Instruction is an easy way to add interactivity to a traditional lecture course without making large changes. It can get our students engaged and interactive, and help students to learn and respond to what our students are thinking, both of which can lead to improved student learning. Peer Instruction is a band-aid on a traditional lecture course structure, which is not ideal for student learning.

- (b) Just-in-Time Teaching (JiTT):** Students answer questions online before class, promoting preparation for class and encouraging them to come to class with a "need to know."
- (c) Open Source Physics:** Open source code libraries, tools, and compiled simulations for physics, computation, and computer modeling. Includes

curriculum resources that engage students and enable them to discover new ways to understand, describe, explain and predict physical phenomena.

In addition to the above strategies, PER has workshop physics, tutorial in introductory physics, interactive lecture demonstrations (ILD), cooperative Group Problem Solving and Activity-based problem tutorials. Henderson and Dancy (2009) have provided a detailed list of research based instructional strategies.

## Conclusions

- The teaching and learning of physics is incomplete and inadequate, unless students have significant conceptual understanding and experience in practical. Physics Teachers can adopt research based teaching strategies and provide the greatest possible learning experiences for their students.
- PER has demonstrated surprising facts about student learning in Physics: Students retain very little from traditional lectures. Ideas propagated by the teacher “Chalk and Talk” are not understood by students in a same manner. Students believe physics as a collection of facts and equations/formulas to be memorised. Indeed, they are unable to understand the concept of physics in a real world.
- In recent decades, as education researchers and cognitive psychologists have published research about how people learn, Interpersonal learning, personalised learning, collaborative learning. Physicists and researchers have now become more interested in using research based pedagogy/Andragogy to improve student learning in introductory physics.
- A new pedagogical/Andragogical (Research Based Instructional/Teaching Strategy) with specific features that would meet the new century expectations is needed. Because the students and learner have access to information through Information and Communication Technology (ICT).

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# Problem-based Learning in Basic Physics – X

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In this article (10th in the PBL series) we consider various examples from different areas of physics where we have systems in which one of the parameter varies continuously and to estimate any effect we need to take differential element and perform integration separately (different from that which is already performed in arriving at standard textbook formula).

**Key Words:** [In this article we present problems for a problem-based learning course based on system with continuously varying parameter.]

1. A block of mass  $m$  sliding on a frictionless horizontal surface experiences an air resistance proportional to its velocity. If it has initial speed  $v_0$  find an expression for its velocity as a function of time.

**Solution**

$$\text{Acceleration } a = \frac{dv}{dt} = -\alpha v$$
$$P = F \cdot v = m \frac{dv}{dt} v$$

Integrating,  $v = v_0 \exp(-\alpha t)$

2. A car starts from rest and start moving while its engine continues to deliver constant power  $P$ . Find the distance travelled by the car in time  $t$ .

**Solution**

In this case, since constant power is delivered, acceleration is not constant.

$$\text{Power delivered } P = F \cdot v = m \frac{dv}{dt} v$$

$\therefore mvdv = Pdt$  ; integrating which, we get

$$\frac{v^2}{2} = \frac{P}{m} t$$

$\therefore \frac{dx}{dt} = \sqrt{\frac{2Pt}{m}}$  integrating which, we get

$$x = \left( \frac{2}{3} \sqrt{\frac{2P}{m}} \right) t^{3/2}$$

3. A cylindrical solid of mass  $10^{-2}$  kg and cross-sectional area  $10^{-4}$  m<sup>2</sup> is moving parallel to its axis (the  $x$ -axis) with a uniform speed of  $10^3$  m/s in the positive direction. At  $t=0$ , its front face passes the plane  $x=0$ . The region to the right of this plane is filled with dust particle of uniform density  $10^{-3}$  kg/m<sup>3</sup>. When a dust particle collides with the face of the cylinder, it sticks to its surface. Assuming that the dimension of the cylinder practically remains unchanged and the dust sticks only to the front face of the  $x$ -coordinate of the front of the cylinder. Find the  $x$ -coordinate of the front of the cylinder at  $t=150$  s.

[JEE 1993]

**Solution**

In this case we have an object (cylinder) whose mass keeps on increasing (variable mass problem) as  $m = m_0 + \rho Ax$  and equation will be  $m \frac{dv}{dt} = -v \frac{dm}{dt}$  If we assume mass of

the cylinder as  $m_0$  and velocity at  $t=0$  as  $v_0$ , then integration yields  $v = \frac{m_0 v_0}{(m_0 + \rho Ax)}$ . The

same would also follow from conservation of total momentum.

Further integration yields,

$$\frac{1}{2} \rho Ax^2 + m_0 x - m_0 v_0 t = 0$$

Upon substitution of parameters gives  $x=10^5$  m at  $t = 150$  s.

4. A uniform chain of length  $L$  is kept on a smooth frictionless horizontal table with small length hanging from the edge. This makes chain slide down from the table. Find the speed when it just loses contact with the table.

**Solution**

Initially, let a small length hang from the table. Thus gravity pulling it down with the

acceleration  $a = g \frac{x}{L}$

$$\therefore \frac{dv}{dt} = g \frac{x}{L} \quad \therefore \frac{dv}{dx} \frac{dx}{dt} = g \frac{x}{L}$$

$$\therefore \frac{x}{L} v dv = \frac{g}{L} x dx$$

Integrating we get  $v^2 = \frac{g}{L} x^2$

When chain just leaves the table, its vertical length  $x \rightarrow L \therefore v = \sqrt{gL}$  is the speed when it just loses contact with the table.

5. Calculate the gravitational potential energy of a uniform spherical distribution of mass  $M$  and radius  $R$ .

**Solution**

When the a mass  $dm$  comes from infinity to the surface of sphere of mass  $m$  and radius  $r$ ,

its potential energy is  $dU = -\frac{gmdm}{r}$

When mass accumulates and grows from zero to  $M$  and radius from zero to  $R$ , potential

energy becomes  $U = \int_0^M \frac{Gmdm}{r}$

Since mass distribution is uniform, density

$$\rho = \frac{M}{\frac{4\pi}{3}R^3} = \frac{m}{\frac{4\pi}{3}r^3}$$

This gives  $dm = \rho 4\pi r^2 dr$  and integral becomes  $U = -\frac{16\pi^2}{3} G \rho^2 \int_0^R r^4 dr$

Which upon integration gives

$$U = -\frac{16\pi^2}{15} G \rho^2 R^5 = -\frac{3GM^2}{5R}$$

[Calculation of electrostatic potential energy of a charged sphere is identical to the one discussed here for gravitational potential energy.]

6. For a particle performing SHM with time period  $T$ , calculate time required to travel from  $a/2$  to  $a$ , where  $a$  is the amplitude.

**Solution**

For a particle performing SHM,

velocity  $v = \omega\sqrt{a^2 - x^2}$  where  $x$  is

displacement and  $\omega = \frac{2\pi}{T}$ ,

Thus,  $\frac{dx}{dt} = \omega\sqrt{a^2 - x^2}$

which gives  $\int \frac{dx}{\omega\sqrt{a^2 - x^2}} = \int dt$

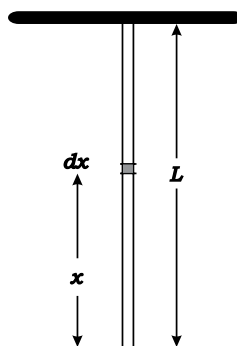
$$\therefore \Delta t = \frac{1}{\omega} \left[ \sin^{-1} \left( \frac{x}{a} \right) \right]_{\frac{a}{2}}^a = \frac{1}{\omega} \left[ \sin^{-1}(1) - \sin^{-1} \left( \frac{1}{2} \right) \right]$$

$$= \frac{1}{\omega} \left[ \frac{\pi}{2} - \frac{\pi}{6} \right] = \frac{\pi}{3\omega}$$

$$\therefore \Delta t = \frac{T}{6}$$

7. A uniform rope of mass 0.4 kg and length 2.45 m hangs from a ceiling.

- Find an expression for increase in length of the rope.
- Find the speed of the transverse wave in the rope at a point 0.5 m distance from the lower end.
- Calculate the time taken by a transverse wave to travel the full length of the rope. Derive the formula used. [Take  $g = 9.8 \text{ m/s}^2$ , and  $Y = 2 \times 10^{11} \text{ N/m}^2$ ]. [(ii) and (iii) Roorkee 1991]

**Solution**


Consider an element of length  $dx$  at a distance  $x$  from the lower end of the rope.

The stress experienced by this element is given by  $\rho xg$  where  $\rho$  is the density of the rope.

If length of this element increases by  $d\Delta x$ , then strain =  $\frac{d \Delta x}{dx} = \frac{\text{stress}}{Y} = \frac{\rho g x}{Y}$ . Here  $Y$  is

the Young's modulus of the material of the rope.

$\therefore$  increase in length of this element

$$d \Delta x = \frac{\rho g x}{Y} dx$$

$\therefore$  increase in length of the rope

$$\Delta x = \int_0^L \frac{\rho g x}{Y} dx = \frac{\rho g L^2}{2Y} = \frac{MgL}{2AY}$$

where  $M$  is the mass of the rope and  $A$  is its area of cross-section.

(ii) velocity of the wave at a distance  $x$  from the lower end  $v = \sqrt{\frac{T}{m}} = \sqrt{\frac{\rho g x A}{\rho A}} = \sqrt{gx}$

here  $T$  is the tension at a distance  $x$  from the lower end and  $m$  is linear density of the rope.

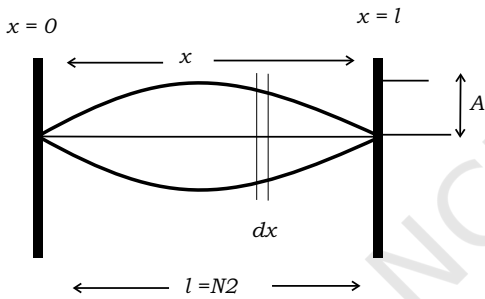
(iii) time taken by wave to travel the rope

$$\Delta t = \int_0^l \frac{dx}{v} = \int_0^l \frac{dx}{\sqrt{gx}} = 2\sqrt{\frac{l}{g}} = 1 \text{ sec}$$

8. A string tied between  $x=0$  and  $x=l$  vibrates in fundamental mode. The amplitude  $A$ , tension  $T$  and mass per unit length  $\mu$  is given. Find the total energy of the string.

[JEE 2003]

**Solution**



The amplitude at any point  $x$  is given by  $a=A \sin$

$$kx \text{ where } k = \frac{2\pi}{\lambda} = \frac{\pi}{l}$$

Where  $\omega = 2\pi n = \frac{\pi}{l} \sqrt{\frac{T}{\mu}}$ , mass of string

element of length  $dx$  is  $dm = \mu dx$

Energy of this element while oscillating is

$$dE = \frac{1}{2} dm \omega^2 a^2$$

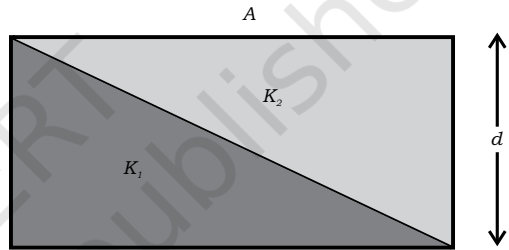
Thus total energy of the string

$$E = \int_0^l dE = \int_0^l \frac{1}{2} \mu \frac{\pi^2 T}{l^2} A^2 \sin^2 \left( \frac{\pi}{l} x \right) dx$$

Which upon integration yields  $E = \frac{1}{4} \pi^2 A^2 \frac{T}{l}$

9. The capacitance of a parallel plate capacitor with plate is  $A$  and separation  $d$  is  $C$ . The space between two wedges of dielectric constants  $K_1$  and  $K_2$ , respectively. Find the capacitance of the resulting capacitor.

[JEE 1996]



**Solution**

Let  $A=bL$ , where  $b$  is the width of the capacitor into the plane of the paper.

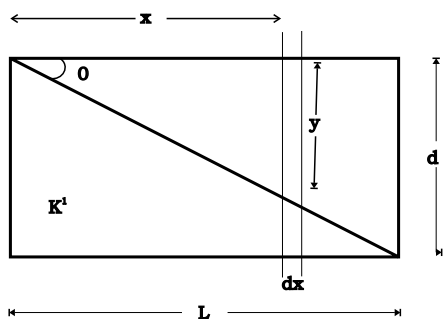
Consider a strip of length  $dx$  at a distance  $x$  from one end as shown below.

The corresponding thicknesses are  $y$  and

$$(d-y). \text{ Notice here that } \tan\theta = \frac{d}{L} = \frac{y}{x} = \frac{d-y}{L-x}$$

Each of these strips have capacitance

$$C_1 = \frac{K_1 \epsilon_0 b dx}{(d-y)} \text{ and } C_2 = \frac{K_2 \epsilon_0 b dx}{y}$$



The series combination gives capacitance of the entire strip  $dC$  given by

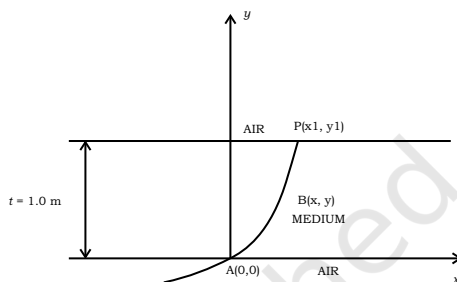
$$\begin{aligned} \frac{1}{dC} &= \frac{1}{C_1} + \frac{1}{C_2} = \frac{d(L-x)}{K_1 \epsilon_0 b L dx} + \frac{xd}{K_2 \epsilon_0 b L dx} \\ &= \frac{d}{\epsilon_0 A} \left[ \frac{L-x}{K_1} + \frac{x}{K_2} \right] \frac{1}{dx} \\ &= \frac{d}{\epsilon_0 A} \left[ \frac{(K_1 - K_2)x + K_2 L}{K_1 K_2} \right] \end{aligned}$$

The capacitance  $C$  of the entire capacitance therefore can be obtained by integrating  $dC$ .

$$\begin{aligned} \therefore C &= \int_0^L dC = \frac{K_1 K_2 \epsilon_0 A}{d} \int_0^L \left[ \frac{1}{(K_1 - K_2)x + K_2 L} \right] dx \\ &= \frac{K_1 K_2 \epsilon_0 A}{d (K_1 - K_2)} \ln \left( \frac{K_1}{K_2} \right) \end{aligned}$$

10. A ray of light travelling in air is incident at grazing angle (incident angle  $\cong 90^\circ$ ) on a long rectangular slab of a transparent medium of thickness  $t = 1.0$

m (see the figure). The point of incidence is the origin  $A(0, 0)$ . The medium has a variable index of refraction  $\mu(y)$  given by  $\mu(y) = [ky^{3/2} + 1]^{1/2}$ , where  $k = 1.0$  (metre) $^{-3/2}$ .



The refractive index of air is 1.0

- Obtain the relation between the slope of the trajectory of the ray at a point  $B(x, y)$  in the medium and the incident angle at that point.
- Obtain the equation of the trajectory  $y(x)$  of the ray in the medium.
- Determine the coordinates  $(x, y)$  of the point  $P$ , where the ray intersects the upper surface of the slab boundary.
- Indicate the path of the ray subsequently.

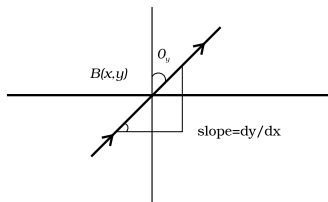
[JEE 1995]

### Solution

Note here that refractive index  $\mu$  depends on co-ordinate  $y$  only.

- (A) For a series of interfaces, Snell's law is  $\mu_1 \sin \theta_1 = \mu_2 \sin \theta_2 = \dots = \mu_n \sin \theta_n$ .

Thus at the point of incidence and point  $B$ , the relation is  $\mu_1 \sin \theta_1 = \mu_y \sin \theta_y$  and  $\theta_1 \approx 90^\circ$ .



(B) Which (referring to figure gives  $\mu(y)\sin\theta_y = 1$  and slope =  $dy/dx = \tan(90^\circ - \theta_y) = \cot\theta_y$

$$\therefore \frac{dy}{dx} = \cot\theta_y = \sqrt{\mu^2 - 1} = [ky^{3/2}]^{1/2}$$

which upon integration yields  $y = k^2 \left(\frac{x}{4}\right)^4$ .

(C) Point P is at  $y_1 = 1.0$  m which gives  $x_1 = 4.0$  m

(D) At point A and P  $\mu_A \sin\theta_A = \mu_P \sin\theta_P$  where  $\theta_A \approx 90^\circ$  where as both  $\theta_A = \mu_P = 1$  as subsequently at P ray enters air. This gives  $\theta_P \approx 90^\circ$

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JEE: Joint Entrance Examination for admission to IIT.

IIT ROORKEE: Roorke University Entrance Examination (Now IIT-Roorke)

# Facilitating Teaching-learning Practices in Science

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The paper discusses the experiences with Class six students about teaching-learning the concept of 'Reversible and non reversible changes'. The discussion depicts the classroom environment and involvement of students during teaching-learning process. The paper also highlights the effectiveness of activity based teaching-learning method for developing concepts in science. Activity based teaching-learning proved to be useful for the students especially at elementary level as it provides space to explore, observe, think, analyse and interpret. Authors have also shared their experiences related to integration of art with teaching-learning of science to make the process interactive, interesting and creative.

**KEY WORDS:** *National Curriculum Framework -2005*, Activity based teaching-learning, Reversible and not reversible changes.

## Introduction

*National Curriculum Framework-2005* (NCF-2005) suggests that at the elementary stage, students should connect the knowledge to the life outside the classroom, ensuring that learning shifts away from rote learning methods, going beyond the textbooks, making assessment more flexible and integrate with classroom life, inculcating values among children (NCF, 2005). Research studies have shown that learning through hands-on experiences with peer group participation becomes an effective way to improve learning abilities (Anabelie, 2015). Learner if provided the opportunity to think and solve the problems on their own then the learning becomes long lasting. The importance of activity based teaching is that it is learner centred and it encourages self-learning (Iqbal, 2014). This is effective with students of special needs also (Deepa, 2014).

Authors have observed that students are not given freedom to explore and express due to various reasons such as completion of syllabus within time frame, teacher's engagements in multiple activities, maintaining classroom discipline, etc. As a result the emphasis is mainly laid on mechanical tasks. These tasks are mostly based on recalling the text that does not permit self explanation and questioning by the students. This reflects students as a passive learner, which ultimately leads to lack of interest in the teaching-learning process of science. This process needs a shift.

The question arises: "How to bring this shift?"

The experience shared below may suggest one of the ways to make teaching-learning process interactive and interesting.

## Methodology

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### Science Classroom: An Observation

Authors observed Science Classroom (Class VI) in government schools of Haryana which had the following features—

- Teacher centric
- Instruction loaded
- Learners as passive receptors
- No space for activities
- Learning within the four walls of classroom
- Information loaded teaching, which leads to rote memorisation
- Follows disciplinary approach
- Examination centred teaching

After observing the science classroom processes, authors got an opportunity to interact with the students. Some of the responses given by the students are highlighted here:

- I do not like science. It is difficult to learn.
- I find science confusing.
- It is difficult to memorise activities.
- I cannot remember terminologies of science.

It is a well known fact that conceptual development in science is a continuous process. Students should be actively involved in teaching-learning process by providing opportunities to observe the world around them. This will help them in relating the concepts of science to everyday life (MHRD, 1993; NCERT, 2005).

What kind of strategies need to be followed to make it possible?

To get the answer, let us enter a classroom where the concept of “Reversible and not reversible changes” is being discussed (NCERT, 2013).

“This was the first time when we were engaging students in teaching-learning process of science. They were sitting on *dari* (carpet) separately in groups of boys and girls. They were little hesitant. To make comfortable rapport with them and to break the stereotype sitting arrangement of the class, we asked them to make a large circle. We also sat with them. We started with a round of introduction where we tried to gather information regarding their areas of interests. Within half an hour they were quite comfortable with us.

**Authors:** “Would you like to play a game?”

They all shouted: YES ssss...! With a smile on their faces.

This was the beginning...

### Activity 1

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#### Making Shapes by Using Paper A Group Activity

Students were encouraged to divide themselves into five heterogeneous groups. Here the term heterogeneous has its own significance. This will provide an opportunity to each and every student to feel equal in terms of abilities, appearance, gender, region, etc. Each group was given a used sheet of paper. They were told to make any shape using the paper without tearing it off. They all were engaged with this activity. After few



minutes they were ready with something in their hands.

**Group 1:** We have made a paper boat.

**Group2:** We have made a ball.

**Group 3:** We have come out with a fan.

**Group 4:** We have made the basket.

**Group 5:** We could create a game called “Day and Night”...

In this way each group has come out with different shapes.

**Authors:** Good attempt! Each group has created beautiful items. Can we refold these items and bring back the original shape of the paper? Try it.

They all did it successfully.

## Activity 2

In this activity used sheets of paper and a pair of scissors were provided to the students. They were motivated to make some other item of their choice by using paper. This time they were allowed to cut the paper. After 15-20 minutes we got following responses.

**Group 1:** Look at my purse with handle.

**Group 2:** We have made a doll. She will carry this purse.

**Group 3:** Your doll can go to grandma’s place on our aeroplane.

**Group 4:** Your doll can take this bunch of flowers for grandma.

**Group 5:** This fan is for your doll. She can use it.

In this way, they all had fun by discussing about the items which they had made. All

groups made different items by cutting the paper.

**Authors:** You all have made beautiful items. Can you bring the piece of paper back in its original shape and size?

A wave of interaction started among children. They all started trying to get the shape and size of the paper back.

**Students:** Oh! How can we get it back? We have cut it.

**Authors:** So, did you observe any difference in Activities 1 and 2?

**Students:** In Activity 1, we were able to get the paper back in its original shape and size whereas in Activity 2, it was not possible because we have cut the paper.

Many more examples such as knitting of yarn, cutting of vegetable, sharpening of pencil, boiling of an egg, burning of paper, etc. were discussed with students. The observations and discussion helped in concluding various changes as reversible and not reversible.



Figure: Collage of different shapes made by students

## Activity 3

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### Group Discussion

Students were given some situations (S1, S2 ...). Each group was supposed to answer the questions with explanation about the given situation(s).

**S 1:** Dissolution of salt in water.

**S 2:** Making of furniture from a log of wood.

**S 3:** Melting of ice-cubes.

**S 4:** Mixing of chick peas and flour (atta).

**S 5:** Heating of a needle.

Students started discussion on each situation.

Each student was involved with the best of his/her potential. Authors observed that it was not so simple for them to categorise these situations into reversible or not reversible.

For example, in Situation 1 (S1) most of them answered "it is not a reversible change".

**Authors:** Why do you think so?

**Students:** We cannot see salt any more.

**Authors:** What happened to the salt?

**Students:** Of course! It is dissolved.

**Authors:** Can we get dissolved salt back from water?

**Radha:** How can it be possible? It has been dissolved into water.

**Authors:** How do we get salt from sea water?

**Ranjan:** By evaporating water.

**Riya:** But how?

**Raja:** By keeping it under sunlight.

**Riya:** Can you imagine how much time will it take?

**Radha:** Ha, ha! Yes, till first term examination!!!

The whole class started laughing. This reflects how students were involved in an interactive and interesting discussion. The discussion continued.

**Rajat:** Can't we heat it? I think heating will do it fast.

**Authors:** Very well said. Let us try.

We demonstrated the activity and showed them the process of separation of salt and water by evaporation and condensation.

**Students:** Wow! We could get both the salt and water back.

**Authors:** So, is this a reversible or irreversible process?

They all shouted "it's reversible".

Situation 2 was answered as not reversible change. As they all agreed that a log of wood cannot be obtained back after cutting and making furniture from it.

Situation 3 initiated a debate among them. Some of them were saying it is a reversible change but others consider it as a non reversible change. They were arguing that if ice cubes are not taken in the same container for refreezing, the shape of ice cubes may be changed. This was the matter of discussion. Such kind of arguments indicated that students have entered into the process of thinking and analysing.

After discussion it was generalised that if we get everything exactly the same as before, i.e. the original material, shape, size, and

appearance, etc., then it is called a reversible change.

Situation 4 was categorised as reversible change. However, some of them were having an opinion that the mixture of chick peas and flour (atta) can be separated by sieving and others suggested the method of hand picking. This was reflecting how they were applying their previous knowledge with their daily life experiences to solve the problem.

For Situation 5 students asked us to demonstrate the heating of needle because they wanted to observe the changes. Although they tried to give the answer on the basis of their previous experiences but they were not sure about it. We demonstrated the heating of a needle. Again a debate initiated on the changes happening with the needle. Some of them were saying that on heating, the needle becomes red and on cooling it becomes dull in appearance and has lost its original shine. They considered it as a not reversible change. Another group argued that although the colour has slightly changed but the needle remains same. Hence, the process is reversible.

It was discussed that in some cases it is easy to decide which changes are reversible or irreversible, but in some cases it is pretty hard to decide. It is possible that through a prolonged process, we can perhaps get the same material back. Broadly, it can be generalised that the processes in which we can get the material with exactly the same properties as before, we call such changes reversible changes.

Students were encouraged to move out of the classroom and observe any five reversible and non reversible changes in their immediate

environment and note them down in their notebooks.

## Discussion and Conclusion

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The ongoing discussion itself was an achievement, as students were involved in the process of learning. This provided opportunities to assess students' progress during teaching-learning process. Generally, the issue of continuous assessment is one of the grey areas for teachers. They usually think that some extra time and efforts are required for the same. The sharing of authors' experiences is actually an attempt to break this myth.

The entire process highlighted that when this kind of concept is discussed in the teacher centric classroom where textbooks give some definitions and examples and students simply remember them without thinking, this leads to rote memorisation and ultimately the learner loses interest in the learning process. However, when students are engaged with some interesting activities where students not only learn through their own experiences but also through experiences of other members of the group, teaching-learning becomes more interesting. It also helps students to learn according to their abilities and skills. Students are not stressed with the heavy scientific terms and definitions. Such student centric classroom provides ample opportunities to raise questions and look for their answers.

Sometimes it is difficult to answer all the questions because of the cognitive level of the child, but at least it develops the habit of asking 'HOW and WHY' which ultimately help students to understand the concepts of science.

## Acknowledgements

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## Super Elastic Electroluminescent 'Skin' will soon Create Mood Robots

Engineers have developed an electroluminescent 'skin' that stretches to more than six times its original size while still emitting light. The discovery could lead to significant advances in health care, transportation, electronic communication and other areas.

These are multi-pixel electroluminescent displays fabricated via replica molding. The device measures 5 mm thick, with each of the 64 pixels measuring 4 mm. It can be deformed and stretched in various ways.

*Credit: Science, Organic Robotics Lab at Cornell University*

Imagine a health care robot that could display the patient's temperature and pulse, and even reacts to a patient's mood. It sounds futuristic, but a team of Cornell graduate students led by Rob Shepherd, Assistant Professor of mechanical and aerospace engineering has developed an electroluminescent 'skin' that

stretches to more than six times its original size while still emitting light.

"This material can stretch with the body of a soft robot, and that's what our group does," Shepherd said, noting that the material has two key properties: "It allows robots to change their color, and it also allows displays to change their shape."

This hyper-elastic light-emitting capacitor (HLEC) can endure more than twice the strain of previously tested stretchable displays. It consists of layers of transparent hydrogel electrodes sandwiching an insulating elastomer sheet. The elastomer changes luminance and capacitance (the ability to store an electrical charge) when stretched, rolled and otherwise deformed.

"We can take these pixels that change color and put them on these robots, and now we have the ability to change their color," Shepherd said. "Why is that important? For one thing, when robots become more and more a part of our lives, the ability for them to have emotional connection with us will be important. So to be able to change their

color in response to mood or the tone of the room we believe is going to be important for human-robot interactions."

In addition to its ability to emit light under a strain of greater than 480 per cent its original size, the group's HLEC was shown to be capable of being integrated into a soft robotic system. Three six-layer HLEC panels were bound together to form a crawling soft robot, with the top four layers making up the light-up skin and the bottom two the pneumatic actuators.

The chambers were alternately inflated and deflated, with the resulting curvature creating an undulating, "walking".

## Greenland's Ice is Getting Darker, Increasing Risk of Melting

An aerial image of Greenland shows rivers of melt water and areas of dark ice. Greenland's surface is absorbing more solar radiation as melting increases grain size and brings old impurities to the surface.

*Credit: Marco Tedesco/Lamont-Doherty Earth Observatory*

Greenland's snowy surface has been getting darker over the past two decades, absorbing more heat from the sun and increasing snow melt, a new study of satellite data shows. That trend is likely to continue, with the surface's reflectivity, or albedo, decreasing by as much as 10 per cent by the end of the century, the study says.

While soot blowing in from wildfires contributes to the problem, it has not been driving the change, the study finds. The real culprits are two feedback loops created by the melting itself. One of those processes is

not visible to the human eye, but it is having a profound effect.

The results, published in the European Geosciences Union journal *The Cryosphere*, have global implications. Fresh meltwater pouring into the ocean from Greenland raises sea level and could affect ocean ecology and circulation.

"You don't necessarily have to have a 'dirtier' snowpack to make it dark," said lead author Marco Tedesco, a research professor at Columbia University's Lamont-Doherty Earth Observatory and adjunct scientist at NASA Goddard Institute of Space Studies. "A snowpack that might look 'clean' to our eyes can be more effective in absorbing solar radiation than a dirty one. Overall, what matters, it is the total amount of solar energy that the surface absorbs. This is the real driver of melting."

The feedback loops work like this: During a warm summer with clear skies and lots of solar radiation pouring in, the surface starts to melt. As the top layers of fresh snow disappear, old impurities, like dust from erosion or soot that blew in years before, begin to appear, darkening the surface. A warm summer can remove enough snow to allow several years of impurities to concentrate at the surface as surrounding snow layers disappear. At the same time, as the snow melts and refreezes, the grains of snow get larger. This is because the meltwater acts like glue, sticking grains together when the surface refreezes. The larger grains create a less reflective surface that allows more solar radiation to be absorbed. The impact of grain size on albedo the ratio between reflected and incoming solar radiation is strong in the infrared

range, where humans can't see, but satellite instruments can detect the change.

"It's a complex system of interaction between the atmosphere and the ice sheet surface. Rising temperatures are promoting more melting, and that melting is reducing albedo, which in turn is increasing melting," Tedesco said. "How this accumulates over decades is going to be important, because it can accelerate the amount of water Greenland loses. Even if we don't have a lot of melting because of atmospheric conditions one year, the surface is more sensitive to any kind of input the sun can give it, because of the previous cycle."

The study used satellite data to compare summertime changes in Greenland's albedo from 1981 to 2012. The first decade showed little change, but starting around 1996, the data show that due to darkening, the ice began absorbing about 2 per cent more solar radiation per decade. At the same time, summer near-surface temperatures in Greenland increased at a rate of about 0.74°C per decade, allowing more snow to melt and fuel the feedback loops.

A likely cause for the large shift around 1996 was a change in atmospheric circulation, Tedesco said. The North Atlantic Oscillation, a large-scale natural weather cycle, went into a phase in which summer atmospheric conditions favoured more incoming solar radiation and warmer, moist air from the south. Later records show those conditions shifted in 2013-2014 to favour less melting, but the damage was already done the ice sheet had become more sensitive. In 2015, melting spiked again to reach more than half of the Greenland ice sheet.

While new snowfall can make the ice sheet brighter again, the dark material built up during the melt years is waiting just below the surface, preconditioning the surface to future melting, Tedesco said.

The scientists also ran a computer model to simulate the future of Greenland's surface temperature, grain size, exposed ice area and albedo. Over the current century, the model projects that the average albedo for the entire ice sheet will fall by as much as 8 per cent, and by as much 10 per cent on the western edge, where the ice is darkest today. Those are conservative estimates the change could be twice that, Tedesco said.

The scientists looked into the hypothesis that soot from forest fires in China, Siberia and North America could be driving the increased darkening of the ice sheet. Using the Global Fire Emissions Database, they analyzed trends in black-carbon emissions from wildfires in those regions and Europe. While the amount of black carbon released by fires varied year to year, the scientists found no statistically significant increase during 1997-2012 to match the darkening of Greenland.

## How Many Types of Neurons are there in the Brain?

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The image illustrates the molecular diversity of V1 inhibitory interneurons (indicated in green) in the mouse lumbar spinal cord. Subsets of V1 interneurons can be defined by the activation of particular combinations of transcription factors (indicated in red, blue, and gray), forming a complex network of microcircuits that likely influence limb motor control.

*Credit: Jay Bikoff, PhD*

For decades, scientists have struggled to develop a comprehensive census of cell types in the brain. Now, in a pair of companion papers, researchers at Columbia's Mortimer B. Zuckerman Mind Brain Behavior Institute describe powerful new approaches to systematically identify individual classes of brain cells, or neurons, in the spinal cord. In doing so, they reveal elements of the underlying circuit architecture through which these neurons shape movement— and highlight how statistical approaches could provide neuroscientists with a critical tool to quantify the cellular diversity of any region of the brain.

The papers are published online in the journal *Cell*.

"Our work allows scientists to assess the diversity of neuronal cell classes in specific regions of the central nervous system— in part by plugging basic cellular characteristics into this fundamental statistical model," said Thomas M. Jessell, PhD, senior author on one of the papers and a co-director of the Zuckerman Institute. "As we continue to build upon and refine this method, scientists could take any cellular circuit and reveal its basic component parts. And once we understand the brain at this level, there are key problems of circuitry and function that can be addressed at a detailed level of resolution."

In today's newly published research, scientists focused on a group of neurons in the spinal cord called V1 interneurons, which form connections that orchestrate the activity and output of motor neurons, the class of neurons that give us the power to move.

"Motor neurons are like the strings of a marionette, with interneurons directing which strings are to be pulled, and in what

order," said Jay Bikoff, PhD, a postdoctoral scholar at Columbia and first author of one of the papers. "Previous studies had shown that V1 interneurons are intimately involved in shaping motor neuron activity, but had been unable to determine precisely how they did so. We needed to classify the varieties of V1 interneurons in a much more systematic and detailed manner— information that would then help to decipher the circuits that underlie movement at an unprecedented organizational level."

There are many characteristics that distinguish one type of neuron from another, such as where it is located or what it looks like. But ultimately, the researchers argue, a neuron can be defined by its genetic identity.

"While at its core every neuron essentially contains the same genetic information, differences between the genes that are switched on, and those that remain dormant confer neurons with individual identities, like a fingerprint," said Mariano Gabitto, a doctoral candidate at Columbia in the department of neuroscience and the first author of the second paper. "So if you have a neuron's fingerprint, you can then use it to distinguish one class of neuron from the next, which is critical for dissecting the functional organization of the nervous system."

In this research, the scientists focused on finding that fingerprint. By studying the V1 interneurons of laboratory mice, researchers first identified 19 genetic 'switches,' called transcription factors, which— when activated in a particular combination— made the genetic profile of one V1 interneuron class different from another. What the scientists needed to do next was match the unique pattern of transcription factors to a particular



type of interneuron, a feat that proved difficult with traditional experimental techniques.

After facing this challenge, the researchers turned to theoretical neuroscientist Larry Abbott, PhD, and statistician Liam Paninski, PhD— colleagues at Columbia's Zuckerman Institute— as well as Ari Pakman, PhD, a postdoctoral fellow in Dr Paninski's lab and co-first author in the second paper, to build a more powerful statistical model. Drs Abbott and Paninski developed a mathematical approach based on Bayesian regression analysis that provides the ability to account for uncertainty in a principled way, while also incorporating the complex genetics of the 19 transcription factors. Using this statistical model the research team was able to distinguish 50 distinct types of V1 interneurons— results that withstood even the toughest statistical and experimental scrutiny.

"Not only did this model reveal to us the number of distinct V1 interneuron types, it also allowed us to infer their precise locations in the spinal cord," said Dr Jessell, who is also the Claire Tow Professor of Motor Neuron Disorders in the Department of Neuroscience and of Biochemistry and Molecular Biophysics at Columbia. "By combining experimental observation with statistical inference, it has been possible to develop a method that can take information about an interneuron's genetic identity and glean insight into its role directing muscle activation."

"What makes this work so foundational is that even with very limited data— such as the prevalence of these transcription factors combined with information on where the neurons were located— we could infer a detailed repertoire of cellular diversity," said

Dr Abbott, the William Bloor Professor of Theoretical Neuroscience, Physiology and Cellular Biophysics at Columbia who served as a senior author on the second paper.

"Some of the most exciting work in neuroscience these days involves efforts to combine many different kinds of experimental measurements using a single unified statistical model— and these papers are one example of this," said Dr Paninski. "We're looking forward to further extending and generalizing these methods and applying them in other parts of the nervous system."

## Long-term Stress Erodes Memory

This is the first study of its kind to establish the relationship between short-term memory and prolonged stress. In the case of the mice, that meant repeat visits from a larger, nasty intruder mouse.

*Credit: © Stepan Popov/Fotolia*

Sustained stress erodes memory, and the immune system plays a key role in the cognitive impairment, according to a new study from researchers at the Ohio State University.

The work in mice could one day lead to treatment for repeated, long-term mental assault such as that sustained by bullying victims, soldiers and those who report to beastly bosses, the researchers say.

"This is chronic stress. It's not just the stress of giving a talk or meeting someone new," said lead researcher Jonathan Godbout, Associate Professor of neuroscience at Ohio State.

Mice that were repeatedly exposed to the aggressive intruder had a hard time recalling

where the escape hole was in a maze they'd mastered prior to the stressful period.

"The stressed mice didn't recall it. The mice that weren't stressed, they really remembered it," Godbout said.

They also had measurable changes in their brains, including evidence of inflammation brought on by the immune system's response to the outside pressure. This was associated with the presence of immune cells, called macrophages, in the brain of the stressed mice.

The research team was able to pin the short-term memory loss on the inflammation, and on the immune system.

*Their work, which appears in The Journal of Neuroscience, builds on previous research substantiating the connections between chronic stress and lasting anxiety.*

The impact on memory and confirmation that the brain inflammation is caused by the immune system are important new discoveries, Godbout said.

"It's possible we could identify targets that we can treat pharmacologically or behaviorally," he said.

It could be that there are ways to interrupt the inflammation, said John Sheridan, who worked on the study and is associate director of Ohio State's Institute for Behavioral Medicine Research.

The mice used in the study are exposed to repeated social defeat— basically dominance by an alpha mouse— that aims to mimic chronic psychosocial stress experienced by humans.

Researchers at Ohio State seek to uncover the secrets behind stress and cognitive and mood problems with a long-range goal of finding ways to help those who are anxious, depressed and suffer from lasting problems, including post-traumatic stress disorder.

This new research focused on the hippocampus, a hub of memory and emotional response.

The researchers found that the stressed mice had trouble with spatial memory that resolved within 28 days. They found that the mice displayed social avoidance, which measures depressive-like behaviour, that continued after four weeks of monitoring.

And they were able to measure deficits in the development of new neurons 10 days and 28 days after the prolonged stress ended.

When they gave the mice a chemical that inhibited inflammation, neither the brain-cell problem nor the depressive symptoms went away. But the memory loss and inflammatory macrophages did disappear.

And that led them to conclude that the post-stress memory trouble is directly linked to inflammation— and the immune system— rather than to other damage to the brain. That type of information can pave the way for immune-based treatments, Godbout said.

"Stress releases immune cells from the bone marrow and those cells can traffic to brain areas associated with neuronal activation in response to stress," Sheridan said. "They're being called to the brain, to the center of memory."

## Penguin Brains not Changed by Loss of Flight

This is an ancient penguin skull and endocast. Scale bar is 2.5 cm and letters indicate parts of the brain: ce, cerebellum; el, endosseus labyrinth; fl, floccular lobe; ol, optic lobe; os, occipital sinus impression; pb, pituitary bulb; t, telencephalon; w, wulst.

*Credit: Courtesy of James Proffitt*

Losing the ability to fly gave ancient penguins their unique locomotion style. But leaving the sky behind didn't cause major changes in their brain structure, researchers from the University of Texas at Austin suggest after examining the skull of the oldest known penguin fossil.

*The findings were published in the Journal of Anatomy in February.*

"What this seems to indicate is that becoming larger, losing flight and becoming a wing-propelled diver does not necessarily change the [brain] anatomy quickly," said James Proffitt, a graduate student at the university's Jackson School of Geosciences who led the research. "The way the modern penguin brain looks doesn't show up until millions and millions of years later."

Proffitt conducted the research with Julia Clarke, a professor in the Jackson School's Department of Geological Sciences, and Paul Scofield, the senior curator of Natural History at the Canterbury Museum in Christchurch, New Zealand, where the skull fossil is from.

The skull is from a penguin that lived in New Zealand over 60 million years ago during the Paleocene epoch. According to Proffitt, it likely lived much like penguins today. But while today's penguins have been diving instead of

flying for tens of millions of years, the change was relatively new for the ancient penguin.

"It's the oldest [penguin] following pretty closely after the loss of flight and the evolution of flightless wing-propelled diving that we know of," Proffitt said.

The shape of bird skulls is influenced by the structure of the brain. To learn about early penguin brain anatomy, Proffitt used X-ray CT-scanning to digitally capture fine features of the skull's anatomy, and then used computer modelling software to create a digital mold of the brain, called an endocast.

The researchers thought that loss of flight would impact brain structure— making the brains of ancient penguins and modern penguins similar in certain regions. However, after analyzing the endocast and comparing it to modern penguin brain anatomy, no such similarity was found, Proffitt said. The brain anatomy had more in common with skulls of modern relatives that both fly and dive such as petrels and loons, than modern penguins.

"It's difficult to know why modern penguins' brains look different than their ancestors' brains", Proffitt said. It's possible that millions of years of flightless living created gradual changes in the brain structure. But the analysis shows that these changes are not directly related to initial loss of flight because they are not shared by the ancient penguin brain.

However, similarities in the brain shape between the ancient species and diving birds living today suggest that diving behaviour may be associated with certain anatomical structures in the brain.

"The question now is do the old fossil penguins' brains look that way because that's

the way their ancestors looked, or does it have something maybe to do with diving?" Proffitt said. "I think that's an open question right now."

## Alma spots Baby Star's Growing Blanket

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Artist's impression of the baby star TMC-1A. The star is located in the centre and surrounded by a rotating gas disk. Gas is infalling to the disk from the envelope further out.

*Credit: Image courtesy of National Astronomical Observatory of Japan*

Researchers using the Atacama Large Millimeter/submillimeter Array (ALMA) have made the first direct observations delineating the gas disk around a baby star from the infalling gas envelope. This finding fills an important missing piece in our understanding of the early phases of stellar evolution. A research team, led by Yusuke Aso (a graduate student at the University of Tokyo) and Nagayoshi Ohashi (a professor at the Subaru Telescope, National Astronomical Observatory of Japan) observed the baby star named TMC-1A located 450 light years away from us, in the constellation Taurus (the Bull). TMC-1A is a protostar, a star still in the process of forming. Large amounts of gas still surround TMC-1A.

Stars form in dense gas clouds. Baby stars grow by taking in the surrounding gas, like a fetus receiving nutrition from the mother's placenta. In this process, gas cannot flow directly into the star. Instead it first accumulates and forms a disk around the star, and then the disk feeds into the star. However, it is still unknown when in the

process of star formation this disk appears and how it evolves. Lack of sensitivity and resolution in radio observations has made it difficult to observe these phenomena.

"The disks around young stars are the places where planets will be formed," said Aso, the lead author of the paper that appeared in the *Astrophysical Journal*. "To understand the formation mechanism of a disk, we need to differentiate the disk from the outer envelope precisely and pinpoint the location of its boundary."

Using ALMA, the team directly observed the boundary between the inner rotating disk and the outer infalling envelope with high accuracy for the first time. Since gas from the outer envelope is continuously falling into the disk, it had been difficult to identify the transition region in previous studies. In particular, the tenuous but high speed gas in rotating disks is not easy to see. But ALMA has enough sensitivity to highlight such a component and illustrate the speed and distribution of gas in the disk very precisely. This enabled the team to distinguish the disk from the infalling envelope.

The team found that the boundary between the disk and envelope is located 90 astronomical units from the central baby star. This distance is three times longer than the orbit of Neptune, the outermost planet in the solar system. The observed disk obeys Keplerian rotation: the material orbiting closer to the central star revolves faster than material further out. The high-sensitivity observations provided other important information about the object. From detailed measurement of the rotation speed, the research team could calculate that the mass of the baby star is 0.68 times the mass of the

sun. The team also determined the gas infall rate to be a millionth of the mass of the sun per year, with a speed of 1 km per second. Gravity causes gas to fall towards the central baby star, but the measured speed is much less than the free-fall speed. Something must be slowing the gas down. The researchers suspect that a magnetic field around the baby star might be what is slowing the gas.

"We expect that as the baby star grows, the boundary between the disk and the infall region moves outward," said Aso. "We are sure that future ALMA observations will reveal such evolution."

These observational results were published as Aso et al. "ALMA Observations of the Transition from Infall Motion to Keplerian Rotation around the Late-phase Protostar TMC-1A" in the *Astrophysical Journal*, issued in October 2015.

## Monkeys drive Wheelchairs using only their Thoughts

A computer in the lab of Miguel Nicolelis, M.D., Ph.D., monitors brain signals from a rhesus macaque. Nicolelis and Duke researchers record signals from hundreds of neurons in two regions of the monkeys' brains that are involved in movement and sensation. As the animals think about moving toward their goal— in this case, a bowl containing fresh grapes— computers translate their brain activity into real-time operation of a wheelchair.

*Credit: Shawn Rocco/Duke Health*

Neuroscientists at Duke Health have developed a brain-machine interface (BMI) that allows primates to use only their thoughts to navigate a robotic wheelchair.

The BMI uses signals from hundreds of neurons recorded simultaneously in two regions of the monkeys' brains that are involved in movement and sensation. As the animals think about moving toward their goal— in this case, a bowl containing fresh grapes— computers translate their brain activity into real-time operation of the wheelchair.

The interface, described in the March 3 issue of the online journal *Scientific Reports*, demonstrates the future potential for people with disabilities who have lost most muscle control and mobility due to quadriplegia or ALS, said senior author Miguel Nicolelis, M.D., Ph.D., co-director for the Duke Center for Neuroengineering.

"In some severely disabled people, even blinking is not possible," Nicolelis said. "For them, using a wheelchair or device controlled by noninvasive measures like an EEG (a device that monitors brain waves through electrodes on the scalp) may not be sufficient. We show clearly that if you have intracranial implants, you get better control of a wheelchair than with noninvasive devices."

Scientists began the experiments in 2012, implanting hundreds of hair-thin microfilaments in the premotor and somatosensory regions of the brains of two rhesus macaques. They trained the animals by passively navigating the chair toward their goal, the bowl containing grapes. During this training phase, the scientists recorded the primates' large-scale electrical brain activity. The researchers then programmed a computer system to translate brain signals into digital motor commands that controlled the movements of the wheelchair.

As the monkeys learned to control the wheelchair just by thinking, they became more efficient at navigating toward the grapes and completed the trials faster, Nicolelis said.

In addition to observing brain signals that corresponded to translational and rotational movement, the Duke team also discovered that primates' brain signals showed signs they were contemplating their distance to the bowl of grapes.

"This was not a signal that was present in the beginning of the training, but something that emerged as an effect of the monkeys becoming proficient in this task," Nicolelis said. "This was a surprise. It demonstrates the brain's enormous flexibility to assimilate a device, in this case a wheelchair, and that device's spatial relationships to the surrounding world."

The trials measured the activity of nearly 300 neurons in each of the two monkeys. The Nicolelis lab previously reported the ability to record up to 2,000 neurons using the same technique. The team now hopes to expand the experiment by recording more neuronal signals to continue to increase the accuracy and fidelity of the primate BMI before seeking trials for an implanted device in humans, he said.

In addition to Nicolelis, study authors include Sankaranarayanan Rajangam; Po-He Tseng; Allen Yin; Gary Lehew; David Schwarz; and Mikhail A. Lebedev.

The National Institutes of Health (DP1MH099903) funded this study. The Itau Bank of Brazil provided research support to the study as part of the Walk Again Project, an international non-profit consortium aimed at developing new assistive technologies for severely paralyzed patients.

## Tunnel through the Head: Internally Coupled Ears Enable Directional Hearing in Animals

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An air-filled cavity connects the eardrums of the two ears of this lizard. In this "tunnel through the head" external and internal sound waves superimpose to produce signals enabling the animal to localize the direction of the sound source.

*Credit: Prof. Dr Frieder Mugele, University of Twente*

Humans use the time delay between the arrival of a sound wave at each ear to discern the direction of the source. In frogs, lizards and birds the distance between the ears is too small. However, they have a cavity connecting the eardrums, in which internal and external sound waves are superimposed. Using a universal mathematical model, researchers at the Technical University of Munich (TUM) have now for the first time shown how new signals are created in this 'inner ear' used by animals for localizing sounds.

Whether perceiving an encroaching predator or finding prey in the dark, precisely localizing the source of a sound is indispensable in the animal kingdom. Almost all mammals, including humans, localize sound sources horizontally via the delay in time in which sound signals arrive at each ear. Using this time difference the brain can calculate the direction from which the sound emanated.

Frogs, many reptiles and birds do not have this option since the distance between their ears often measures merely a few centimetres. The time difference is thus so small that it cannot be processed by the brain. To make up for this disadvantage these

animals have developed a simple albeit very effective system: An air-filled cavity connects the eardrums of the two ears.

This cavity, which runs right through the head, couples the eardrums. The scientists refer to this as "internally coupled ears" or ICE. This "tunnel in the head" is clearly visible when light falls into one ear of a gecko: the light then shines out of the other ear.

Unlike humans, the animals perceive not only external signals, but also a superposition of external sound waves with those that are created internally through the coupling of the two sides. Scientists have determined in experiments that animals use the resulting signals for pinpointing sound sources. But what exactly happens in the coupled ears remains a mystery.

### A Model for 15,000 Species

Now, scientists working led by Leo van Hemmen, Professor of Theoretical Biophysics at the Technical University of Munich (TUM) have for the first time developed a universal mathematical model that describes how sound waves propagate through the internally coupled ears and which clues for localizing sound sources are created in the process.

"Our model is applicable to all animals with this kind of hearing system, regardless that the cavities between the eardrums of the various species look very different," explains van Hemmen. "We now understand what exactly happens inside the ears of these animals and can both explain and predict the results of experiments in all sorts of animals." Over 15,000 species have internally coupled ears— that is more than half of all land-dwelling vertebrate animals.

### External and Internal Signals in Concert

Using their model, van Hemmen and his team discovered that the animals have even developed two different methods of hearing with internally coupled ears. They occur in different frequency domains and augment each other.

In sounds below the fundamental frequency of the eardrum the time difference in the superposition of the internal and external signals is amplified up to five-fold. That is sufficient to facilitate sound localization. In higher frequencies the time difference can no longer be evaluated. Here, another property of the signal becomes relevant: the difference in the amplitude, i.e. the loudness, of the sound perceived by the ears. "The amplitude difference occurs solely through the coupling of the two ears," explains van Hemmen. "That was a surprising result."

This new insight on the mechanisms and especially the advantages of hearing with internally coupled ears is also relevant for industrial applications. It is conceivable that robots will be equipped with this kind of hearing system. "I can very well imagine applications in robotics, because this kind of amplification doesn't need energy" expresses van Hemmen. In the future van Hemmen and his team of scientists hope to refine their model in collaboration with the experimental work of colleagues.

### Exposure to Air Pollution Increases Risk of Obesity

Forbidden City in Beijing (stock image). A new study shows that exposure to air pollution increases the risk of obesity.

*Credit: © bizoon/Fotolia*



Laboratory rats who breathed Beijing's highly polluted air gained weight and experienced cardio-respiratory and metabolic dysfunctions after three to eight weeks of exposure.

A study appearing in the March issue of the *Journal of the Federation of American Societies for Experimental Biology* (FASEB) placed pregnant rats and their offspring in two chambers, one exposed to outdoor Beijing air and the other containing an air filter that removed most of the air pollution particles.

After only 19 days, the lungs and livers of pregnant rats exposed to the polluted air were heavier and showed increased tissue inflammation. These rats had 50 per cent higher LDL cholesterol; 46 per cent higher triglycerides; and 97 per cent higher total cholesterol. Their insulin resistance level, a precursor of Type 2 diabetes, was higher than their clean air-breathing counterparts.

All of these measures support the study's conclusion that air pollution exposure results in metabolic dysfunction, a precursor to obesity. Indeed, pollution-exposed rats were significantly heavier at the end of their pregnancy even though the rats in both groups were fed the same diet.

Similar results were shown in the rat offspring, which were kept in the same chambers as their mothers.

However, the results showed that the negative effects of air pollution were less pronounced after three weeks than they were at eight weeks, suggesting that long-term exposure may be needed to generate the continuous inflammatory and metabolic changes that ultimately increase body weight. At eight weeks old, female and male rats exposed to the pollution were 10 per cent and 18 per cent

heavier, respectively, than those exposed to clean air.

The results of this study, which was funded by several agencies of the Chinese government, are consistent with other studies that show air pollution induces oxidative stress and inflammation in the organs and circulatory system. The findings also echo previous studies linking air pollution with increased insulin resistance and altered fat tissue.

"Since chronic inflammation is recognized as a factor contributing to obesity and since metabolic diseases such as diabetes and obesity are closely related, our findings provide clear evidence that chronic exposure to air pollution increases the risk for developing obesity," said Junfeng "Jim" Zhang, a professor of global and environmental health at Duke University and a senior author of the paper.

"If translated and verified in humans, these findings will support the urgent need to reduce air pollution, given the growing burden of obesity in today's highly polluted world," Zhang said.

## The Intestinal Microbiota: A New Ally for Optimum Growth

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In the mouse, the intestinal microbiota is necessary for optimum postnatal growth and thus contributes to determining the size of adult individuals. Left: an infant mouse reared with its intestinal microbiota; right: a young adult mouse devoid of intestinal microbiota. Note their difference in size. The bacterial colonization of the mice is illustrated by the presence or absence of colonies in bacterial cultures on agar plates.

Credit: © Vincent Moncorgé



The intestinal microbiota is necessary to ensure optimum postnatal growth and contributes to determining the size of adult individuals, notably in the event of undernutrition. The key element in this relationship is Insulin-like Growth Factor-1 (IGF-1), whose production and activity are in part controlled by the microbiota. This has recently been demonstrated in mice by scientists at the Institut de Génomique Fonctionnelle de Lyon (CNRS/ENS Lyon/ Université Claude Bernard Lyon 1), the Laboratoire CarMeN (INSERM/INRA/ Université Claude Bernard Lyon 1/Insa Lyon), and Unit BF21 (INRA/INSA Lyon). These findings, published on 19 February 2016 in *Science*, and obtained in collaboration with researchers from the Czech Academy of Sciences, also show that some strains of intestinal bacteria belonging to the *Lactobacillus plantarum* species may favour the postnatal growth of animals, thus offering a new opportunity to combat the harmful effects of chronic infantile undernutrition.

During the juvenile phase, animal growth is influenced by interactions between nutritional intake and hormone signalling. Acute undernutrition for a few days in the mouse results in marked weight loss, which has been widely documented and attributed— among other factors -- to a disturbance of the intestinal microbiota. Chronic undernutrition will result in the onset of growth retardation. The complex mechanisms underlying this retardation involve a state of resistance to the action of growth hormone secreted by the pituitary, an endocrine gland situated beneath the brain, which normally stimulates the production by numerous tissues of growth factors such as Insulin-like Growth Factor 1 (IGF-1). This

tissue resistance to growth hormone causes a drop in the production of IGF-1, leading to a delayed development and reduced size of an individual compared with age. Until now, the influence of the microbiota on these mechanisms remained unknown.

Under different nutritional conditions, the scientists compared the development of standard mice with a normal microbiota with that of so-called germ-free mice without intestinal microbiota. They were able to demonstrate, for the first time, the role played by the bacteria in the intestinal flora in controlling growth. Whether under a normal diet or in a situation of undernutrition, the researchers observed that the germ-free mice had not only gained less weight but were also smaller than their standard counterparts. In germ-free specimens, numerous bone growth parameters such as bone length or thickness were reduced, without bone mineral density (the amount of calcium in the bones) being affected. In addition, the team showed that the germ-free mice displayed lower IGF-1 levels, with less activity, than the other mice. By interfering with the activity of IGF-1 in normal mice, or by injecting IGF-1 into the germ-free mice, the scientists determined that the intestinal microbiota favoured growth by influencing the production and activity of this important growth factor.

Previous studies in *Drosophila* had demonstrated the ability of bacterial strains in the *Lactobacillus plantarum* species to favour postnatal growth in the event of chronic undernutrition. The researchers therefore analyzed the growth of so-called monocolonized mice (i.e. containing a single bacterial strain as their microbiota).

They thus demonstrated that mice monocolonized with a specific *Lactobacillus plantarum* strain (called LpWJL), and reared under standard nutrition or chronic undernutrition, produced more IGF-1, gained more weight and grew better than germ-free mice or those monocolonized with other strains. These results thus prove that certain strains of *Lactobacillus*, including LpWJL, are able to favour postnatal growth in mammals.

## The 'Ugliest Fossil Reptiles' who roamed China

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The skeleton of *Shihtienfenia*, a large pareiasaur from the latest Permian of Shanxi Province, China. The skeleton outline is based on close relatives from Russia, and known bones are shaded.

*Credit: Image courtesy of University of Bristol*

Long before the dinosaurs, hefty herbivores called pareiasaurs ruled earth. Now, for the first time, a detailed investigation of all Chinese specimens of these creatures— often described as the 'ugliest fossil reptiles'— has been published by a University of Bristol, UK palaeontologist.

Pareiasaurs have been reported from South Africa, Europe (Russia, Scotland, Germany), Asia (China), and South America, but it is not known whether there were distinct groups on each of these continents.

In a new study published in the *Zoological Journal* of the Linnean Society, Professor Mike Benton of Bristol's School of Earth Sciences shows there are close similarities between Chinese fossils and those found in Russia and South Africa, indicating that the huge

herbivores were able to travel around the world despite their lumbering movement.

Professor Benton said: "Up to now, six species of pareiasaurs had been described from China, mainly from Permian rocks along the banks of the Yellow River between Shaanxi and Shanxi provinces. I was able to study all of these specimens in museums in Beijing, and then visited the original localities. It seems clear there were three species and these lived over a span of one to two million years."

Pareiasaurs were hefty animals, two to three metres long, with massive, barrel-shaped bodies, short, stocky arms and legs, and tiny head with small teeth. Their faces and bodies were covered with bony knobs.

It is likely the pareiasaurs lived in damp, lowland areas, feeding on huge amounts of low-nutrition vegetation. No stomach contents or fossilized faeces from pareiasaurs are known to exist, but in Russia, pareiasaurs have been found with evidence they had made wallows in the soft mud probably to cool off or coat themselves in mud to ward off parasites.

The new study confirms that the three Chinese pareiasaur species differed from each other in body size and in the shapes of their teeth.

Professor Benton added: "My study of the evolution of pareiasaurs shows that the Chinese species are closely related to relatives from Russia and South Africa. Despite their size and probably slow-moving habits, they could walk all over the world. We see the same sequence of two or three forms worldwide, and there is no evidence that China, or any other region, was isolated at that time."

Pareiasaurs were the first truly large herbivores on earth, and yet their tenure was short.

As in other parts of the world, the species in China were wiped out as part of the devastation of the end-Permian mass extinction 252 million years ago, when 90 per cent of species were killed by the acid rain and global warming caused by massive volcanic eruptions in Russia.

Without forests, landscapes were denuded of soils which washed into the seas. Shock heating of the atmosphere and oceans as a result of the massive release of carbon dioxide and methane also killed much of life. The end-Permian mass extinction killed off the pareiasaurs after they had been on earth for only 10 million years.

## **Fifty-seven Different Pesticides Found in Poisoned Honeybees**

Honeybees are under threat globally: in the US, dramatic declines in bee populations due to a condition called colony collapse disorder (CCD) continues to put crops at risk and farmers out of business.

*Credit: © luigipinna/Fotolia*

European honeybees are being poisoned with up to 57 different pesticides, according to new research published in the *Journal of Chromatography*. A new method for detecting a whole range of pesticides in bees could help unravel the mystery behind the widespread decline of honeybees in recent years, and help develop an approach to saving them.

Honeybees are under threat globally: in the US, dramatic declines in bee populations due to a condition called colony collapse disorder

(CCD) continues to put crops at risk and farmers out of business. Several studies have shown a link between pesticide use and bee deaths and the European Union has banned the use of neonicotinoid pesticides.

But it is not as simple as banning one pesticide that is killing bees; the relationship between pesticide use and bee death is complex and scientists are still trying to figure out exactly what is happening. In the new study, researchers from the National Veterinary Research Institute in Poland have developed a method for analyzing 200 pesticides at the same time, to figure out what's really putting honeybees at risk.

"Bee health is a matter of public concern—bees are considered critically important for the environment and agriculture by pollinating more than 80 per cent of crops and wild plants in Europe," said Tomasz Kiljanek, lead author of the study from the National Veterinary Research Institute in Poland. "We wanted to develop a test for a large number of pesticides currently approved for use in the European Union to see what is poisoning the bees."

With so many pesticides currently in use, it is difficult to work out which ones are harming the bees. Certain combinations of pesticides, or their use over time, could affect honeybees in different ways. In order to understand what is really going on, we need to know which pesticides and at what concentration levels are present in honeybees.

Kiljanek and the team used a method called QuEChERS, which is currently used to detect pesticides in food. With this analysis, they could test poisoned bees for 200 different pesticides simultaneously, as well as several additional compounds created when the

pesticides are broken down. About 98 per cent of the pesticides they tested for are approved for use in the European Union.

The team used the method to investigate more than 70 honeybee poisoning incidents. Their findings revealed 57 different pesticides present in the bees— it is a toxic puzzle they hope their new method will help solve.

"This is just the beginning of our research on the impact of pesticides on honeybee health," said Kiljanek. "Honeybee poisoning incidents are the tip of the iceberg. Even at very low levels, pesticides can weaken bees' defense systems, allowing parasites or viruses to kill the colony. Our results will help expand our knowledge about the influence of pesticides on honeybee health, and will provide important information for other researchers to better assess the risk connected with the mix of current used pesticides."

## Links between Money and Happiness Uncovered

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A new study explores the link between money and happiness.

*Credit: © Minerva Studio/Fotolia*

Changes in income do not affect most people's happiness, most of the time, according to a new study led by the University of Stirling.

The research, which examined levels of life satisfaction and income changes in more than 18,000 adults over a nine year period, revealed that income change is only important when individuals with specific personality characteristics experience an income loss.

Researchers at the universities of Stirling and Nottingham found that for most people

happiness is likely to rest on avoiding loss, rather than aiming for continual financial gain.

The study, involving two separate samples from Germany and the UK, asked participants annually about their income level and how satisfied they were with life. Participants also answered questions on their personality at the start of the study.

Results revealed that regardless of personality, income increases did not affect life satisfaction. When people lost income, however, there was a reduction in their life satisfaction. This was far greater for those who reported themselves as being conscientious, namely they were thorough in their attitudes to life and work, energetic, and effective and efficient in how they did things.

Leading the research, Dr Christopher Boyce of the Behavioural Science Centre at the University of Stirling, said: "It is often assumed that as our income rises so does our life satisfaction, however, we have discovered this is not the case. What really matters is when income is lost and this is only important for people who are highly conscientious."

The study, which accounted for shifting circumstances such as entering or leaving work, and changes to health and household make up, found that for people that were only even moderately conscientious, a loss of income had a negative impact at least two and a half times greater than less conscientious individuals.

Dr Boyce said: "Continually increasing our income is not an important factor for achieving greater happiness and well-being for most people living in economically developed countries. Instead, we should aim for financial stability to achieve greater

happiness, while protecting those individuals who experience negative income shocks."

The study was funded by the Economic and Social Research Council.

## Form of Genetically Elevated 'Good' Cholesterol may actually be Bad

HDL, or 'good' cholesterol, can remove cholesterol from arteries and shuttle it to the liver where it is eliminated, but this process can be disrupted in certain circumstances (such as deficiency of SCARB1).

*Credit: The lab of Daniel Rader, MD, Perelman School of Medicine, University of Pennsylvania*

The generally accepted medical maxim that elevated HDL cholesterol (HDL-C) is 'good' has been overturned by a multi-centre, international study, led by researchers from the Perelman School of Medicine at the University of Pennsylvania. They show that a certain genetic cause of increased HDL-C may actually be 'bad', noting that a specific mutation in a gene which encodes a cell receptor protein that binds to HDL prevents the receptor from functioning. The mutation causes an increased risk of coronary heart disease even in the presence of elevated levels of HDL-C or 'good' cholesterol. Their findings are published this week in *Science*.

Previous research raised the possibility that HDL might not be quite as protective against heart disease as generally believed by cardiologists, especially after several clinical trials of HDL-raising drugs showed little or no effect. "The thinking about HDL has evolved recently to the concept that it may not directly protect against all heart disease," said senior author Daniel J. Rader, MD, chair

of the department of Genetics. "Our results indicate that some causes of raised HDL actually increase risk for heart disease. This is the first demonstration of a genetic mutation that raises HDL but increases risk of heart disease."

Rader and his colleagues sequenced the lipid-modifying regions of the genomes of 328 people with markedly elevated HDL (along with a control group with lower HDL) to identify genetic causes of high HDL. One of the genes they focused on was SCARB1, which encodes for Scavenger Receptor B1 (SR-B1), the major receptor for HDL on cell surfaces.

In the course of this sequencing, they identified, for the first time, a person without any SCARB1 function, typified by an extremely high HDL-C level of about 150 mg/dL, whereas the normal level is about 50 mg/dL. The subject had two copies of a SCARB1 mutation called P376L, which the team showed caused a breakdown in HDL receptor function.

Among the many approaches they took, the researchers generated induced pluripotent stem cells (iPSCs) from the SCARB1-deficient person, used them to create liver cells, and showed these new cells had profound reduction in their ability to take up HDL. "This mutation prevents the receptor from getting to the cell surface where it needs to be situated in order to bind and take up HDL," Rader explained. "This disruption in the receptor's job is due to mistakes in its folding and processing during protein synthesis."

Going back to the other sequenced genomes, the researchers were then able to show that persons who carry only one copy of the SCARB1 P376L mutation have significantly

higher HDL-C levels. From this, Rader and colleagues had a hunch, based on their knowledge of SCARB1 function and previous studies in mice, that having the SCARB1 P376L mutation, despite raising HDL, might paradoxically increase the risk of heart disease.

Working with other researchers around the world, the Penn team was able to show exactly what they had surmised. "This SCARB1 variant, while rare, is just frequent enough that it allowed us to ask the question about its effect on HDL and heart disease in people with only one copy of the mutation," Rader said.

The Penn team and their colleagues plan to characterise and test other SCARB1 mutations for their relationship to HDL levels and heart disease. Other genes may also have similar effects. "Eventually we may want to perform genetic testing in persons with high HDL to make sure they don't have mutations— like this one--that raise HDL but don't protect against, or may even increase, risk for heart disease," Rader said. Since the P376L mutation in SCARB1 appears to be specific to people of Ashkenazi Jewish descent, testing in this ethnic group might be particularly important.

Rader suggests that a therapeutic approach to increase the expression or activity of SCARB1 could be a new way to reduce the risk of heart disease even though it would reduce HDL blood levels. "The work demonstrates that the protective effects of HDL are more dependent upon how it functions than merely how much of it is present," Rader concluded. "We still have a lot to learn about the relationship between HDL function and heart disease risk."

## 'Ultra-processed' Foods make up more than Half of all Calories in US Diet

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Lady using a modern vending machine

*Credit: © kasto/Fotolia*

'Ultra-processed' foods make up more than half of all calories consumed in the US diet, and contribute nearly 90 per cent of all added sugar intake, finds research published in the online journal BMJ Open.

Ultra-processed foods are formulations of several ingredients. Besides salt, sugar, oils and fats, they include substances not generally used in cooking, such as flavourings, emulsifiers, and other additives designed to mimic the qualities of 'real foods'.

Ultra-processed foods include mass produced soft drinks; sweet or savoury packaged snacks; confectionery and desserts; packaged baked goods; chicken/fish nuggets and other reconstituted meat products; instant noodles and soups.

To assess the contribution of ultra-processed foods to the intake of added sugars in the US diet, the researchers drew on dietary data involving more than 9000 people from the 2009-10 National Health and Nutrition Examination Survey (NHANES), an ongoing nationally representative cross sectional survey of US civilians.

They looked at the average dietary content of added sugars and the proportion of people who consumed more than 10% of their total energy intake— the maximum recommended limit— from this source.

Ultra-processed foods made up over half of total calorie intake (just under 60%) and contributed almost 90% of energy intake from added sugars.

Added sugars represented 1 in every 5 calories in the average ultra-processed food product— far higher than the calorie content of added sugars in processed foods and in unprocessed or minimally processed foods and processed culinary ingredients, including table sugar, combined.

A strong linear association emerged between the dietary content of ultra-processed foods and the overall dietary intake of added sugars.

Furthermore, the proportion of people exceeding the recommended upper limit of 10% of energy from added sugars was far higher when ultra-processed food consumption was high, rising to more than 80% among those who ate the most ultra-processed foods.

Notably, only those Americans whose ultra-processed food consumption was within the lowest 20% had an average daily added sugar intake that fell below the maximum recommended limit.

Several leading health bodies, including the World Health Organisation, the Canadian Heart and Stroke Foundation, the American Heart Association, and the US Dietary Guidelines Advisory Committee have concluded that excess added sugar intake increases the risk not only of weight gain, but also of obesity and diabetes, which are associated with a heightened risk of cardiovascular disease, and tooth decay.

Cutting back on the consumption of ultra-processed foods could be an effective way of curbing excessive added sugar intake in the US, conclude the researchers.

## Prolonged Daily Sitting Linked to 3.8 per cent of all-cause Deaths

Sedentary behaviour, particularly sitting, has recently become a prevalent public health topic and target for intervention. As work and leisure activities shift from standing to sitting, increased sitting time is starting taking a toll on our bodies. A new study in the *American Journal of Preventive Medicine* found that sitting for more than three hours per day is responsible for 3.8% of all-cause mortality deaths. Investigators also estimate that reducing sitting time to less than three hours per day would increase life expectancy by an average of 0.2 years.

In order to properly assess the damaging effects of sitting, the study analyzed behavioural surveys from 54 countries around the world and matched them with statistics on population size, actuarial table, and overall deaths. Researchers found that sitting time significantly impacted all-cause mortality, accounting for approximately 433,000, or 3.8%, of all deaths across the 54 nations in the study. They also found that sitting had higher impact on mortality rates in the Western Pacific region, followed by European, Eastern Mediterranean, American, and Southeast Asian countries, respectively.

This type of information is crucial to evaluating the effect sitting has on our lives, especially in light of recent research that shows prolonged sitting is associated with an increased risk of death, regardless of activity level. Researchers now believe that periods of moderate or vigorous physical activity might not be enough to undo the detrimental effects of extended sitting.

While researchers found that sitting contributed to all-cause mortality, they also estimated the impact from reduced sitting time independent of moderate to vigorous physical activity. "It was observed that even modest reductions, such as a 10% reduction in the mean sitting time or a 30-minute absolute decrease of sitting time per day, could have an instant impact in all-cause mortality in the 54 evaluated countries, whereas bolder changes (for instance, 50% decrease or 2 hours fewer) would represent at least three times fewer deaths versus the 10% or 30-minute reduction scenarios," explained lead investigator Leandro Rezende, MSc, Department of Preventive Medicine, University of Sao Paulo School of Medicine.

Studies are beginning to show us exactly how detrimental prolonged sitting is for our health, even when coupled with exercise; however, changing habits is a difficult proposition. "Although sitting is an intrinsic part of human nature, excessive sitting is very common in modern societies," commented Rezende. "Sedentary behaviour is determined by individual, social, and environmental factors, all strongly influenced by the current economic system, including a greater number of labor-saving devices for commuting, at home and work, and urban environment inequalities that force people to travel longer distances and live in areas that lack support for active lifestyles."

The results of this analysis show that reducing sitting time, even by a small amount, can lead to longer lives, but lessening time spent in chairs may also prompt people to be more physically active in general. "Although sitting time represents a smaller impact compared with other risk factors, reducing sitting time might be an important aspect for active lifestyle

promotion, especially among people with lower physical activity levels," emphasised Rezende. "In other words, reducing sitting time would help people increase their volumes of physical activity along the continuum to higher physical activity levels."

The public health burden of prolonged sitting is real. Accounting for 3.8% of all-cause mortality in this study, sitting is shortening the lives of people across the world. "The present findings support the importance of promoting active lifestyles (more physical activity and less sitting) as an important aspect for premature mortality prevention worldwide, and therefore the need for global action to reduce this risk factor."

## **Change by the Bundle: Study Shows People are Capable of Multiple, Simultaneous Life Changes**

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Let's say you've decided to make some changes in your life. You're out of shape, your mind wanders, your self-esteem is wavering, and you have no idea what you just read. So you decide to focus on one thing— losing weight, maybe— and tackle the other issues later. You don't want to take on too much at once, right?

A new paper by researchers at UC Santa Barbara, however, suggests you're selling yourself short. "Pushing the Limits: Cognitive, Affective and Neural Plasticity Revealed by an Intensive Multifaceted Intervention," published this week in *Frontiers in Human Neuroscience*, strongly suggests that we have seriously underestimated our ability to change our lives for the better.

Michael Mrazek, director of research at UCSB's Center for Mindfulness and Human



Potential and lead author of the paper, said the six-week study from which the paper is drawn demonstrates that simultaneous and significant improvement across a broad range of mental and physical functions is possible. Participants in the intervention all showed dramatic improvements in more than a dozen different outcomes, including strength, endurance, flexibility, working memory, standardised test performance, focus, mood, self-esteem, mindfulness and life satisfaction.

"Part of what distinguishes this work is finding such broad improvements across so many different domains, particularly given that the effect sizes were so large," Mrazek explained. Large effect sizes signify that the results were not only statistically significant but also indicative of substantial changes. "Many of these effects were very large—larger than you tend to find in studies that focus on changing only one thing."

In the study, 31 college students were recruited for an intensive lifestyle change programme; 15 participated in the intervention and 16 were in the waitlist control group. Those in the intervention put in five hours a day each weekday for six weeks. They did 2.5 hours of physical exercise (including yoga and Pilates), one hour of mindfulness practice and 1.5 hours of lecture or discussion on topics such as sleep, nutrition, exercise, mindfulness, compassion, relationships or well being. They were advised to limit alcohol consumption to one drink a day, eat a diet of mostly whole foods and sleep 8-10 hours a day.

Throughout the study, the participants were tested on a variety of factors, including physical fitness, cholesterol and triglyceride levels, working memory capacity, reading comprehension and more. They also

underwent Magnetic Resonance Imaging (MRI) of their brains to examine areas known to be associated with a range of cognitive functions.

"The neuroimaging findings help us understand and contextualise the other significant results," Mrazek explained. "For instance, participants made dramatic improvements in their mindfulness, their reading comprehension, their working memory capacity. So we look to the neuroimaging data to understand what's happening in the communication between brain networks that's allowing for these changes."

Overall, the results were clear and striking, Mrazek said. Even six weeks after the intervention, participants continued to show improvement in all areas. "We predicted that the intervention would lead to substantial improvements in health, cognitive abilities and well-being, but we didn't know how long they would last. It seemed possible that some of the benefits wouldn't extend beyond the training. So I was surprised that even without any contact and support, participants maintained significant improvements at the six-week follow up."

Determining exactly why all these changes were possible will require future study, Mrazek noted, but he suspects that a comprehensive approach allows each area of improvement to reinforce the others. "Recent research suggests it's often more effective to make two or more changes simultaneously, especially when those changes reinforce one another. It's easier to drink less coffee if at the same time you get more sleep. Our intervention extended this logic by helping people make progress in many ways, which

can create an upward spiral where one success supports the next," he said.

Mrazek said conventional thinking about changing one's behaviour focuses on working on one thing at a time. This is also the way most science is done— manipulating just one thing and observing the effect. He and his team, however, decided to try a fresh approach. "It occurred to us that real changes in people's lives don't occur in a vacuum. We wanted to see how much change is possible if you help someone improve all these dimensions of their life simultaneously."

The study could have wide applications beyond the college campus, Mrazek noted. Although the subjects were college students, they weren't extraordinary in any way. "People showed up with all sort of different challenges, including in some cases mental illness and physical limitations. These were just college students, some of whom were doing great and others who were really struggling," he said. "More research is necessary to know if these results generalise to other populations, but there may eventually be opportunities for similarly modelled programmes to be integrated into education, medicine, or social services."

Students in K-12 schools might particularly benefit from programmes similar to the study's intervention, Mrazek said. "Many students spend nearly all day in school for 10 or more years of their lives," he observed. "Our intervention was fairly intensive in spending six weeks with these participants, but that's nothing in comparison to how much time kids spend in school. If future research can show similar benefits among middle school or

high school students, then multifaceted programmes like ours could help schools advance their priorities of improving both academic achievement and student well-being."

At the other end of the age spectrum, new retirees might also benefit from a programme to kick-start the next phase of their lives, Mrazek said. "My intuition is that these things can be very helpful at any age," he said. "I think there's a big opportunity for people who are finishing up their careers and hopefully have decades of life still to enjoy. They have time, wisdom and in some cases resources to contribute to the world. Could something like this help them avoid cognitive decline and find an exciting new way forward as they transition into a later stage in their lives? I think it might, and that's something we would like to assess in future research."

Jonathan Schooler, senior author on the paper and a professor in the Department of Psychological and Brain Sciences and director of the Center for Mindfulness and Human Potential, also observed that the research has both scientific and societal relevance. "This work advances society in demonstrating a straightforward route toward realizing people's full potential, and science in elucidating the brain mechanisms that may underpin such gains," he said.

Ultimately, Mrazek said, he'd like the study to be a source of optimism. "I hope this research raises a sense of possibility, and maybe even sense of expectation, about what is possible for someone who wants to improve his or her life," he said. But he also doesn't think we have all the

answers yet. "As encouraging as these results are, I think this is only a preview of what will ultimately be achieved through future interventions that draw on continual advances in science and technology," he said. "The true limits of how much a person can change is a mostly unexplored frontier of scientific understanding."

## Smartphones could improve Skin Cancer Detection in Developing Countries

With the help of a smartphone microscope, UTHealth's Richard Jahan-Tigh, MD, was able to detect non-melanoma skin cancer about 90 per cent of the time.

*Credit: The University of Texas Health Science Center at Houston (UTHealth)*

Everyone knows smartphones can be used as calendars, calculators, radios and cameras. But, did you know they can also be used as microscopes that have the potential to save lives?

They are called smartphone microscopes and dermatologists at the University of Texas Health Science Center at Houston (UTHealth) think these devices could improve the detection of skin cancer in developing countries.

"Doctors in some remote areas don't have access to the high-powered microscopes we use to evaluate skin samples," said Richard Jahan-Tigh, MD, Assistant Professor of Dermatology at John P. and Kathrine G. McGovern Medical School at UTHealth. "Doctors there could conceivably use their smartphones to photograph growths and forward them for examination."

When it comes to the diagnosis of cancer, smartphone microscopes are reasonably accurate, according to a study conducted by Jahan-Tigh and colleagues at McGovern Medical School and Harvard Medical School. Findings appear in the *Archives of Pathology & Laboratory Medicine*.

"We did a head-to-head comparison with a traditional light microscope and while the smartphone microscope wasn't as accurate it resulted in the detection of about 90 per cent of the non-melanoma skin cancers," said Jahan-Tigh, the paper's lead author. "With the smartphone microscope, the detection rate for melanomas was 60 per cent."

The incidence of both non-melanoma and melanoma skin cancers has been increasing in recent decades, the World Health Organisation reports. Between two and three million non-melanoma skin cancers and 132,000 melanoma skin cancers occur globally each year.

"This is a good first step to show that smartphone microscopy has a future in dermatology and pathology," Jahan-Tigh said.

A smartphone microscope can be made with a 3 mm ball lens, a tiny piece of plastic to hold the ball lens over the smartphone lens and tape to grip everything in place. A ball lens costs about \$14 at an electronics store and is typically used for laser optics.

Here is how a smartphone microscope works. A doctor or technician holds a smartphone microscope over a skin sample that has been placed on a slide and waits for the sample to come into focus. The doctor then either reads the sample if he or she is a pathologist, or takes a photo and emails it to a pathologist for its interpretation.

Researchers examined 1,021 slides of specimens, which had a total of 136 basal cell carcinomas, 94 squamous cell carcinomas and 15 melanomas. The smartphone microscope was used to pick up 95.6 per cent of the basal cell carcinomas and 89 per cent of squamous cell carcinomas.

Jahan-Tigh said additional studies are needed to enhance the detection rate.

Jahan-Tigh used a smartphone microscope to evaluate the specimens and the conventional microscope was operated by Ronald Rapini, MD, chairman of the Department of Dermatology, Marvin E. Chernosky, MD, Endowed Distinguished Chair in Dermatology and Josey, Professor in Dermatology with McGovern Medical School.

Both men are dermatologists and dermatopathologists, which means that in addition to being able to screen patients for skin cancer they can examine biopsied tissue to determine if it cancerous.

Rapini was the paper's senior author and Garrett M. Chinn, MD, of Harvard, a co-author.

In their conclusion, the authors wrote that mobile phone-based microscopy has excellent performance characteristics for the inexpensive diagnosis of non-melanoma skin cancers in a setting where a traditional microscope is not available.

"This is just the tip of the iceberg," Jahan-Tigh said.

## Detecting Radioactive Material from a Remote Distance

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Researchers have proposed a new way to detect radioactive material using two co-located laser beams that interact with

elevated levels of oxygen ions near a gamma-ray emitting source.

*Credit: Joshua Isaacs, et al/ University of Maryland*

In 2004 British national Dhiren Barot was arrested for conspiring to commit a public nuisance by the use of radioactive materials, among other charges. Authorities claimed that Barot had researched the production of "dirty bombs," and planned to detonate them in New York City, Washington DC, and other cities. A dirty bomb combines conventional explosives with radioactive material.

Although Barot did not build the bombs, national security experts believe terrorists continue to be interested in such devices for terror plots. Now researchers from the University of Maryland have proposed a new technique to remotely detect the radioactive materials in dirty bombs or other sources. They describe the method in a paper in the journal *Physics of Plasmas*, from AIP Publishing.

While the explosion of a dirty bomb would likely cause more damage than the radioactive substances it spreads, the bombs could create fear and panic, contaminate property, and require potentially costly cleanup, according to the US Nuclear Regulatory Commission.

Radioactive materials are routinely used at hospitals for diagnosing and treating diseases, at construction sites for inspecting welding seams, and in research facilities. Cobalt-60, for example, is used to sterilize medical equipment, produce radiation for cancer treatment,

and preserve food, among many other applications. In 2013 thieves in Mexico stole a shipment of cobalt-60 pellets used in hospital radiotherapy machines, although the shipment was later recovered intact.

Cobalt-60 and many other radioactive elements emit highly energetic gamma rays when they decay. The gamma rays strip electrons from the molecules in the surrounding air, and the resulting free electrons lose energy and readily attach to oxygen molecules to create elevated levels of negatively charged oxygen ions around the radioactive materials.

It is the increased ion density that the University of Maryland researchers aim to detect with their new method. They calculate that a low-power laser aimed near the radioactive material could free electrons from the oxygen ions. A second, high-power laser could energize the electrons and start a cascading breakdown of the air. When the breakdown process reaches a certain critical point, the high-power laser light is reflected back. The more radioactive material in the vicinity, the more quickly the critical point is reached.

"We calculate we could easily detect 10 milligrams [of cobalt-60] with a laser aimed within half a metre from an unshielded source, which is a fraction of what might go into a dirty bomb", said Joshua Isaacs, first author on the paper and a graduate student working with University of Maryland physics and engineering professors Phillip Sprangle and Howard Milchberg. Lead could shield

radioactive substances, but most ordinary materials like walls or glass do not stop gamma rays.

The lasers themselves could be located up to a few hundred metres away from the radioactive source, Isaacs said, as long as line-of-sight was maintained and the air was not too turbulent or polluted with aerosols. He estimated that the entire device, when built, could be transported by truck through city streets or past shipping containers in ports. It could also help police or security officials detect radiation without being too close to a potentially dangerous gamma ray emitter.

The proposed remote radiation detection method is not the first, but it has advantages over other approaches. For example, terahertz radiation has also been proposed as a way to breakdown air in the vicinity of radioactive materials, but producing terahertz radiation requires complicated and costly equipment. Another proposed method would use a high-power infrared laser to both strip electrons and break down the air, but the method requires the detector be located in the opposite direction of the laser, which would make it impractical to create a single, mobile device.

So far the researchers at the University of Maryland have analyzed the feasibility of the new approach and experiments are underway to test it in the lab.

Isaacs said it would be difficult to estimate when a detection device based on the new method might be commercialised, but he didn't foresee a specific manufacturing challenge that would stand in its way.

"We specifically chose well developed technology for each component of the proposed system," he said.

## Scientists Part the Clouds on How Droplets Form

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Cloud droplets form when the amount of water vapor reaches a threshold value. Larger cloud droplets form when organic molecules (in red) are present on the surface instead of dissolving in the interior, or bulk, of the droplet.

*Credit: James Davies, Berkeley Lab*

There is enough known about cloud formation that replicating its mechanism has become a staple of the school science project scene. But a new study by scientists at the US Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) reveals that much more is going on at the microscopic level of cloud formation than previously thought.

The scientists determined that organic molecules effectively depressed the surface tension of the water, allowing for more efficient formation of bigger cloud droplets.

"Conventional wisdom says that the water solubility of the aerosol is the key factor in the formation of cloud droplets," said study senior author Kevin Wilson, the deputy director of science at Berkeley Lab's Chemical Sciences Division. "The more easily a particle dissolves in water, the easier it is for a cloud droplet to form. What we're finding is that relying upon solubility alone doesn't always work. Our study suggests that what the aerosol is doing at the interface with water is what matters in

accurately predicting whether it will go on to form cloud droplets."

The findings, to be published in the March 25 issue of the journal *Science*, could improve the accuracy of climate change models that predict the potential cooling effect of reflective clouds based upon the particles in the air.

"Accurately describing the connection between the chemistry of aerosol particles and the formation of cloud droplets remains difficult, and it is a key challenge for models to correctly predict climate," said Wilson.

Wilson worked with study lead author Christopher Ruehl, who did the research while he was a postdoctoral scholar; and co-author James Davies, a current postdoctoral scholar at Berkeley Lab.

The devil's in the details

The current understanding of how cloud droplets form involves water vapor that encounters cooler air, often at higher altitudes and lower pressure. The vapor then condenses into small droplets of water or ice crystals that comprise clouds.

But the real catalyst in this process is the condensation of water on aerosol particles. These particles, known as cloud condensation nuclei, seed the formation of the cloud droplets. The details surrounding this microphysical process remain unclear, but the belief took hold among many atmospheric scientists and meteorologists that the main factor of significance when cloud droplets formed was the solubility of the aerosol.

These microscopic interactions could have macroscopic effects. The size of the droplets in a cloud affects its brightness. The smaller

and more numerous the droplets, the more light gets scattered. Reflecting more light has the effect of cooling earth's surface.

Certain inorganic particles, like sea salt, dissolve easily in water, but the atmosphere is typically a complex mixture of organic and inorganic aerosols. Sources of organic aerosols include diesel and gasoline emissions, forests, wildfires and even algal blooms in the ocean.

To account for this mix of particles, the Berkeley Lab researchers conducted experiments using custom-built equipment to model cloud droplet formation. They used dicarboxylic acids, a type of organic compound, and ammonium sulfate, an inorganic salt. They measured the size of the droplets formed when the particles were exposed to water vapor under typical cloud-forming conditions.

"We were finding that the cloud droplets were 50 to 60 per cent larger than predicted using standard models that relied upon how easily the particles could dissolve," said Ruehl, who is now an engineer studying vehicle emissions at the California Air Resources Board. "That's when we realised something else was going on, so we created a new model."

By factoring in the effects of surface tension depression, the researchers were able to correctly predict the size of the droplets formed.

"The role of inorganic and organic aerosols in cloud formation has been a highly contentious issue that's been argued about for many years," said Wilson. "Based on the paper's findings, I would say that these surface interactions play a central role in cloud

droplet formation, and that they should be considered in climate models."

## Embryo Development: Some Cells are more Equal than others even at Four-cell Stage

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This is a four-cell stage embryo.

*Credit: Zernicka-Goetz Lab, University of Cambridge*

Genetic 'signatures' of early-stage embryos confirm that our development begins to take shape as early as the second day after conception, when we are a mere four cells in size, according to new research led by the University of Cambridge and EMBL-EBI. Although they seem to be identical, the cells of the two day-old embryo are already beginning to display subtle differences.

Once an egg has been fertilised by a sperm, it divides several times, becoming a large free-floating ball of stem cells. At first, these stem cells are 'totipotent', the state at which a stem cell can divide and grow and produce everything— every single cell of the whole body and the placenta, to attach the embryo to the mother's womb. The stem cells then change to a 'pluripotent' state, in which their development is restricted to generating the cells of the whole body, but not the placenta. However, the point during development at which cells begin to show a preference for becoming a specific cell type is unclear.

Now, in a study published in the journal *Cell*, scientists at the University of Cambridge and the European Bioinformatics Institute (EMBL-EBI) suggests that as early as the four-cell embryo stage, the cells are indeed different.

The researchers used the latest sequencing technologies to model embryo development in mice, looking at the activity of individual genes at a single cell level. They showed that some genes in each of the four cells behaved differently. The activity of one gene in particular, Sox21, differed the most between cells; this gene forms part of the 'pluripotency network'. The team found when this gene's activity was reduced, the activity of a master regulator that directs cells to develop into the placenta increased.

"We know that life starts when a sperm fertilises an egg, but we're interested in when the important decisions that determine our future development occur," says Professor Magdalena Zernicka-Goetz from the Department of Physiology, Development and

Neuroscience at the University of Cambridge. "We now know that even as early as the four-stage embryo— just two days after fertilisation— the embryo is being guided in a particular direction and its cells are no longer identical."

Dr John Marioni of EMBL-EBI, the Wellcome Trust Sanger Institute and the Cancer Research UK Cambridge Institute, adds: "We can make use of powerful sequencing tools to deepen our understanding of the molecular mechanisms that drive development in individual cells. Because of these high-resolution techniques, we are now able to see the genetic and epigenetic signatures that indicate the direction in which early embryonic cells will tend to travel."

Source : Science Daily Online



## WEB WATCH

In this section, we present websites and a brief introduction about them. Inclusion of a site does not imply that *School Science* endorses the content of the site. Sites have been suggested on the basis of their possible utility to school systems.



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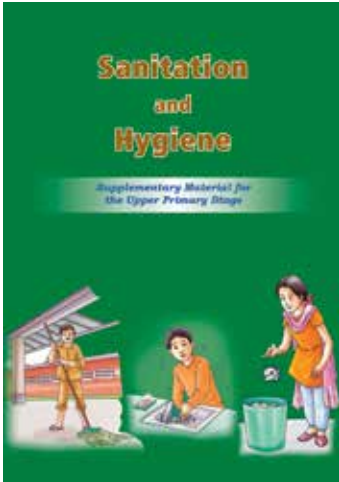
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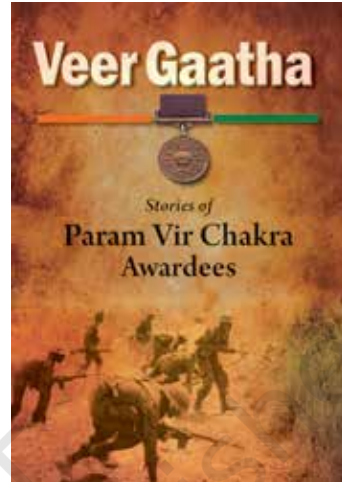
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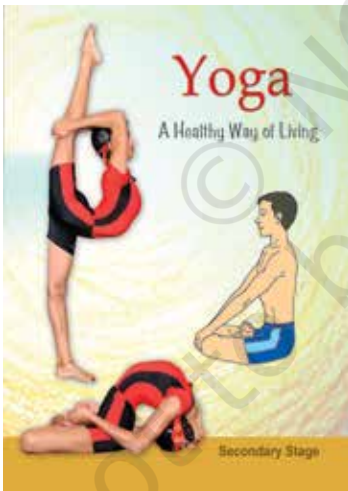
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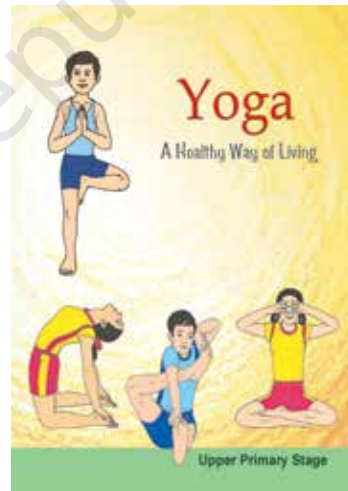
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