We can see with our ears too

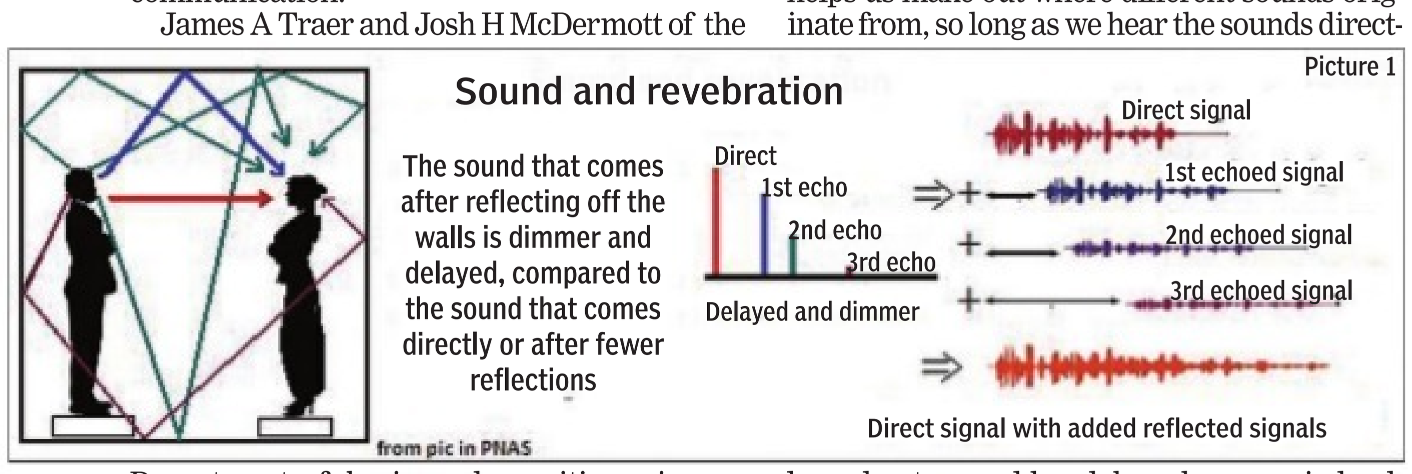
SENSING THE ENVIRONMENT WITH THE HELP OF SOUND IS NOT THE EXCLUSIVE DOMAIN OF BATS AND DOLPHINS, WRITES S ANANTHANARAYANAN

We become conscious of the environment through our senses — and the principal human senses are vision, touch and sound. Sight reveals colour and great spatial detail while touch makes us aware of heat and texture. Hearing is both an important medium of perception and in many species, the chief means of communication.

James A Traer and Josh H McDermott of the Department of brain and cognitive sciences, Massachusetts Institute of Technology, in their paper published in the journal, *Proceedings of the National Academy of Sciences* of the USA, point out that the signal the ears receive is a mixture of information from many sources and there is considerable distortion and duplication of sound waves before they are heard. The kind of distortion, however, depends on the geometry of the space around us, they say, and their research is about the mechanics of how biological systems are able to segregate sources and assess surroundings.

The principal difference in the way the eyes and ears function is that the eyes need to move and face the source of light but the ears react equally to sound that comes from all directions. The reason, of course, is that light, for practical purposes, travels in straight lines while sound waves, whose wavelength is in metres, passes freely around corners. And then, sound is also efficiently reflected by most surfaces. The result, however, is that the eyes are able to focus on specific objects and create a detailed map of the field of view, which is possible only to some extent for the ears.

Apart from the eyes being provided with lenses that focus objects clearly on the retina, which aids estimate of distance, the fact that we have a pair of eyes enables us to see "in depth" or to make out what objects are near and which ones are further away. An auditory parallel of such "stereoscopic" vision is "stereophonic" sound, where the fact that we have two ears helps us make out where different sounds originate from, so long as we hear the sounds directly, and not second hand, by echoes or via loudspeakers. In the case of depth vision, the effect is thanks to the slightly different views that each eye sees, because they are placed a few inches apart, and the brain learning to make use of the perspective.

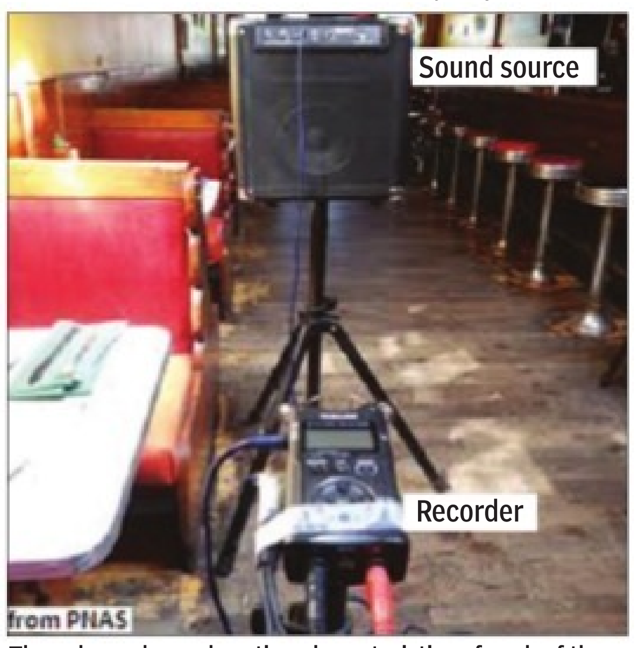


But in the case of sound, the separate ears receive, from each source, sound waves that are either a little louder or softer, or a little out of phase, which is to say, the stage of wave motion, depending on the distance from the ears. When the sounds are equally loud or in phase, of course, we sense the sound as coming from directly before or behind us. Even such limited judgment, however, is often obscured by the ears receiving sound that has been reflected off other objects or surfaces, which obscures the source and causes "reverberation".

Reverberation is an effect that can even result in speech being unintelligible because the echo of each word from the walls and roof a large hall runs into the sound of the following word.

The study of the MIT duo was regarding the characteristics of the ever-present reverberation of sounds in places — the ones people usually inhabit and what part of this people can actually discern — which helps them isolate the sources. Based on the experience of reverberation in known places, the study reveals that the brain is able to separate sound into contributions from the source and the environment. That helps recognition of sounds and also provides information about the surroundings.

In the case of bat or dolphins, the use of sound is much more effective and the animals' ears are the chief organ of navigation. The difference in these cases is that what the animals listen to are not sounds created by objects in the surroundings, but the distinct echo of a high pitched "click" that the animal itself generates. There would, of course, be an element of secondary echoes in the return sound that is heard, and this may contribute to enhancing the information received, in the manner that the MIT researchers have discovered in the case of human subjects of their study.



The echo and reverberation characteristics of each of the 271 identified places were measured. This was done by playing a fixed noise signal through a speaker, one metre away from a microphone which recorded what a person would hear. The MIT paper explains that what is expected to be heard is first the sound played and in quick succession, even running into the first sound, the first, second and third, or more, echoes, as shown in picture 1.

The first step in the study conducted was to see if there were statistical regularities in the reverberation space of the normal aural environment of people. If there was such a "normal" pattern, this may explain the observation that the brain is able to filter out the distortion caused by reverberation and purify the meaningful signal. The study therefore first identified places, which could be objectively considered a "normal" environment by tracking a group of volunteers with the help of random text messages 24 times a day for two weeks. The volunteers were required to respond by stating the place where they were when they received the message, and this generated a starting list of 301 locations, in the Boston metropolitan area — in 271 of them it was possible to conduct further study.

Trials at each of the 271 places resulted in data of the nature of sound energy received by a listener at these places, particularly the timing and amplitude of the echoes and the falling off of the loudness, as the sound died out. The result of the trials, the study says, was to find that there was a common feature of the way the later part of the sound decayed. This finding — that the reverberation that arises when sounds are generated in places which people frequent — has common characteristics, leads to the possibility that the brain, with experience, learns these patterns and can then devise a way to filter the distortion out.

The next part of the experiments was to play these sounds, and also synthetic sounds that had the same characteristics or had been modified, to human listeners, to see if they could make out the changes in the nature of reverberation. The result, the study says, was that the subjects were able to consistently identify the cases where the patterns were different from the normal. Next, the experimenters tested whether listeners could identify the part of the sound that came from the original source. Here again, the subjects gave statistically significant correct answers when the source sound was accompanied by a "natural" synthetic reverberation but not when the reverberation added was different from normal.

The study thus shows that the auditory system has a working method of using past experience to filter out the distortion caused by reflections from surroundings, which the listener is familiar with. This helps to both identify the source of the sound and also gives her an idea of "normal" surroundings, when the nature of distortion by echoes is like what is normally experienced. The ability, to take experience into account when data is distorted or insufficient, parallels what happens in the visual field too.

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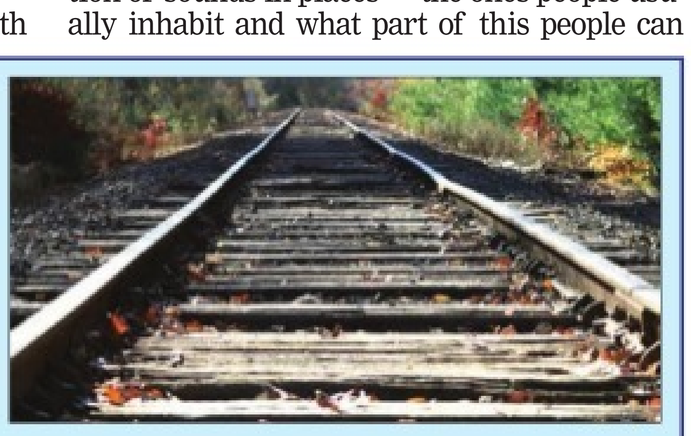
Seeing in depth



IT is the pair of slightly different images that are seen by each eye, which the brain puts together to create a three-dimensional image. But we still routinely see things with only one eye, even while driving, for instance, and we manage to make correct judgments of the distances of things. This is possible because the brain fills in "from experience", when the visual signals are inadequate, and generally does not go wrong.

One case where the brain is not able to compensate is when we take a photograph. The camera has only one lens and only one image is captured and "depth information" is hence lost in a photograph. This is the reason that photographs of things that have much depth like a landscape with nearby houses and distant mountains look flat and lifeless. But such photographs can be "brought to life" by deceiving the brain to enter the act and fill "in depth" information where none is there in the photograph. This is done by viewing the photograph not with both eyes but with one eye shut. The brain then does its bit and the photograph springs to life.

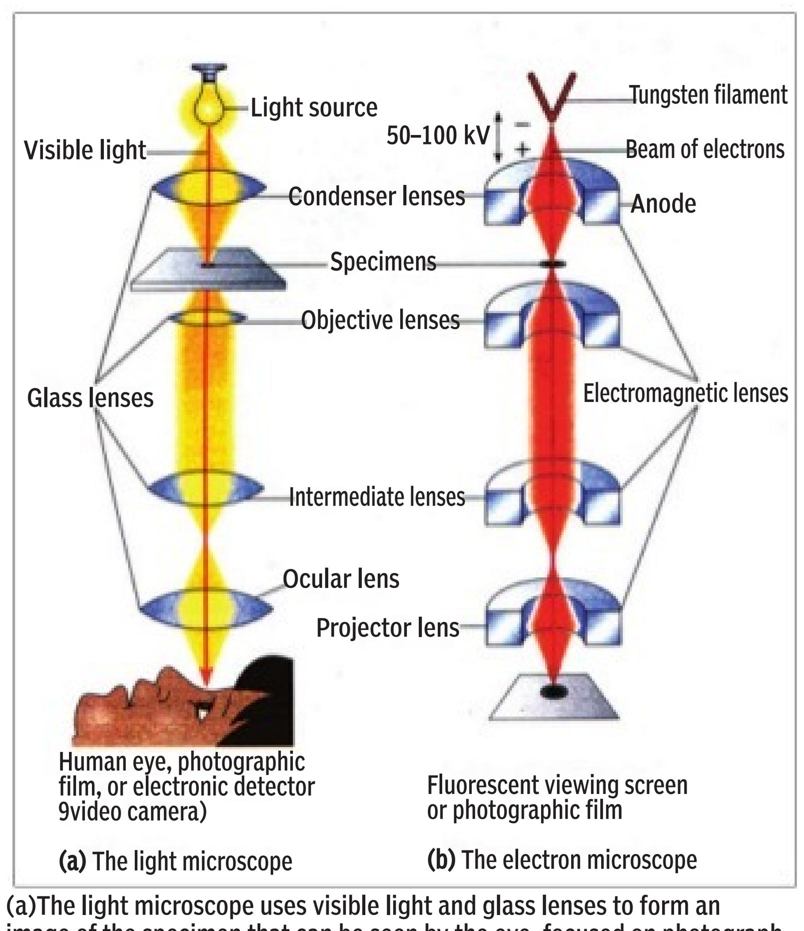
OF WAVES AND ITS FORMS

DESPITE DIFFERENCES IN ILLUMINATION SOURCE AND INSTRUMENT DESIGN, BOTH A LIGHT AND AN ELECTRON MICROSCOPE ADHERE TO THE SAME PRINCIPLES OF OPTICS, WRITES TAPAN KUMAR MAITRA

Cell biologists often need to examine the structure of cells and their components. The microscope is an indispensable tool for this purpose because most cellular structures are too small to be seen by an unaided eye.

In fact, the beginnings of cell biology can be traced to the invention of the light microscope, which made it possible for scientists to see enlarged images of cells for the first time. The first generally useful light microscope was developed in 1590 by Z Janssen and his nephew, H Janssen. Many important microscopic observations were reported during the next century, notably those of Robert Hooke, who observed the first cells, and Antonie van Leeuwenhoek, whose improved microscopes provided our first glimpses of internal cell structure. Since then, the light microscope has undergone numerous improvements and modifications, right up to the present time.

Just as the invention of the light microscope heralded a wave of scientific achievement by allowing us to see cells for the first time, the development of the electron microscope in the 1930s revolutionised our ability to explore cell structure and function. Because it is at least a hundred times better at visualising objects than the light microscope, the electron microscope ushered in a new era in cell biology, opening our eyes to an exquisite sub-cellular architecture never before seen and changing the way we think about cells forever.



(a)The light microscope uses visible light and glass lenses to form an image of the specimen that can be seen by the eye, focused on photographic film, or received by an electronic detector such as a video camera, (b) The electron microscope uses a beam of electrons emitted by a tungsten filament and focused by electromagnetic lenses to form an image of the specimen on a fluorescent screen, a digital detector, or photographic film.

But despite its inferior resolving power, the light microscope has not fallen into disuse. To the contrary, light microscopy has experienced a renaissance in recent years as the development of specialised new techniques has allowed researchers to explore aspects of cell structure and behaviour that cannot be readily studied by electron microscopy. These advances have involved the merging of technologies from physics, engineering, chemistry, and molecular biology, and they have greatly expanded our ability to study cells using the light microscope.

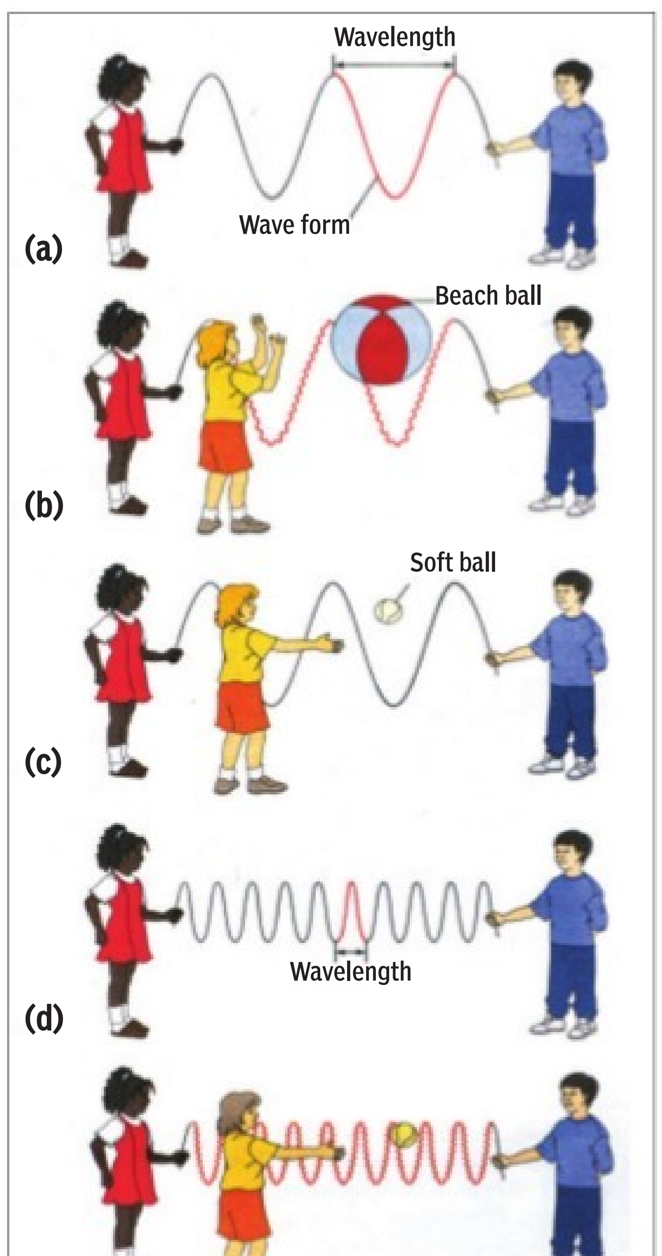
Although light and electron microscopes differ in many ways, they make use of similar optical principles to form images. Regardless of the kind of microscope being used, three elements are always needed to form an image — a source of illumination, a specimen to be examined, and a system of lenses that focuses the illumination on the specimen and forms the image. In a light microscope, the source of illumination is visible light, and the lens system consists of a series of glass lenses. The image can either be viewed directly through an eyepiece or focused on a detector, such as photographic film or an electronic camera. In an electron microscope, the illumination source is a beam of electrons emitted by a heated tungsten filament, and the lens system consists of a series of electromagnets. The electron beam is focused either on a fluorescent screen or on photographic film or is digitally imaged using a detector.

Despite these differences in illumination source and instrument design, both types of microscopes depend on the same principles of optics and form images in a similar manner. When a specimen is placed in the path of a light or electron beam, physical characteristics of the beam are changed in a way that creates an image, which can be interpreted by the human eye or recorded on a photographic detector. To understand this interaction between the illumination source and the specimen, we need to understand the concept of wavelength.

If two people hold onto opposite ends of a slack rope and wave the rope with a rhythmic up-and-down motion they will generate a long, regular pattern of movement in the rope called a wave form. The distance from the crest of one wave to the crest of the next is called the wavelength. If someone standing to one side of the rope tosses a large object such as a beach ball toward the rope, the ball may interfere with, or perturb, the wave form of the rope's motion. However, if a small object such as a softball is tossed toward the rope, the movement of the rope will probably not be affected at all. If the holders move the rope more rapidly, the motion of the rope will still have a wave form but the wavelength will be shorter. In this case, a softball is tossed towards the rope and it is quite likely to perturb the rope's movement.

This simple analogy illustrates an important principle — the ability of an object to perturb a wave motion depends crucially on the size of the object in relation to the wavelength of the motion. This principle is of great importance in microscopy, because it means that the wavelength of the illumination source sets a limit on how small an object can be seen.

To understand this relationship, recognise that the moving rope is analogous to the beam of light (photons) or electrons that is used as an illumination source in a light or electron microscope, respectively — in other words, both light and electrons behave as waves. When a beam of light or electrons encounters a specimen, the specimen alters the physical characteristics of the illuminating beam, just as the beach ball or softball alters the motion of the rope. And because an object can be detected only by its effect on the wave, the wavelength must be comparable in size to the object that is to be detected.



The wave motion of a rope held between two people is analogous to the wave form of both photons and electrons, and can be used to illustrate the effect of the size of an object on its ability to perturb wave motion, (a) Moving a slack rope up and down rhythmically will generate a wave form with a characteristic wavelength, (b) When thrown against a rope, a beach ball, or other object with a diameter that is comparable to the wavelength of the rope will perturb the motion of the rope, (c) A softball or other object with a diameter significantly less than the wavelength of the rope will cause little or no perturbation of the rope, (d) If the rope is moved more rapidly, the wavelength will be reduced substantially, (e) A softball can now perturb the motion of the rope because its diameter is comparable to the wavelength of the rope.

By this relationship between wavelength and object size, we can readily appreciate why very small objects can be seen only by electron microscopy — the wavelengths of electrons are much shorter than those of photons. Thus objects such as viruses and ribosomes are too small to perturb a wave of photons but they can readily interact with a wave of electrons.

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PLUS POINTS

Stunning new theory

A new theory of gravity explains the way galaxies rotate without the need for the theoretical presence of dark matter, according to a renowned expert in string theory. According to mainstream physics, more than 80 per cent of all matter cannot be seen. Its presence and the extra gravity it provides is required under current thinking to explain why stars do not fly off into the universe as their galaxies spin.

However, Professor Erik Verlinde of Amsterdam University has now published a research paper in which he argues his startling theory of "emergent gravity", first put forward in 2010, explains the movement without the need for dark matter, as per a report on the phys.org website. "We have evidence that this new view of gravity actually agrees with the observations. At large scales, it seems, gravity just doesn't behave the way Einstein's theory predicts," said Verlinde. The current theory of gravity appears to work well in most situations, but scientists have struggled to show it is compatible with the strange world of tiny particles described by quantum physics. It is thought that two of the most important theories of physics cannot both be true. According to his theory of emergent gravity, it is not one of nature's fundamental forces. Instead it "emerges" from changes in "information" stored in the structure of spacetime, in a similar way that temperature is produced by the movement of microscopic particles.

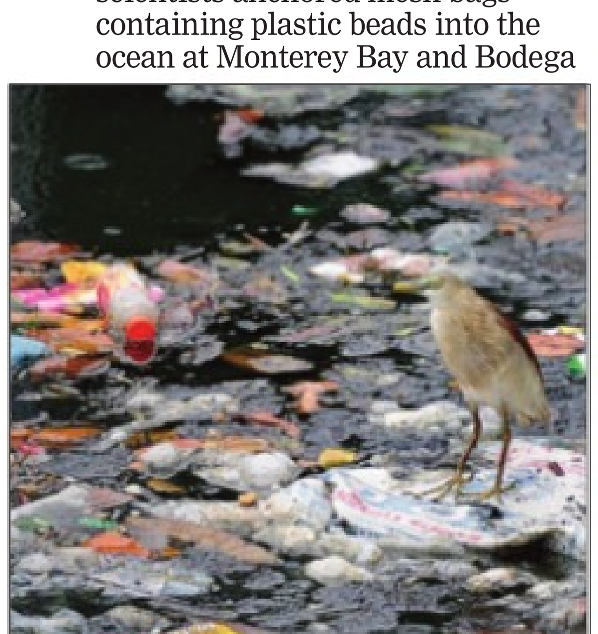
IAN JOHNSTON / THE INDEPENDENT

Smells of food

Sea birds gobble up plastic because it has a smell that reminds them of food, scientists have discovered. Plastic debris poses a serious environmental threat to many kinds of marine life, including fish, turtles and birds. But until now the reason why some sea birds have such a voracious appetite for the stuff has been a mystery. The new research shows that plastic waste in the ocean emits the aroma of a sulphurous compound certain birds have associated with food for thousands of years.

It effectively tricks them into believing plastic will provide a nutritious and healthy meal. Among the birds most severely affected by plastic consumption are "tube-nosed" species such as petrels and albatrosses which have a keen sense of smell. In some cases, the birds have been found with bellies full of plastic. US lead researcher Matthew Savoca, from the University of California at Davis, said, "It's important to consider the organism's point of view in questions like this. Animals usually have a reason for the decisions they make. If we want to truly understand why animals are eating plastic in the ocean, we have to think about how animals find food."

As part of the study the scientists anchored mesh bags containing plastic beads into the ocean at Monterey Bay and Bodega



Bay off the coast of California.

Previous research had shown that dimethyle sulphide is released when algae is eaten by animals such as krill, small crustaceans which are a favourite food of seabirds. For the birds, the smell of it is like a dinner gong telling them where to find a meal. Seabirds that track the scent to find prey are six times more likely to eat plastic than those which do not, the study published in the journal Science Advances showed.

JOHN VON RADOWITZ / THE INDEPENDENT