Resembling the lookalike

Light has been shown to behave like particles in the same way that particles behave like light itself, says s ananthanarayanan

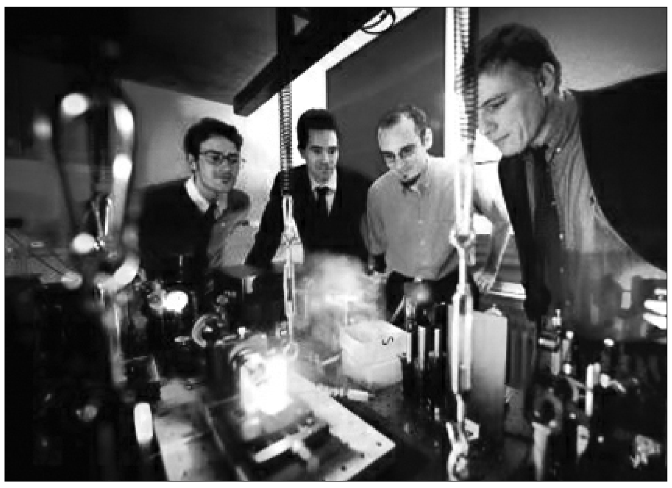
THE great revolution in physics in the early 20th century was the discovery that particles exhibited wave-like properties and that waves also carried momentum, which showed in their frequency. The wave-like properties of atomic and nuclear particles were formulated in the quantum theory, which led to very precise and verified computations.

Martin Weitz and colleagues at the University of Bonn have created a situation where light itself, while behaving like particles, exhibits an unusual property of particles that is actually wave-like!

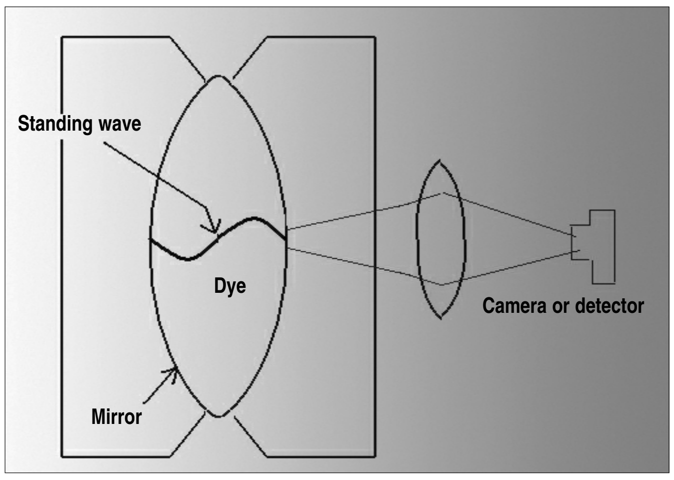
Many mysteries of physics in the early 20th century were explained by considering a light wave to propagate in packets with energy proportionate to its frequency. Energy means momentum and momentum means mass – hence, the photon, or the particle of light, which was "pure wave", was also found to have an effective mass!

It was this property of the photon that helped explain the photo-electric effect where light falling on some metals creates an electric current. The current is found to increase with the intensity of light and the voltage with the frequency of the light used. The phenomenon is exactly explained by taking light to consist of photons with a packet of energy that depends on their frequency. The colour of the light then decides the maximum energy that a photon can pass on to electrons in the metal, to give rise to the current. Incidentally, it was for this work that Albert Einstein got the Nobel Prize in 1926.

The other side of the coin was that particles themselves interacted like waves. Such wave-like behaviour, along with the laws of motion, naturally led to the rules of quantum mechanics, with the transfer of energy in steps, or "quanta", rather than smoothly, being linked to matter resonating in a wave-like way at the first, second or third harmonic, etc. The energy levels of atoms, molecules and nuclei, solid-state physics, nanotechnology, all of current day physics revolves around this manner of treatment of matter at small dimension.



Creators of the "super-photon": Julian Schmitt (from left), Jan Klaers, Dr Frank Vewinger and Dr Martin Weitz of the University of Bonn.



Superfluids

A most surprising property of certain forms of matter at small dimensions and at low temperatures is that they can start to flow without resistance. We are trained to expect that all motion is against some degree or resistance, or friction. In the case of fluids, this is expressed as viscosity, which shows in moving fluids as loss of energy in whorls and vortices. But superfluids overcome all resistance, can spontaneously creep out of a container and, once set in motion, will continue forever.

The way this phenomenon is explained is by considering that all particles of the fluid have collapsed into the same, low energy state, are indistinguishable and hence move as a single "mega particle" rather than separate particles. This works out when the physics of small dimensions is applied with a formulation for a kind of matter, the Bose-Einstein Statistics, discovered by the Indian, Satyen Bose, and refined by Albert Einstein.

The normal form of superfluidity is found only in particles that have a quantum mechanical quality called "spin", which is in whole numbers, like 0, 1, 2, rather than fractional ones, like ½ , 3/2, etc. These kinds of particles, the ones that have integral spin which are known as *Bosons*, follow rules of indistinguishable or "identical" particles. Typical bosons are the helium nuclei, which consist of two protons and two neutrons and hence have integral spin.

The argument for superfluidity is like this: if there are P different particles, which have to be in state A or state B, which have equal energy, the number of ways the particles can be distributed depends on whether they are identical or distinct. If they are distinct, there are 2^P ways in which the particles can be distributed. The distributions where the particles are equally divided between the two states are found to be the most numerous and this, in fact, is what is seen, statistically. If the particles are identical, however, the number of ways reduces drastically. If there are Q particles in state A, then the number in state B has to be P-Q. The distribution of particles within a state cannot be distinguished. So there can be only as many different states as there can be values of Q, which is zero to P, which comes to P+1.

But if the state A is of *slightly* higher energy than state B, then in the non-identical case the combinations with more particles in state B would slightly increase. But in the identical particle case, there is no statistical reason for equal numbers and all the particles are likely to collapse to state B. It is this collapse to the lowest energy state that accounts for the unusual bulk properties of superfluidity.

Photons

What has been described is a brief account of the way particles that are identical can distribute themselves. As a result of the wave-like behaviour of particles at very small dimensions, this distribution of energies results in an entanglement of the state of all the particles and very low energies, like in the case of liquid helium, and the particles begin to exhibit overt, macro-scale "herd behaviour", specifically in the form of superfluidity. Matter in this superfluid state has a characteristic statistical distribution of particles in the lowest energy states and the critical conditions when superfluidity sets in.

Photons, or the particles of light, are also particles with spin zero, which is integral spin, which makes them bosons. Photons should hence exhibit superfluidity just like other bosons. But the reason this does not happen is that photons, unlike material particles, do not exist for ever. Even when they are reflected, in fact they are being absorbed and re-emitted and their numbers are not fixed. Whatever, the condition of "flow without resistance" may mean in the case of photons, the fact that their numbers are not fixed makes them fundamentally different. But the question remains, what would photons be like if they, like atoms of a gas, were fixed in number?

The Bonn experiment

Weitz and colleagues at Bonn have devised an experimental set-up that creates this condition – where photons exist with conservation of numbers. Their process was to trap light between a pair of curved reflectors, so that light formed a standing wave between the reflectors, like a guitar string between the bridge and the fret. As the dimensions were of the order of microns, the frequency of the standing wave was exceedingly high. The space between the reflectors was also filled with a dye, but the frequency of the photons was much higher than that corresponding to the temperature of the dye.

This effective temperature difference has the impact that there is not much change in the energy of the photons when they interact with the particles of the dye. This leads to a pair of systems in equilibrium, particularly the photons not undergoing a change in numbers, just like the numbers of the bulk of atoms of a gas do not change except at a spot seen in isolation, as the atoms move around.

These are typically the conditions where the so called "Bose-Einstein condensation" of the gas condensing to the superfluid state is observed. The Weitz group has found, sure enough, a great similarity between the photon gas between the reflectors and any gas in the condensed state, one feature of which is the typical distribution of energy. Another is the change of state taking place at just the photon density expected.

Reducing a sample of photons to a condensed energy state has implications, for one, in the production of light at a uniform frequency and phase, as in a laser. This technique would enable creating laser light at UV and X-Ray frequencies, which are difficult to realise.

But this apart, the achievement has academic importance in that here is typically particle behaviour that has been mimicked in a photon context. It is a step forward in the march of interchangability between mass and energy, particles and waves, and their properties, which has been the hallmark of physics in the last century.

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How dino demise led to super-sized mammals

We would not have elephants today had it not been for the death of Argentinosaurus, one of the biggest-ever dinosaurs, and others like it. steve connor **explains**

SCIENTISTS have conclusively demonstrated for the first time that the demise of the dinosaurs created the ecological opportunity for the diminutive prehistoric mammals of the time to become the largest creatures on earth today. A worldwide study of fossilised mammals has demonstrated beyond any doubt that it was the extinction of the dinosaur some 65 million years ago that was the key trigger leading to the explosive growth of the warm-blooded mammals.

Although it was long suspected that this was the reason for the transition from dinosaur dominance to mammalian supremacy, a thorough investigation of fossil mammals dating back 140 million years has confirmed that we would not have elephants today had it not been for the death of Argentinosaurus, one of the biggest-ever dinosaurs, and others like it. The study found that for the first 40 million years or so of their existence, the mammals were mostly small, shrew-like creatures that lived in a narrow range of habitats. However, after the dinosaur disappeared, the mammals evolved relatively rapidly into much larger creatures capable of exploiting a wide variety of ecological niches, from leaf-eating giant sloths to tundra-munching mammoths.

"Basically, the dinosaur disappeared and all of a sudden there is nobody else eating the vegetation. That's an open food source and mammals start going for it, and it's more efficient to be a herbivore when you're big," said Professor Jessica Theodor of the University of Calgary in Canada. "You lose dinosaurs 65 million years ago and within 25 million years the system is reset to a new maximum for the animals that are there in terms of body size. That's actually a pretty short time frame, geologically speaking. That's really rapid evolution."

The study in the journal *Science* found that many different types of mammals grew into gigantic forms on different continents. The biggest was a hornless rhinoceros-like herbivore that lived in Eurasia 34 million years ago called Indricotherium transouralicum, which weighed 17 tons and stood 18 feet high at the shoulder – four times the size of a modern elephant. Being big is an advantage in a habitat with a large landmass of lots of vegetation, although it can make species vulnerable to sudden extinction if the environment changes rapidly.

With the dinosaur gone, and no other large animals already on earth to take their place, the scene was set for the mammals to evolve into bigger and bigger forms that could better exploit the natural resources available to them. "Nobody has ever demonstrated that this pattern is really there. People have talked about it, but nobody has ever gone back and done the math. We went through every time period and said 'OK, for this group of mammals that's the biggest one.' And then we estimated its body mass," said Professor Theodor.

John Gittleman of the University of Georgia, who took part in the study, said that the fossil record for mammals was better than for many other animals, which was a key factor that helped to nail down the main conclusion. "Once the dinosaur went extinct, mammals evolved to be much larger as they diversified to fill the ecological niches that became available. This phenomenon was well documented in North America. We wanted to know if the same thing happened all over the world," Dr Gittleman said. "Having so many different lineages independently evolve to such similar maximum sizes suggests that there were similar ecological roles to be filled by giant mammals across the globe."

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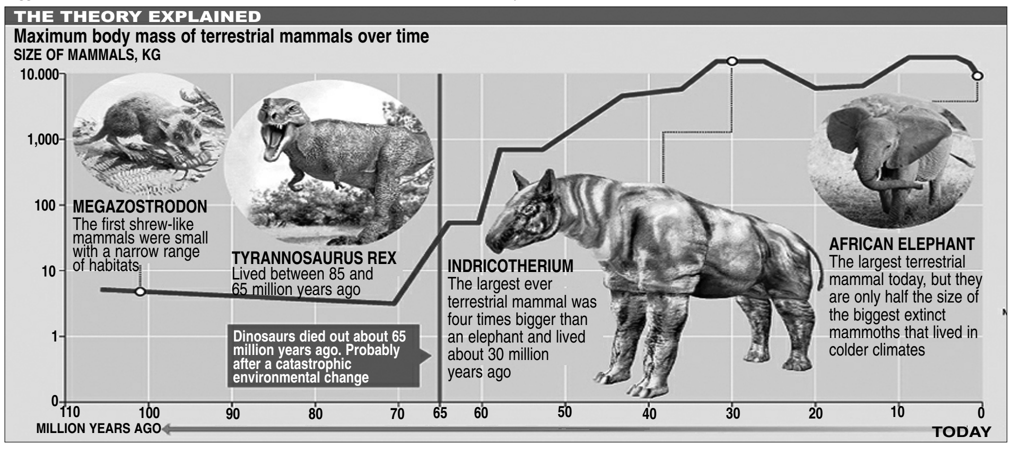


Microbial subversion

tapan kumar maitra **underlines some basic forms of antibiotics resistance and possible ways of countering lethal pathogenic organisms**

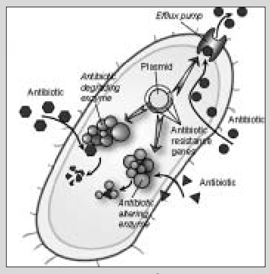
WITH the extensive use of antibiotics in medical practice, many species of pathogenic micro-organisms have become resistant to them. Resistance may develop to one or, simultaneously, to many antibiotics — multiple resistance.

The molecular mechanism of the production of resistance to antibiotics is determined by genes localised in the bacterial nucleoids or in the plasmids — the cytoplasmic transmissible genetic structures.

Resistance to antibiotics occurs as the result of a disturbed translation of genetic information, the altered synthesis of the polypeptide chain, diminished permeability of the cytoplasmic membrane and cell wall and the formation — due to the effect of R-plasmids — of enzymes inactivating antibiotics: ampicillin, chloramphenicol, kanamycin, streptomycin and tetracycline.

Mutations according to the nucleoid genes, leading to antibiotic resistance, form with a frequency of 10^{-6} to 10^{-12}. Owing to which, the occurrence of simultaneous mutations to two and more antibiotics is excluded; they may develop, however, as the result of independent mutation in a strain primarily resistant to one of the antibiotics.

Resistance to penicillin is linked with penicillinase (b-lactamase) synthesis controlled by one of the genes of the R-factor. Penicillinases are synthesised under the effect of not only the R-factor genes but also the nucleoid genes. Resistance to chloramphenicol is determined by the action of the enzyme — chloramphenicol acetyl-phenicolacetyl transferase coded by the gene of the R-factor. Five enzymes are responsible for the resistance to antibiotics of the aminoglycoside group. Inactivation of antibiotics in the R+ strains with multiple resistance is accomplished by three types of reactions — phosphorylation, acetylation, and adenylation. It has been established that a bacterial cell may be resistant to more than one antibiotic by one gene.



Mechanisms of antibiotic resistance in bacteria.

Due account is given in medical practice to cross-resistance to antibacterial agents which have the same chemical structure. It has been found to exist between preparations of the tetracycline series and new semisynthetic antibiotics (morphocycline, glycocycline, dibiomycin, and ditetracycline), preparations of penicillin (benzylpenicillin, phenoxymethylpenicillin, ephycillin), compounds of the nitrofuran group and between sulphanilamides.

Due to the wide distribution of staphylococci resistant to antibiotics a search for new preparations became necessary. At present semisynthetic staphylococcal penicillin has been obtained which has a distinct bacteriostatic action on resistant strains of pathogenic staphylococci. With the isolation of the penicillin nucleus, 6-aminopenicillinic acid, it became possible to obtain various derivatives of penicillin.

Dimethylchlorotetracycline from the group of tetracyclines is used for the treatment of many infectious diseases and in doses half as strong as tetracycline. A good result has been obtained in treatment of inflammatory processes of the urinary tract. With the discovery of the antibiotic griseofulvin dermatology was enriched with an effective preparation with the help of which diseases of the skin, hair and nails caused by fungi imperfecti could be treated.

Some antibiotics have a poisonous effect on rats, insects and mites. They are used for exterminating rodents and arthropods, the vectors of infectious diseases. Antibiotics — kormogrisin, chlortetracycline, etc — stimulate the growth of animals and fowl, and are, therefore, widely used in agriculture.

Of interest is the very difficult problem of chemotherapy of viral diseases. At present there are no effective drugs against viral infections. This is due to the biological peculiarities of viruses as obligatory intracellular parasites, which must be acted upon by other means than those used in microbial diseases. In recent years, many new antibiotics have been obtained which have a good effect in the treatment of murine leucoses. Some of them are employed successfully in agriculture for treating fowl leucoses.

It has been established that large doses of penicillin and streptomycin have a neurotoxic action, tetracyclines affect the liver, chloromycetin has a toxic effect on the haematopoietic organs and chlortetracycline and oxytetracycline upon intravenous injection may lead to collapse with a lethal outcome. Upon injection of penicillin and streptomycin a rash, contact dermatitis, angioneurotic oedema, anaphylactic reactions or allergic asthma may occur. Quite frequently, allergic reactions arise during local application of antibiotics. Of the utmost practical importance is their indirect action, which is mainly due to the development of resistant strains of micro-organisms, sometimes causing furuncles or severe generalised diseases which develop, vigorously, in some cases with a lethal outcome. In case of the application of antibiotics with a wide spectrum of action, infections may develop which are caused by resistant strains of Proteus and fungi.

Staphylococcal colitis proceeds very severely and is characterised by profuse diarrhoea, dehydration, shock and collapse. Of great hazard is the formation of resistant staphylococci which cause various postoperative complications — persistent furunculosis and staphylococcal septicaemias. A severe complication is anaphylactic shock from the use of penicillin in which a rapid drop in blood pressure, cyanosis, superficial breathing, loss of consciousness and convulsions are observed.

The use of preparations which block selectively R-plasmid replication and those which promote the elimination of antibiotic modifying enzymes can, hopefully, counter multiple antibiotic resistance.

The writer is associate professor of botany, Ananda Mohan College, Kolkata