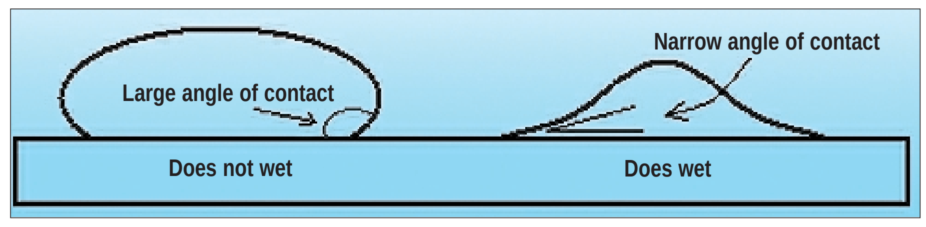
Slip up and slide in

A plant that traps animals by luring them on to a slippery surface has inspired new materials, says
s ananthanarayanan



THE *Venus Fly Trap* is a well-known insect-eating plant. Its leaves are divided into two lobes that are hinged along the midriff. Sensitive hairs on the lobes sense the entry of an insect and, with the same mechanism as in nerve action, they cause the midriff to collapse and the leaves snap shut.

Another kind of trap used by plants is of the *butterwort* family, which has sticky surfaces, like flypaper. Once an insect is caught, the leaf may roll up or form a depression to secure and digest the prey. The *bladderworts* change the salt concentration inside cavities to force water to flow out, creating a vacuum. Trigger hairs that respond to prey open a doorway through which the animal is sucked in by the vacuum, to be digested within the bladder. The *corkscrew* plant uses a lobster-pot trap — inward pointing spikes that allow entry but restrict exit!

But a common variety of carnivores is the *pitfall trap* kind, also called *pitcher plants* — the edges of the leaves are connected to form a cone, or a pitcher, and the insides are made slippery so that an animal that falls in cannot clamber out. The openings secrete nectar to lure animals and the nectar has evolved to contain the alkaloid, *coniine*, a component of hemlock, which makes the prey lose its footing! These plants routinely trap animals as large as mice or frogs. The nature of the slippery surface, which can shrug off water and dirt as efficiently as the oily surface of an animal's feet, has been of interest to create industrial materials.

Tak Sing Wong and others at Harvard University report in the journal *Nature* that the surface of *Nepenthes*, the insect-eating pitcher plant, has helped them develop a synthetic, slithery material that is robust and versatile.

The lotus effect

Lotus leaves and petals are celebrated for their water repelling quality, which keeps them clean and fresh even in grimy water. As water does not wet the lotus material, the water grabs any dirt on the surface and rolls off, leaving the surface clean and dry. The reason for the lotus effect, then, is that water does not adhere to the surface and the droplets, to keep their surface area to the minimum, take on a spherical shape. Whether a liquid adheres to a material or not depends largely on atomic composition and whether the atoms of the liquid attach to the surface more than they attract to themselves.

The angle that a drop of liquid makes at the point of contact with the surface is an indicator. The picture shows the angle of contact in a drop of water on an oily surface, which water does not wet, and on a sheet of glass, which water does wet.

When the liquid does not wet the surface, it tries to compress itself into a ball. But in the other case, it tries to maximise the surface in contact by spreading out. In very small drops, the internal attraction is strong and the drops remain spherical, even if the surface is attractive. Conversely, even when the surface is repelling, very large drops will spread out because of the weight. Apart from atomic structure, in the case of the lotus leaf, the actual surface in contact is restricted by creating an irregular surface through

Tak Sing Wong.

microscopic protrusions called *papillae*, coated with a water-repelling wax. Because of the protrusions, air is trapped and only a small part of a water droplet is actually in contact with the leaf, and the droplet just does not adhere, but runs off.

Oil repellent

Many initiatives to mimic the lotus leaf structure have been taken and there are now a number of water-repellent synthetic surfaces used for waterproofing, keeping surfaces moisture free to prevent ice formation, etc. But the limitation in being only "lotus like" is that the surfaces are not protected against wetting by oily liquids. The atomic structure of the water molecule has uneven distribution of charge, which makes for its strong tendency to cling and minimise its surface. In the case of oils, this quality is not there and they do not readily form droplets. As organic and oil-based contaminants are common, a surface that repels both water as well as oils would have wide application.

Another limitation of "lotus like" surfaces that have been developed is that they buckle under pressure and can be damaged. Along the lines followed for mimicking the lotus leaf, attempts to create *oleophobic* (or oil repelling) surfaces involved creating complex surface geometries to restrict the area of contact of oily liquids, but with limited success. The method used by the Harvard group, reported in *Nature*, has been to follow an alternate route, of the Nepenthes, pitcher-plant, rather than the way of the lotus leaf.

In Nepenthes, the objective is to prevent the feet of insects and small animals, which are coated with natural oils, from getting a grip on the "pitcher" surface. This means the surface has to be "oil repelling", so that the oil interface with the animals' feet "slides", rather than attach to the surface. At the same time, the plants are found in areas of heavy rainfall and the surface needs to be waterproof, or water-repellent too.

The way Nepenthes manages all this is in a way that is different from the lotus leaf. In place of posing irregularities to restrict the area of contact, Nepenthes places a layer of liquid lubricant between the surface and the animal's feet or oil or water droplet. The lubricant is held in place by protuberances, albeit not regular, on the plant's "pitcher" surface and it presents a smooth surface to the insect's feet. The material is oil-repellent and does not let the feet, which are coated with fats, get a grip. As pitcher plants are usually in high rainfall areas, there are spillways to let out the water that collects, except at the bottom where there are digestive juices that extract nutrients from the trapped animals.

Slips

The Harvard group has imitated the Nepenthes model in the form of Slippery Liquid-Infused Porous Surfaces, which is a synthetic surface with high "slip quotient". The base of the material is a sponge-like substrate, impregnated with the lubricating liquid. When a droplet of another liquid is placed on the surface, the lubricant keeps the droplet away from the base material, acting somewhat like the air trapped in the protuberances on the lotus leaf. But the lubricant also forms a plane surface, like the lubricant in Nepenthes, and lets the drop, with no point of attractive contact, move rapidly away. As the lubricant can be chosen to be oil- or water-repellent, or even not compatible with both, the surface can be effectively "all purpose". Such surfaces can then be used to withstand composite liquids, part water-like and part oil-like.

In addition, unlike the surfaces constructed on the lotus leaf model, these surfaces can be built to withstand high pressures and as the medium is liquid, can even flow and repair scratches and localise damage. Further, by suitable selection of the base and lubricant materials, the surface can have a desired colour and transparency, enabling display applications, in addition to flow control of liquids or solids coated with liquid films.

With a variety of commercially available lubricants, the researchers are extending their use of Slips and anticipate application in biomedical fluid handling, fuel transport, anti-fouling, anti-icing, self-cleaning windows and optical devices, and areas that are beyond the reach of current technology.

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Mushroom magic

Given the social prejudices regarding food habits in India, these fungal growths are a storehouse of much required animal protein, says tapan kumar maitra

IN a developing country like India the problem of malnutrition continues to posing a serious threat at the national level, with about 80 per cent of children suffering from severe undernourishment. Protein malnutrition is an acute problem and India has the lowest rate of consumption at present. In spite of a good availability of animal protein, social prejudices regarding eating habits in this country create a problem for the proper utilisation of animal sources. As such, various nutrition scientists and the administration have been trying to find other ways of supplementing protein production.

In this regard, consider mushrooms. These have long been established as a food. An absolutely fungal product, mushrooms are edible, palatable and highly nutritive because of their *Basidiomycetes* fungi. Analyses of mushrooms have revealed they are appreciably rich in protein, vitamin, carbohydrates and minerals and ample published evidence has already accumulated in favour of their edibility and digestibility. Rural people, constituting the "low income group", are mostly underfed and undernourished. Tribals, particularly those inhabiting forest areas, collect edible mushrooms that proliferate during the rainy season. What they don't consume they sell in local markets.

There are more than 2,000 species of edible fungi reported throughout the world and about 200 species are available in India. Eight to 10 of these species have been cultivated so far, the common ones being *Agaricus bisporus, Volvariella volvacea, Flammulina velutipes, Plenrotus ostreatus, P. sajor-caju, Tricholoma matsutake, Trimella fusiformis, Auricularia polytricha* and *Agrocybe agerita.* The use of mushrooms is possibly as old as civilisation itself and they were earlier preferred for their specific odour and taste. Later, their nutrition value was recognised. On a dry weight basis, mushrooms are comparatively richer in protein content than cereals, pulses, vegetable, etc, their proteins having 60-80 per cent digestibility. They contain all the Essential Amino Acids, as also a significant amount of carbohydrates, minerals and water on a fresh weight basis. They rich in vitamins B, C, D, and K and minerals like calcium, potassium, phosphorus, iron and copper. They are completely devoid of starch and so can constitute a good item in the diet of diabetics.

The remarkable point is that the vitamins are well retained during cooking, drying, canning and freezing. There are even reports that indicate their potential as life-saving drugs, antibiotics and a biologically active substance Moreover, mushrooms have various industrial uses.

Lintzel's (1943) experiments proved that the proteins of *Psalliota campestris, Boletus edulis* and *Morchella esculenta* were comparable to muscle protein. The nutritional contribution of some mushrooms to the human diet have been comparatively evaluated with that of milk, meat and egg yolk (Fenelli, 1968). Research by Torev and Stefanov (1969) reported that *Tricholoma nudum, Cantharellus cibarius* were of high biological value as they contained high percentage of *lysine, phenylalanine, arginine, threonine, methionine* and *cystine.*

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Nanotech's mega hazards

What's good for industry isn't necessarily good for human health, writes
dinsa sachan

NANOTECHNOLOGY has revolutionised industry. It is used to improve a wide range of products, from cosmetics, toys and toothpastes to textiles and missiles. Industry thinks the technology holds promise to change every facet of life in some way. Substances at nano scale, or nanoparticles, demonstrate novel physiochemical properties compared to larger particles of the same substance. Their use, thus, helps improve products. But their safety to human health and the environment has not been understood well.

To encourage the use of nanoparticles, build capacity and promote research, the Department of Science and Technology launched Nano Mission in 2007 under the 11th Plan. It is set to end in 2012, but there is no policy yet to regulate the use of nanoparticles.

This despite the Indian Institute of Toxicology Research calling it toxic and recommending guidelines in February this year for their safer handling in research laboratories. The report was authored by a team of scientists called the Nanomaterial Toxicology Group. The IITR receives funds from the Nano Mission to conduct research on the impact of nanoparticles.

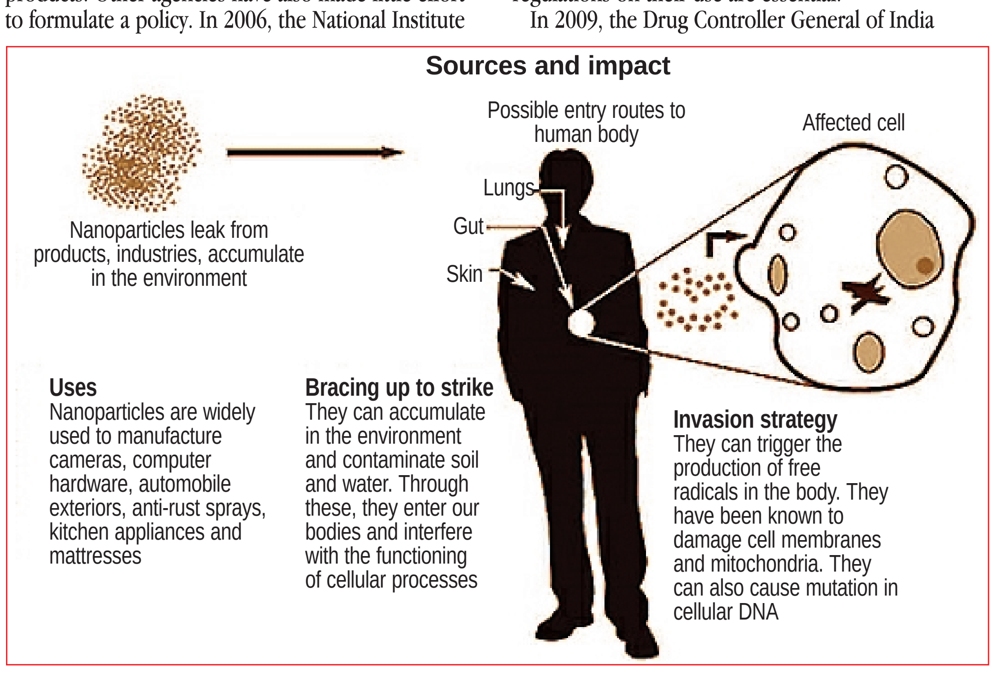
"The aim is to help the government introduce a policy on nano safety," says Mukul Das, one of the authors of the guidelines. "We have sent our document to the regulatory authorities and are waiting for the guidelines' implementation at the national level." But it seems doubtful considering the DoST's past approach towards the subject. Of the Rs 1,000 crore earmarked for Nano Mission, the department set aside only Rs 9 crore for assessment of the hazards of nanotechnology.

"We do not know who will regulate what," says Praveer Asthana, director of Nano Mission. At present, the department is orchestrating a debate and a taskforce to make a regulatory framework, he adds.

Under the Nano Mission, research institutes across the country were given projects to develop and promote products using nanoparticles. Some of these were commercialised and rolled into the market. At present, there are more than 200 nanoparticle-based products. Other agencies have also made little effort to formulate a policy. In 2006, the National Institute of Pharmaceutical Education and Research launched a programme to formulate guidelines for the use of nanotechnology in drug delivery. After five years, there is no word on its progress. KB Tikoo, head of the nanotoxicology department at Niper, justifies the delay. "Guidelines take long to be formulated," he says.

"Is the government waiting for mishaps to happen? They can't treat us like guinea pigs," says Gopal Krishna, convenor of ToxicsWatch Alliance, an environmental non-profit organisation. Separate researches on the ill effects of nanoparticles are being carried out, but most are still inconclusive. However, there is evidence that nanoparticles are harmful and regulations on their use are essential.

In 2009, the Drug Controller General of India recalled Albupax, a nano-based medicine for breast cancer. US firm Abraxis BioScience had complained against the maker, Natco Pharma of Hyderabad, saying the drug damaged the liver.



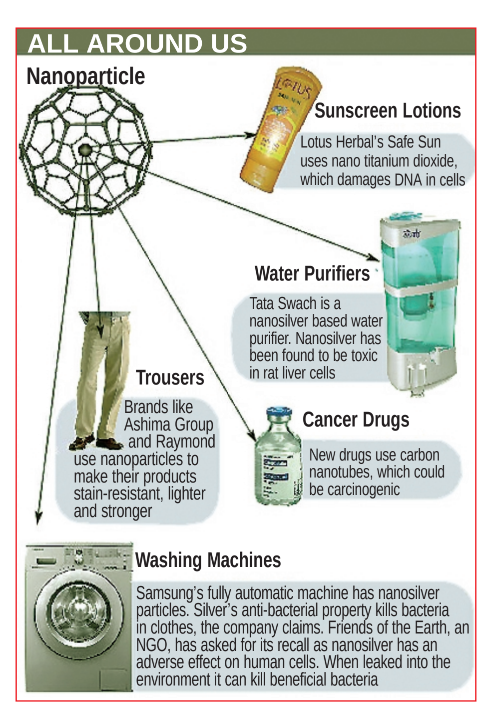
The generic failed the DCGI test. The same year, the deaths of two factory workers were reported in China. At least six workers of the same factory developed serious lung ailments. Researchers at Chaoyang Hospital in Beijing linked these to continued inhalation of nanoparticles. The factory was making paint with nanoparticles.

"In medicines, nano particles are so tiny that they can pass through the blood-brain barrier," says Barry Castleman, environment engineer and consultant. "They are toxic, but this is little understood." Carbon as graphite used in pencils is innocuous, he says. But carbon nanotubes show alarming similarities to asbestos.

Nanoparticles of zinc and titanium oxide damage DNA in cell lines, the IITR found. The two are important constituents of sunscreen lotions.

The indiscriminate use of nanosilver is detrimental to children's immune system, Friends of the Earth, an international environmental NGO, found. Nanosilver has anti-bacterial properties, but its unrestricted use weakens children's ability to fight infections. Nanoparticles accumulate in the environment and kill beneficial bacteria. A study by Iowa State University in the USA found that nanotitanium dioxide particles interfered with the genetic functioning of zebra fish embryos.

While the world lags in concrete nanotech-specific regulations, Australia has shown the way. In May this year, teachers in Victoria urged schools to ban sunscreens that contained nanoparticles. In August this year, the Danish Enviromental Protection Agency released risk profiles of nanoparticles used in many consumer products.



To understand the impact of nanoparticles on human health, the US Food and Drug Administrator established a nanotechnology taskforce in 2006. In January this year, it issued draft guidelines on the safe use of nanoparticles in consumer products. The European Commission's Reach, a regulatory framework for chemicals, has not suggested a policy that covers nanomaterials but it does call them substances that need to be tested. Nidhi Srivastava at the Energy and Resources Institute in Delhi says,

"There's concern that the procedures Reach has outlined for testing may not be sufficient." The European Commission has not come up with a policy for nanomaterial safety, but it has definitely been instrumental in initiating a debate on the issue, she says.

Regulation is essential, but is also difficult. "Nanoparticles behave differently in different products," says Srivastava. Nanosilver, for instance, behaves differently in a washing machine than in paint. Regulatory bodies, therefore, have to develop a framework that encompasses this aspect of nanomaterial. The DoST should now facilitate a dialogue among the concerned departments to formulate a sound policy, she adds.

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