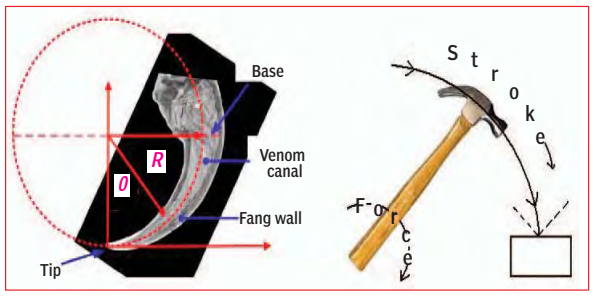
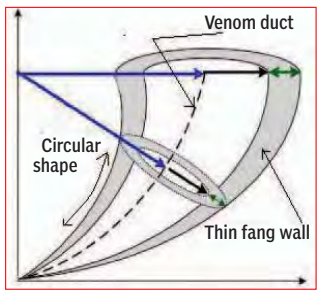
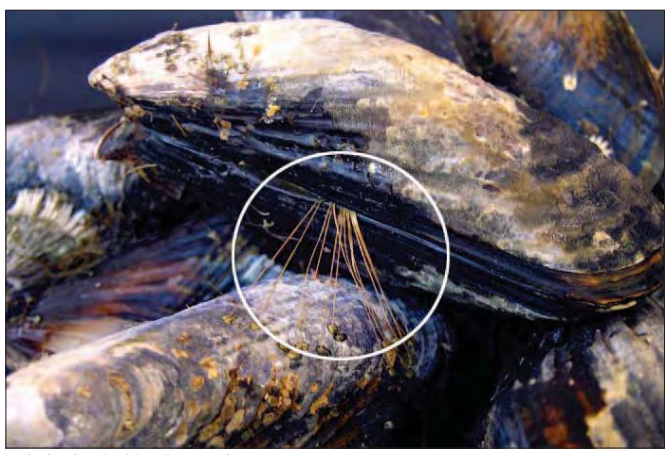
# The spider bares it fangs

## THIS ARACHNID PACKS A LEAN MACHINE IN ITS STINGING HOOK, SAYS **S ANANTHANARAYAN**





Anchoring threads of the zebra mussel.

The spider feeds almost entirely on insects and other spiders, usually trapped in its web and incapacitated by a jab of the creature's fang, which injects the victim with venom. Apart from this organ, the spider does not have a real jaw or teeth and it partly digests its food *in situ*, and takes only liquids into its proper digestive system.

The spider's prey, in turn, use ways to escape from the web, which the owner impedes by throwing out further strands while the victim struggles, and the prey also have hard a body covering to save themselves from the deadly jab of the spider's fang. The fang, then, needs to be hard and strong and also not too rigid, so that it can take the compression, bending and twisting in the course of an attack.

In a report in the journal *Nature Communications*, Benny Bar-On, Friedrich G Barth, Peter Fratzl and Yael Politi at the Max Planck Institute of Colloids and Interfaces, at Potsdam, Germany, and the Faculty of Life Sciences at Vienna, examine the design and architecture of the spider fang and suggest that the understanding may "lead to the development of novel bio-inspired engineering materials with superior characteristics".

The researchers note that natural structures are adapted to the difficult and conflicting demands placed on them, primarily by managing how the material of their components is distributed. This could be both by having the most suitable shape and also by using different grades of material in the construction of portions of limbs, as well as differences in the microstructure.


The fang is about two millimetres long. The spider itself is about 25 mm long

The threads by which some species of clam, for instance, attach themselves to rocks are made up of two kinds of structural protein, and the ratio of the mix changes from the nearer end to the farther end, making the farther end stiffer, while the nearer end is flexible, so that the thread can stand heavy impact loads.

The composition of the turtle shell and the beak of the squid similarly vary the materials and the way they are laid out to optimise functions of hardness and lightweight.

The Potsdam and Vienna group modelled the same features of the fang of a large, wandering species of spider and tried out different combinations of structure and distribution of materials to understand how the actual form in the natural spider fang made it more functional.

The spider's fang, which is made of the same material as horns and nails, is a part of the arachnid's mouth parts and is connected to the body by a hinge joint and a set of muscles. While the fang can be used like a limb for cleaning or widening the egg sac to release baby spiders, its main function is to pierce the hard armour of insects and inject them with venom, as also to hold down prey, like a claw. For this exacting purpose, the tip of the fang needs to be hard, and the whole fang needs to resist damage that could arise over repeated encounters with insect prey.

The fang itself is a hollow, curved cone, curved to be able to strike with the greatest impact, hollow to contain the venom duct and conical for mechanical strength. The material of construction is chitin, a fibrous polymer, embedded in a protein-rich framework. The researchers used models of the fang, based on data already available, and analysed the mechanical properties of stiffness and hardiness, which the model assumed with different forms of internal architecture.

The first observation was that the shape of the centre line of the natural fang was that of a circle, with the venom duct lying along the curve. The width of the fang reduces uniformly, over the length of the quarter circle, to end in a sharp point at the tip. The effect of the curved shape was to lend maximum impact, like the striking of a hammer, for its particular function, and unlike the mosquito stylet or bee stinger. And then there was the tapering, conical profile.

Trying out the model, the spider fang revealed that the hollow, conical shape of the natural fang, where its width increased uniformly as one moved from the tip to the base, as the picture shows, is one that provides the best possible stiffness, while using the least material. The combination of the curve and the tapering hollow cone gives the fang the highest efficiency in being able to deliver a powerful blow, with a weapon of the greatest strength, and yet at the least cost.

The widening of the shape as one moves away from the tip also increases the capacity of the fang to bear the load of the strike. While the high pressure of impact is borne by the tip, which has a harder material composition, the load is distributed over a larger surface towards the base of the fang, permitting softer and less rigid structures. This design permits 10 times the load that a needle-like structure can bear.

In addition to high impact, the fang is also subject to shear and twisting forces. This challenge is met by a graded pattern in the way the material of the fang is arrayed. The tip of the fang, the composition of which is rich in atoms of metals to give it greater stiffness, has fibres predominantly oriented *in parallel*, as opposed to a *plywood type* orientation. This provides for greater ability to penetrate and moderate resistance to shear forces, as arise in twisting. The fibre orientation gradually changes to more of the plywood type as one moves towards the base, which makes for damage resilience.

The study, carried out with models where different factors, like the thickness of the wall, the chitin-protein mix, or the parallel-plywood structure could be varied, has revealed that at the relevant scale the natural spider fang architecture is the best adaptation for its bio-mechanical function. Understanding the mechanics of the spider fang would help better appreciate what pressures drove the evolution of other sharp-edge structures, like the scorpion stinger or the elephant tusk.

While this study was at the larger scale distribution of material and structure, the authors of the paper say that further studies at the molecular level may lead to greater insight.

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# A REACHABLE GOAL

## **TAPAN KUMAR MAITRA** ELABORATES ON THE GENE THERAPIES BEING DEVELOPED FOR TREATING HUMAN DISEASES

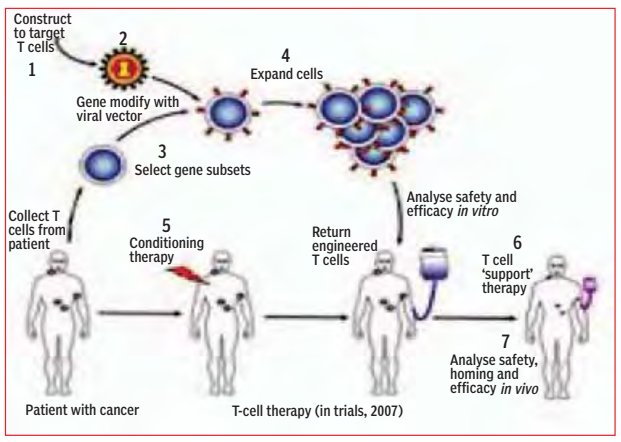
We suffer from many diseases that might conceivably be cured by transplanting normal, functional copies of genes into people who possess defective, disease-causing genes. One of the first successful demonstrations of the feasibility of gene transplantation was reported in animals by Richard Palmiter, who transferred the gene for growth hormone into a mouse egg, thereby creating a transgenic mouse that carried a gene from another organism in its cells. His success raised the question of whether gene transplantation techniques might be applied to the problem of repairing defective genes in humans. Obvious candidates for such an approach, called gene therapy, include inherited genetic diseases like cystic fibrosis, hemophilia, hypercholesterolemia, hemoglobin disorders, muscular dystrophy, lysosomal storage diseases and an immune disorder called Severe Combined Immuno-Deficiency.

The first person to be treated using gene therapy was a four-year-old girl with a type of Scid caused by a defect in the gene coding for Adenosine Deaminase (Ada), the loss of which activity leads to an inability to produce sufficient numbers of immune cells called T lymphocytes. As a result, the girl suffered from frequent and potentially life-threatening infections. In 1990, she underwent a series of treatments in which a normal copy of the cloned Ada gene was inserted into a virus that was used to infect T lymphocytes obtained from her blood, and the lymphocytes were then injected back into her bloodstream. The result was a significant improvement in her immune function, although the effect diminished over time and the treatment did not seem to help most Scid patients.

In the years since these pioneering studies, there has been considerable progress in developing better techniques for delivering cloned genes into target cells and getting them to function properly. In 2000, French scientists finally reported what seemed to be a successful treatment for children with Scid (in this case, an especially severe form caused by a defective receptor gene rather than a defective Ada gene). By using a virus that was more efficient at transferring cloned genes and by devising better conditions for culturing cells during the gene transfer process, these scientists were able to restore normal levels of immune function to the children treated. In fact, the outcome was so dramatic that for the first time these children were able to leave the protective isolation "bubble" used in the hospital to shield them from infections.

But it was a great disappointment when two of the 10 children treated in the initial study developed leukemia a few years later. Examination of their leukemia cells revealed that the virus used to deliver the corrective gene had inserted itself next to a normal gene that, when expressed abnormally, can cause cancer to arise. Exactly how can such an event, called i*nsertional mutagenesis*, initiate cancer development?

This outcome was an unexpected setback because the virus possessed no gene or other feature that would have allowed scientists to predict its cancer risk. We should not, of course, lose sight of the fact that these studies also provided one of the first hopeful signs that gene therapy can cure a life-threatening genetic




disease. But the associated cancer risks must be better understood before further progress is possible.

One tactic for addressing the problem of cancer risk is to change the type of virus being used to ferry genes into target cells. The Scid studies employed retroviruses that randomly insert themselves into chromosomal DNA and possess sequences that inadvertently activate adjacent host genes. Another type of virus being investigated as a vehicle for gene therapy, called Adeno-Associated Virus, is less likely to insert into chromosomal DNA and less likely to inadvertently activate host genes when it does become inserted. Some encouraging results using this virus have been obtained in patients with hemophilia, an inherited disease characterised by life-threatening episodes of uncontrollable bleeding. In gene therapy trials, several hemophilia patients were injected in the leg with AAV containing a gene coding for the blood-clotting factor that they require. A few months later, their leg muscles were producing the blood-clotting factor in sufficient quantities to briefly ameliorate, although not cure, the disease. This was an intriguing discovery because, unlike the Scid trials, where genes were inserted into isolated cells that had been removed from the body, the hemophilia studies used a gene-carrying virus that was injected directly into people.

In the years since the enormous potential of gene therapy was first publicised in the early 1980s, the field has been criticised for promising too much and delivering too little. But most new technologies take time to perfect and encounter disappointments along the way, and gene therapy is no exception. Despite the setbacks, it appears likely that using normal genes to treat genetic diseases is a reachable goal that may one day become common practice, at least for a few genetic diseases that involve single gene defects.

Of course, the ability to alter people's genes raises important ethical, safety and legal concerns. The ultimate question of how society will react to the growing ability to change the human genome is an issue that will need to be thoroughly discussed, not just by scientists and physicians but by people at large.

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# Better than Google

## WHILE INDIVIDUAL 'SCOUT' ANTS MAY SEEM CHAOTIC IN THEIR MOVEMENTS, THEY ARE LEAVING A PHEROMONE TRAIL TO ALLOW OTHER ANTS TO FOLLOW THEM TO FOOD SOURCES, WRITES **JAMIE MERRILL**

The dedication and stamina of the worker ant, toiling through the summer months and preparing for winter, were celebrated in Aesop's Fables — in contrast to the lazy, singing grasshopper, unready for the hardships ahead. Now research shows that ants don't just flourish because they work hard and will slavishly sacrifice themselves for the collective. Their success is also due to their group ability to process information "far more efficiently than Google" in the daily search for food, according to scientists.

A major behavioural mathematics study, which could also have ramifications for how we understand human behaviour on the Internet, used complex computer modelling to reveal how ants bring order to chaos by creating "highly complex networks" to govern their actions. It found that not only are ants "surprisingly efficient", they are also able to deploy ingenious navigation strategies to divide themselves between "scout" and "gathering" ants during "complex feed-search movements".

The joint Chinese-German study, which is published in *Proceedings of the National Academy of Sciences*, found that while individual "scout" ants may seem "chaotic" in their movements, they are leaving a trail of pheromones to allow following "gathering" ants to refine and shorten their journeys to food sources in the vicinity of the colony.

As this journey is repeated again and again by worker ants carrying their loads, a "self-reinforcing effect of efficiency" creates a shorter trail, saving the colony the time and energy of "continued chaotic foraging".

"While single ants can appear chaotic and random-like, they very quickly become an ordered line of ants crossing the woodland floor in the search for food," co-author of the study Professor Jurgen Kurths said.

"That transition between chaos and order is an important mechanism and I'd go so far as to say that the learning strategy involved in that is more accurate and complex than a Google search. These insects are, without doubt, more efficient than Google in processing information about their surroundings."

Previous studies had shown that worker ants tended to assign the most dangerous food-gathering tasks to older, less valuable insects. This suggested that ant colonies were reluctant to risk their younger, more productive members.

However, the new study shows that older ants are valued for their increased knowledge of their nest's surroundings. According to Professor Kurths, the mathematical model used in the study — which converted well-known ant behaviour patterns into equations and algorithms — is equally applicable to other animals that share homing instincts, such as albatrosses.

It could even be used to provide a "new perspective" on behavioural patterns of humans in areas as diverse as transportation systems and how we browse the Internet. The study comes a week after a team from the Georgia Institute of Technology revealed that ants' skills at building stable tunnels in loose sand could aid in the design of a new generation of search-and-rescue robots. The team used high-speed cameras to observe how fire ants used their antennae as extra limbs to catch themselves when they fell, in a development that could be reproduced to arrive at fledgling rescue technologies.

THE INDEPENDENT


Ants were found to create "highly complex networks" in their search for food.

## PLUS POINTS


Scientists in 2004's *Eternal Sunshine of the Spotless Mind* were able to wipe painful memories, but with complicated results.

### Erasing bad memories

Scientists hope a new drug can be repurposed to erase painful memories from people who have suffered trauma and pain. Experiments on mice have found that fingolimod, a multiple sclerosis drug, could rid them of the memories of physical pain.

In an experiment, published in *Nature Neuroscience*, mice were fed the drug and then given a mild electric shock. These rodents tend to stop moving when their anxiety is high and fear the chamber where they were given the shock, but that behaviour rapidly reduced when they had taken fingolimod.

Scientists hope the drug can be used to remove the bad feelings associated with traumatic events, which can then be relearnt without the painful memories. That process is known as "fear extinction". That could help rid sufferers of post-traumatic stress and phobias from their anxiety and trauma.

But researchers have struggled to find a drug that could suppress those feelings successfully. Hopes had previously rested on drugs that suppress an enzyme known as HDAC — but while some experiments using those drugs have found success, others seem to amplify memories. Others have been unable to cross the blood-brain barrier.

The team studying fingolimod hopes it might be able to develop a new version of the drug that has the memory-suppressing effects but avoids changes to the immune system. Scientists have been attempting to heal painful memories for decades, but progress has picked up quickly over the last 10 years. In 2004, the film, *Eternal Sunshine of the Spotless Mind*, was released, depicting a couple that chooses to erase their memories. It is likely never to be possible to remove individual memories without destroying others, but the pace of progress towards real solutions for painful memories and trauma has picked up.

ANDREW GRIFFIN/THE INDEPENDENT

### Death traps

The latest urban air quality database released by the World Health Organisation reconfirms what we already know — that most Indian cities are becoming death traps because of very high air pollution levels. India appears among the group of countries with the highest Particulate Matter levels. Also, its cities have the highest levels of PM10 and PM2.5 (particles with a diameter of 10 microns and 2.5 microns) when compared to other cities. The Who's urban air quality database covers 1,600 cities across 91 countries and it shows that Pakistan has the highest PM2.5 level of 101 microgramme/cubic metre, followed by Qatar, Afghanistan, Bangladesh, Iran, Egypt, Mongolia, United Arab Emirates (range of 92 to 61 microgramme/cubic metre) and India with 59. These countries have PM2.5 levels that exceed safe levels prescribed by Who by six to 10 times.

This database confirms our worst fears about how hazardous air pollution is in our region. Last year, the ""Global Burden of Disease" study pinned outdoor air pollution as the fifth largest killer in India after high blood pressure, indoor air pollution, tobacco smoking and poor nutrition; about 620,000 early

deaths occurred in India from air pollution-related diseases in 2010.

The PM10 and PM2.5 database contains data of 124 Indian cities and an analysis indicates that all India's cities exceed the Who guideline of 20 microgramme/cubic metre for PM10. In the case of PM2.5, except one city (Pathanamthitta in Kerala, is at the guideline limit of 10), all exceed the Who guideline of 10 microgramme/cubic metre.

The PM2.5 levels are worst in Delhi and Patna, exceeding the guideline by about 15 times, followed by Gwalior, Raipur, Ahmedabad, Lucknow and Ferozabad, all exceeding the safe levels by nine to 14 times. Kanpur, Amritsar, Ludhiana, Allahabad, Agra, Jodhpur, Dehradun and Chandrapur closely follow the above-mentioned hot spots.

What also becomes clear is how weak our National Ambient Air Quality Standards are in protecting public health. If we consider our standards as a yardstick to compare the air quality — then 60 cities would meet the PM2.5 standard and 21 cities, PM10. This is because our standards are three to four times more lax compared to Who guidelines.

VIVEK CHATTOPADHYAY/CSE-DOWN TO EARTH FEATURE SERVICE