Through the looking glass

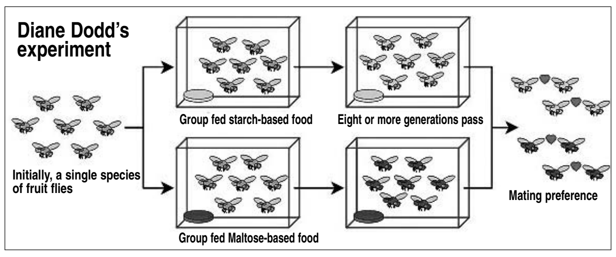
Circumstances encourage a form of evolution generally thought impossible, says
s ananthanarayanan

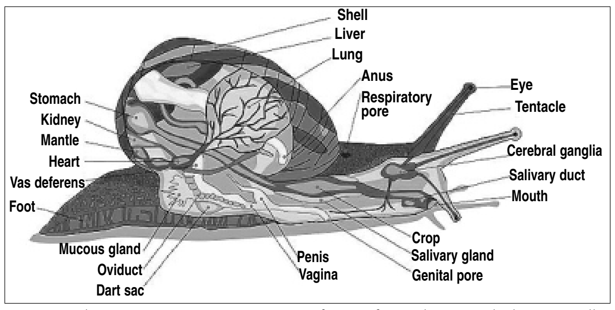
EVOLUTION takes place when a small change in an organism confers a survival advantage and, in time, the evolved population grows apart, into a separate species. Masaki Hoso and colleagues in different institutes in Japan report, in the journal *Nature*, an instance of a separate population growing despite a reproductive disadvantage, thanks to the same feature also keeping predators away.

The snail is a remarkably evolved creature that carries with it its shell, which is its habitation and its protection from elements and predators. In fact, the snail has no bones unless we say it has its skeleton on the outside! Many of the snail's organs are within the shell and the whole can retract into the shell when desired. For efficiency and economy, the shell is shaped as a coiled tube — the coil helps keep the dimensions manageable and grows narrower towards the centre, which gives protection.

But because the shell is coiled, there is the question of which way the coil goes round. The vast majority of snails have shells that go round clockwise, very few with shells that go round counter-clockwise. The first kind are called *dextral* , or right-handed, and the second kind is *sinistral*, or left-handed.

But this handedness of the snail has a serious consequence that opposite-handed snails cannot easily reproduce! Right-handed snails, which are the great majority would, thus, mate only with their own kind and the question about left-handed snails, which effectively form a separate species, is how they came about and continue to exist.





Masaki Hoso reports that Pareas iwasakii*, the snail-eating snake, has lopsided jaws to better enable it to tug snails out of their shells. Most snails have shells that whirl clockwise (to the right) so this snake has evolved an upper jaw with more teeth on the right side than the left.*

Speciation

The emergence of a new species happens when portions of a population accumulate genetic differences to the point that they can only reproduce within themselves. When species diverge, it usually happens because a population is divided, physically, by a mountain or a river, so that there can be no "gene exchange", or when populations migrate and evolve separately. This is the most common way and is called *allopatric speciation*. The term means "other fatherland" and what happens is that there is a "habitat fragmentation". Over time, they undergo a "genetic drift" and become reproductively incompatible.

Another method is by domesticated animal husbandry. While the mechanisms are not clear, in the case of domestic sheep, they no longer produce viable offspring with some of their ancestral species. But domestic cattle can be considered the same species as many varieties of wild ox, gaur, yak, etc, are able to effectively breed with them.

Biologist Diane Dodd was able to show that only eight generations of dietary separation can create speciation via mating preferences in fruit flies.

Milder forms of allopatric speciation are in *peripatric* and *parapatric* speciation, where there is partial separation of populations. But *sympatric* speciation is when an ancestral species grows into two or more, while still in the *same* location. While there are instances of insect populations that become dependant on different host plants, whether the sympatric is a separate mechanism or only a form of micro-allopatric speciation, is not decided.

It is in this context that the emergence of the sinistral snail population, within a predominantly dextral community, presents a paradox.

Genes and evolution

Genetic changes that lead to evolution often come about with changes in only a few genes that control a large number of features. Handedness, which arises in all species, is controlled by a set of genes called *Nodal*, which control the multiplication of cells in different places to develop as the particular organs. Deficiency in Nodal, for instance, causes asymmetries and congenital heart defects in about eight of 1,000 newborns.

Handedness in snails is found to depend on a single maternal gene in at least four kinds of common snails that have lungs. Genetically engineering snails to select for this gene could, thus, generate separate dextral and sinistral populations. Such left-to-right reversal, in fact, has been observed to arise frequently and repeatedly among land snails, and not by genetic manipulation. The question is: how can such a mutation, when it occurs, be sustained when the reverse handedness is a direct reproductive handicap?

Predator specialisation

What Masaki Hoso and colleagues have discovered is that reverse-handedness, in fact, confers such a survival advantage, willy-nilly, that it compensates for the mating disadvantage. The advantage comes about because of the specialised evolution of Southeast Asian snakes to prey more conveniently on right-handed snails! *Pareas Iwasakii* is a common snail-eating snake in Japan. As the reptile specialises in hunting its prey, it has evolved apparatus adapted to holding the shell and accessing the succulent contents. Thanks to the great majority of snails being dextral, the whole family of pareitdae, or snail- and slug-eating snakes, has evolved a remarkable asymmetry in the number of teeth in the jawbone to enable gripping of the right-spiralling snail shell But thanks to this specialisation, the evolved snakes can rarely get a grip on a sinistral snail!

The hypothesis of Masaki Hoso and others was, hence, that left-handed snails should emerge more frequently in an environment that had the snakes, as compared to other areas. Anther thing – the emergence of sinistral lines should be more common with flat or larger snails than with taller snail species. The reason is that it is virtually impossible for flat snails of opposite-handedness to mate, while it is still possible with tall snails that mate by "shell mounting". And, again, it is the larger shell that presents the greater difficulty for gripping, if it is sinister, for the snake. So the larger sinister snails would have a greater survival advantage.

The scientists carried out a worldwide analysis of populations of dextral and sinistral snails and pareatidae snakes that clearly showed that a single gene which causes reproductive incompatibility could generate a new species, given natural selection by ecological factors.

The writer can be contacted at simplescience@gmail.com

Situs inversus

JUST like with sinistral snail, congenital inversion of the major organs can occur in humans. The human body is externally symmetrical – we have two eyes, two ears, two arms and legs and each side of the body looks the same. But our major organs are not duplicated – the stomach and spleen are on the left side of the abdomen and the liver and gall bladder are on the left. The internal structure of the brain and heart is not the same on both sides and the heart is located to the left, within the thorax.

A rare genetic peculiarity is when all the organs are on the opposite side. This condition is called *situs inversus* and is seen less than once in 10,000 births. The positions of the organs are reversed, even the heart, except in exceedingly rare cases where the heart alone is in the correct position. We can see that for transplant, a *situs inversus* recipient will need a similar donor!

Celebrities who were ***situs inversus*** include American basketball player Randy Foye and Canadian comedy actress Catherine O'Hara. Dr No, in Ian Flemming's James bond novel, was also *situs inversus* and survived an attempt of murder because the assassin, who was aiming for the heart, stabbed on the wrong side!

Safety first

tapan kumar maitra **elaborates on the various protective devices used by pesticide sprayers**

TO prevent pesticides from getting into organisms through the skin, respiratory organs and mucous membranes, all workers must be provided with means for individual protection.

In selecting the means for individual protection, account is taken of the physicochemical properties of the pesticides, their toxicity, way of application and the conditions of work. Each worker is given individual means of protection of his size that are stored in the special clean and dry room in separate lockers.

Special clothing, gloves and boots are used to protect the skin. While working with dusty substances, one must use overalls of a dust-proof fabric with a smooth surface such as moleskin. When spraying or working with liquid pesticides, one must use clothing made from acid-proof fabrics or dust-proof overalls with a film coated apron and arm sleeves made from a rubberised fabric.

Canvas footgear is used for protection when working with dusty toxicants, and rubber boots when spraying. Rubber gloves are used to protect the hands when working with liquid forms of pesticides, and cotton gloves with a film coating and acid proof impregnation or combined gloves with Textin palm guards when working with dusty toxicants. It is prohibited to use medical rubber gloves to protect the hands.

To protect the eyes from pesticides, one must use hermetic goggles PO-2, "Monoblok" goggles, or protective enclosed goggles SZZM-bts. Anti-dust or anti-gas (universal) respirators and gas masks are used to protect the respiratory organs. It is strictly prohibited to use gauze bandages.

When working with dusty substances whose volatility at ordinary temperatures is not high (copper oxychloride, simazine, thiram, etc), anti-dust respirators may be used. When dusting or spraying plants and treating seeds with highly toxic volatile compounds, gas mask respirators with gas mask filters of the corresponding grade must be used. When fumigating premises with highly poisonous substances such as methyl bromide, industrial gas masks with cases "A" coloured brown must be used.

The anti-dust respirator is the simplest means of protecting the respiratory organs is a type "Lepestok" respirator. It consists of two round pieces of gauze between which a layer of a special fabric is sandwiched that has a high dust-trapping ability. The respirator is conveniently secured on the head with the aid of laces and flexible plates and tightly fits against the face. The exhaled vapour moistens the fabric, as a result of which it gradually loses its protective properties. Therefore, such a respirator may be used only during one shift (a one-time respirator). It cannot be used during rain, fog, or stored in a damp premise. It provides good protection from dust particles of substances with a low and moderate toxicity only in normal humid conditions.

The "Lepestok" respirators are of three types: "Lepestok-200" protects from highly dispersed dust contained in up to 200 Maximum Tolerated Concentration; "Lupestok-40" protects from fine and medium dispersed dust in concentration up to 40; and "Lepestok-5" from fine and medium dispersed dust in concentration up to five and from coarse dispersed dust in concentration up to 200.

The anti-dust respirator U-2K consists of a filtering half-mask whose outer layer is made from a large-pore polyurethane cellular plastic and whose inner layer is made from a thin polyethylene film in which an inhalation valve is installed. The space between the two layers is filled with a filtering material made from synthetic fibres. The front part of the half-mask accommodates the exhalation valve also used to remove the moisture accumulating inside the half-mask during respiration. The air is cleaned by filtration through the entire surface of the half-mask. The respirator protects the respiratory organs from highly dispersed dust of pesticides having a low or moderate toxicity. The average period of use is 30 days.

The anti-dust respirator F-62Sh has a filtering box with replaceable filters and a rubber half-mask with an exhale valve installed in it. This respirator protects the respiratory organs from pesticides having low or moderate toxicity that are suspended in the air in the form of a highly dispersed dust. The average service life of a respirator is one year and that of a filter 30 days. Anti-dust respirators do not protect the respiratory organs from poisonous gases and vapours.

The anti-gas respirator RPG-67 consists of a rubber half-mask in which there are installed an exhalation valve and two anti-gas filtering cartridges. The absorber filling a cartridge determines the type of cartridge (A, V, G, KD) in a respirator and its designation. RPG-67-A protects from phosphorus- and chlorine-containing organic pesticides, RPG-67-V from acid gases (sulphur dioxide, hydrogen sulphide, hydrogen chloride) as well as from phosphorus- and chlorine-containing pesticides, but with a smaller duration of protection than with an A-type cartridge. RPG-67-G protects from mercury vapour and RPG-67-KD from hydrogen sulphide and ammonia.

The universal respirator RU-60M is similar in design to the RPG-67 model, but its cartridges contain — in addition to absorbents — aerosol filters ensuring the simultaneous protection of the respiratory organs from harmful substances in the air in the form of vapours, smoke, gases, dust and mist. The cartridge types determine the types of the respirator and their application.

Rubber gloves are frequently used while spraying liquid pesticides.

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

Into the abyss

jerome taylor **details a diving suit that turns men into fish**

HUMANS have proven themselves remarkably adept at learning to do what other animals can do naturally. We have taught ourselves to fly like birds, climb like monkeys and burrow like moles. But the one animal that has always proven beyond our reach is the fish.

The invention of scuba diving has allowed us to breathe underwater but only at very shallow depths. Thanks to our inability to conquer the bends, diving below 70 metres still remains astonishingly dangerous to anyone but a handful of experts. Ultra-deep diving is so lethal that more people have walked on the moon than descended below 240 metres using scuba gear. Now an inventor in the USA believes he has solved the riddle of how to get humans down to serious depths – by getting us to breathe liquid like fish.

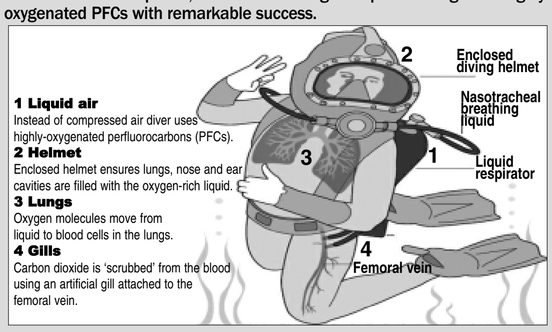
Arnold Lande, a retired American heart and lung surgeon, has patented a scuba suit that would allow a human to breathe "liquid air", a special solution that has been highly enriched with oxygen molecules.

The idea immediately conjures up the terrifying spectre of drowning but our lungs are more than capable of taking oxygen from a solution. "The first trick you would have to learn is overcoming the gag reflex," explains Lande, a 79-year-old inventor from St Louis, Missouri. "But once that oxygenated liquid is inside your lungs it would feel just like breathing air."

He envisages a scuba suit that would allow divers to inhale highly-oxygenated perfluorocarbons – a type of liquid that can dissolve enormous quantities of gas. The liquid would be contained in an enclosed helmet that would replace all the air in the lungs, nose and ear cavities. The CO_2 that would normally exit our body when we breathe out would be "scrubbed" from our blood by attaching a mechanical gill to the femoral vein in the leg. By using oxygen suspended in liquid, divers would no longer have to worry about decompression sickness — the often fatal condition known as "the bends", which occurs when nitrogen dissolved in the blood under the immense pressures of deep water bubbles out as we rise. It could potentially allow them to descend to far greater depths than is currently possible.

Liquid ventilation might sound like science fiction – it played a major role in James Cameron's 1989 sci-fi film The Abyss – but it is already used by a handful of cutting-edge American hospitals for highly premature babies.

Children born before 28 weeks have huge difficulties breathing, often because their lungs are not developed enough to comfortably adjust from the liquid environment of the womb to inhaling gaseous air. Immature alveoli, the final branchings inside the lung that feed oxygen into the blood, lack vital surfactants that stop the tiny cavities sticking together when we breathe out. In response, doctors have begun experimenting with highly-oxygenated PFCs with remarkable success.



Professor Thomas Shaffer, a paediatrics specialist from Delaware, has experimented with liquid breathing since the late 1970s. He spent much of his early career testing various animals in oxygenated perfluorocarbons.

Place a mouse in oxygenated liquid and instinct immediately kicks in as the animal flounders wildly. Everything the mouse has ever learned screams at it to avoid inhaling a solution it thinks will kill it. Yet when we drown there comes a moment when the instinct not to breathe liquid is overridden by a stronger instinct to take in one last breath. It is a desperate final attempt to get oxygen into the blood. If the liquid we are in contains oxygen molecules that happily cross from the solution into our blood stream, life will return. After all, it is not water that kills us when we drown. It's our inability to take oxygen from the water that condemns us.

By the mid-1990s, Shaffer and a handful of doctors had begun using liquid ventilation techniques on premature babies and were stunned by the results. "A lot of the children I see have less than a five per cent survival rate," he explains. "But when we get them on to liquid breathing we see close to 60 per cent going on to lead fully healthy lives."

The technique remains rare, however, because of a chronic lack of investment. "Liquid ventilation is not used widely because there is very little funding from the drug companies," he says. "Unfortunately, premature babies don't have a voice. They don't bring in money, so no one really wants to invest. But it does work. Physiologically, liquid ventilation is very do-able."

The recent oil spill in the Gulf may change that lack of interest. Although drug companies are reluctant to fully explore liquid breathing, the Deep Water Horizon disaster has reignited the debate over how to get divers safely down to extreme depths. Currently, the only way divers can work for long spells in the deep is either from the safety of robotic vessels and submarines; or by using saturation diving, an incredibly complicated technique where divers have to be brought up to the surface in a pressurised container over a matter of weeks.

With saturation diving, the deepest anyone has gone is 701 metres. Using scuba equipment, the record is 318 metres, set by South African diver Nuno Gomes in June 2005. It took him 14 minutes to descend and 12 hours to come back up to the surface.

The reason for these slow ascents is our reliance on compressed gasses to breathe in water. Under the incredible pressure exerted by billions of tones of ocean, gasses like nitrogen and helium dissolve into our bloodstream, much like CO_2 is dissolved in a soda bottle. Ascending towards the surface is like opening that soda bottle — the gas comes out of solution and into our bodies. If we don't give our bodies enough time to expel those gasses by ascending slowly, we die.

"The beauty of doing it all from a liquid is that you don't have to use these highly compressed gasses in the lungs that are going to dissolve into the blood," says Dr Lande, who recently presented a paper on his patent to the first International Conference on Applied Bionics and Biomechanics in Venice. "You have a liquid that you can infuse just as much oxygen as you need."

Shaffer has previously experimented with animals and highly-oxygenated perfluorocarbons at depth and found the technique works. "I have personally put mammals down to a simulated depth of 1,000 feet and then decompressed them in half a second and they have no decompression sickness," he says.

The US Navy Seals also reportedly experimented with liquid ventilation in the early 1980s, according to Shaffer, who says he met a former Seal turned doctor that was on the team. "This paediatrician never really revealed why they were doing it," he explains. "Other than going very deep I don't know what the point was. But they tried it. The navy pushed them to the point where they did it several times a week."

Being so much more viscous than air, liquid is difficult to breathe. Some of the Seals reportedly developed stress fractures on the ribs cause by the sheer force of trying to get a liquid in and out of the lungs. But Lande envisages using a cuirass, a ventilation device named after a piece of medieval armour, that compresses the diaphragm and makes it easier to breathe liquid. Now all he needs now are developers and a fresh set of human guinea pigs willing to test his ideas.

"I'm sure someone out there would be willing," he says. "We've climbed the highest mountains, sent people into space. It's time to find ways of exploring the deep oceans."

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