Vampires sense the heat

These bats and some snakes have 'eyes' that 'see' heat in the place of light, says S ananthanarayanan

THE first advantage of seeing with heat, instead of light, is that it can be done in the night. The second is that an animal sometimes needs to determine more than just the shape of its prey, it also needs to identify a vulnerable spot, where blood flows and the animal is most sensitive. In the case of the vampire bat, the whole objective is 25 cc of blood, so it needs to strike an artery or not at all! A paper just published in *Nature* by a group of scientists in California, Maryland and Venezuela on the heat-detecting machinery in the vampire bat complements earlier work on the molecular bases of the same ability in snakes.

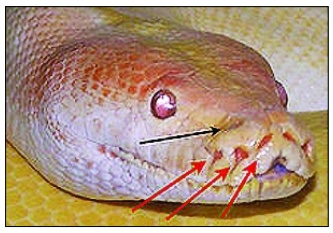
Pit vipers, as well as boas and pythons, have "pits" or depressions between the nostrils and eyes that are sensitive to heat. The depression in the pit viper is a deep cavity in the upper jaw with a narrow opening, so that it works like a *pinhole camera*. Heat radiation forms an image, although rather blurred, and in the case of vipers, on a membrane that is suspended inside the cavity. The membrane is rich in nerve tissue that is sensitive to photons of *infra red light*, which is radiated from warm-blooded prey and the cavities act like a pair of eyes that work in the infra red. In the case of pythons and boas, the heat-sensitive surface is not a membrane but the cavity lining.

There are some reasons for the evolution of a special organ like this. The first is that the eyes, which work in visible light, cannot work in the infra red. The reason is that the nerves in the eye detect light through photochemical reactions that the photons of light set off. Infra red photons do not have the energy to be detected in the same way. The second reason is that most lens' materials are opaque to infra red radiation and, hence, the need for a pinhole camera construction, which eliminates the lens. A third reason is the need for the detection mechanism to very rapidly cool, once heat has been detected, and be ready for another signal. For this requirement, the detection mechanism needs to be different from the photochemical route followed in the eyes.

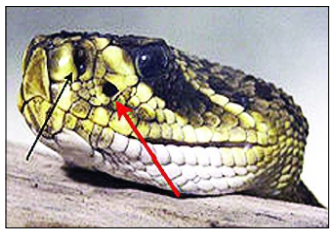
The heat detecting mechanism in the pit viper is a heat sensitive "ion channel", which nerve cells use to communicate. The way nerve cells do so is by creating changes in the concentration of their chemical contents so that electric charges build up till they "fire" and transfer from one cell to another. Changes in contents of cells, for charges to build, need the entry of chemical groups called ions through the cell wall and there are specific areas where this is possible.

The ion channel, called the *Transient Receptor Potential Ion channel*, or *TRPA1*, is a feature in the cell wall that is sensitive to both heat as well as pungent chemicals, like those present in mustard oil, and this channel is abundant in the nerve bundles found in the heat-sensitive pits.

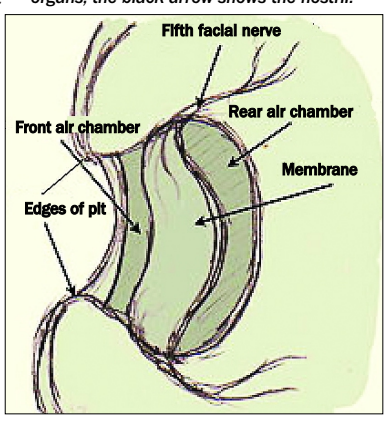
TRPA1 in vipers has evolved to be most sensitive to infra red radiation from objects at about 28? Celcius, the temperature of a warm-blooded animal. In the normal state, the nerve fibres are firing at a constant rate because of the normal infra red radiation from the surroundings. But if there is a warm object, the heat strikes the cells and they begin firing at a faster rate. The sensitivity has been estimated to be better than 0.001? Celcius. If the warm object continues to be present, the nerve cells adapt to normal firing at the higher temperature, till the object is removed, when they again adapt. The time taken for adaptation is estimated to be as low as 50-150 milliseconds. When an infra red photon has been detected, the nerve cell has also been warmed. To cool down the cell and keep it ready for the next photon, the membrane in the heat-sensing pit is specially provided with ample blood supply.



The python – the red arrows show the pit organs; the black arrow shows the nostril.



The rattlesnake – the red arrow shows the single pit organ.



The vampire bat

The usual bat uses sonar, or a picture formed by the reflection of high frequency sound waves, for navigation in the night. But the vampire bat needs more than that to avoid obstacles or detect prey. It needs to find the artery of a prey animal so that it can get its regular fix of fresh blood! The vampire bat has also evolved to use the pit mechanism to detect infra red radiation. Just like TRPA1, the vampire bat uses the *TRPV1 ion channel*, which is common in mammals for detecting pungent chemicals and also heat greater than 43? Celcius. The nerve cells in vipers and pythons are rich in TPRA1, which is adapted for heat and at a lower temperature. It is found that the vampire bat has evolved so that TRPV1 is the active ion channel, and this has been adapted, in the facial region, where heat-detecting pits are present, to the proper temperature range.

Pit vipers usually prey on small, warm-blooded animals and are efficient at detecting warms spots in the night, within a range of about a metre. An interesting offshoot is the defensive adaptation by the *California ground squirrel*. When a common predator, like the *Pacific rattlesnake* is in sight, the ground squirrel waves with its tail to divert the rattlesnake's strike. A display that is not there if the attacker is another kind of snake that does not have the heat-seeking equipment!

Vampire bats are sensitive to heat for about 20 cm, and use this to find spots that are not covered by fur or feathers, for instance, on their prey. There is no evidence of the prey developing defences, like the California ground squirrel, against the vampire bat. This may be because the bat only takes some two tablespoons of blood — it does not kill the victim – from its prey, which are often cattle. But the bat's saliva has agents that prevent clotting of blood so that it can feed conveniently. Some animals have reacted by developing antibodies against the anti-coagulants!

The studies on pit vipers and vampire bats underscore the variety of adaptation of species. Snakes are without ears, but their whole length is sensitive to movement and they detect ground vibrations that warn them of the lightest footfall. Their darting tongues pan the air for samples of scents. And at closer range, they detect faint variations in temperature to complete the picture. The bat traditionally uses sonar to guide its rapid flight, and its feeding on insects in pitch darkness. But where it needs to find a source of blood, it adapts to detect temperature gradients using a different molecular channel than snakes, because it got here by a different evolutionary route.

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Why we can't get enough of the Red Planet

steve connor reports on the obsession with Mars

SEASONED Mars observers could be forgiven for a feeling of *déjà vu* on Monday when they read about the discovery of running water on the surface of the Red Planet. Such announcements come with frequent and rather confusing regularity from the National Aeronautics and Space Administration. The reason, of course, for this obsession with liquid water on Mars is that it raises the prospect of life on a planet that has captivated generations of schoolboys and science fiction writers. Planetary scientists are agreed that extraterrestrial life almost certainly requires liquid water to exist, just as it does on earth.

In 2000, Nasa announced that it had discovered deep-sided gullies running down the dusty slopes of Martian craters. The immediate suggestion was that these channels were cut by running water, although when this was supposed to have happened was open to speculation as the gullies could have been created at any time over the past few million years.

Then, in 2006, the American space agency revealed to an eager global audience that it had found evidence of running water on the present-day Martian surface. It had taken two sets of satellite images of the same Martian craters, one in 1999 and the other in 2006, and witnessed the appearance of lightly shaded patches that indicated the sudden flow of underground water.

Nasa's lead scientist on the Mars exploration programme, Dr Michael Meyer, said at the time that these patches suggested the presence of liquid water on the Red Planet today. "These observations give the strongest evidence to date that water still flows occasionally on the surface of Mars," he said in December 2006.

Life may not automatically follow from the discovery of flowing water on Mars, but it certainly brings the prospect closer. And the discovery of life on another planet, no matter how primitive and microbial, would certainly amount to one of the greatest scientific finds of all time. It would mean, for example, that life has originated at least twice in a single solar system – provided we can eliminate the possibility that any Martian life forms were somehow carried there from earth. Two planets with life in a single solar system would indicate that the origin of life is a fairly common event, and that our galaxy, composed of billions of solar systems, must therefore be teeming with extraterrestrial life forms.

A universe where life is so common would presumably be governed by the same rules of Darwinian evolution that produced intelligent, conscious humans here on earth. Discovering even the simplest life form on Mars, therefore, would almost certainly mean the existence of advanced, intelligent aliens in other solar systems with civilisations comparable to our own on earth.

Ultimately, this is what lies behind Nasa's apparent obsession with the possibility of water on Mars. If liquid water exists, then so could primitive Martian life. And if Martian microbes exist, then intelligent aliens can no longer be confined to the realm of science fiction. As Charles Boden, head of Nasa, said regarding this week's announcement: "Nasa's Mars exploration programme keeps bringing us closer to determining whether the Red Planet could harbour life in some form, and it reaffirms Mars as an important future destination for human exploration."

The search for life on Mars is nothing new, of course. It began in earnest at the end of the 19th century when Milanese astronomer Giovanni Schiaparelli observed long, straight lines on the planet's surface. These channels, or *canali* as he called them, became known through mistranslation as "canals", and people quickly assumed they were created artificially by intelligent Martians. Indeed, an American astronomer called Percival Lowell reasoned that as Mars was an arid place, the canals must have been built to divert this most precious resource.

"With this leap of the imagination, Lowell created one of the most enduring tropes of science fiction: Mars as a dying planet. It would live on in the works of HG Wells, Edgar Rice Burroughs, Leigh Brackett and many, many others," said science writer Oliver Morton, author of *Mapping Mars*. In Wells' *War of the Worlds*, written in 1894, we are introduced to the idea of Martians from a water-starved planet invading earth to take home the only thing they lack: that essential aqua vitae.

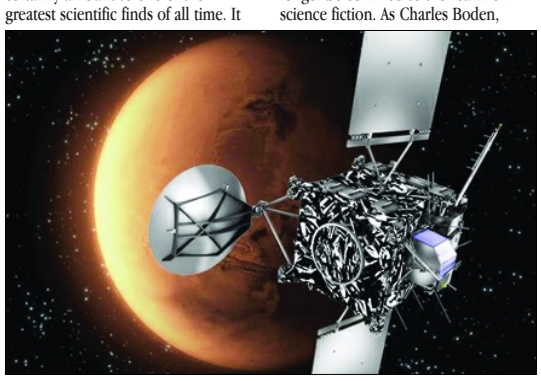
This week's announcement brings us closer to knowing whether Mars does indeed hold water. The downhill features identified by the HiRise camera on board Nasa's Mars Reconnaissance Orbiter show much narrower gullies than the ones identified in 2000, and, crucially, these gullies appear to be seasonal, fading in winter and appearing again in spring and summer. The gullies observed in 2000 now appear to be caused by the defrosting of carbon dioxide, whereas the latest finger-like streaks running down the slopes of Mars bear all the hallmarks of being caused by the flow of salty water, which freezes far below 0 degrees Celcius and could easily exist in liquid form in the bitterly cold Martian temperatures.

"The best explanation for these observations so far is the flow of briny water," explained Alfred McEwen of the University of Arizona, principal scientific investigator on the mission. "The flows are not dark because of being wet. They are dark for some other reason. It's a mystery now, but I think it's a solvable mystery with further investigations and laboratory experiments," he said.

So the search for water on Mars continues, although final, unequivocal proof of its existence may come sooner rather than later. Nasa already has many instruments monitoring the Red Planet, and it will have even more later this decade with the launch of joint US-European probes.

More importantly, by following the water, Nasa hopes to achieve its ultimate goal – finding life on Mars.

The Independent



Reaction to this week's Nasa newsflash reminds us that Mars still occupies a unique place in human imagination.

In 1543, Nicolaus Copernicus publishes On the Revolutions of the Celestial Spheres, *arguing – from the movements of the planets, including Mars – that the earth is not at the centre of the universe.*

Chromosome calculation

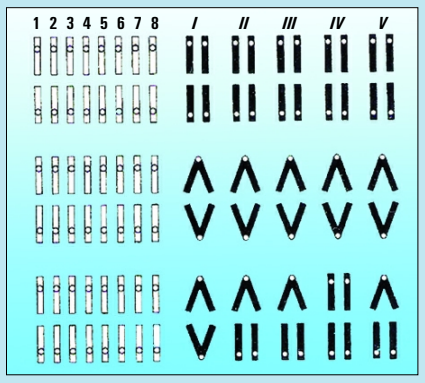
tapan kumar maitra **explains centric fusion, a little-known biological mechanism recent research has done much to bring to light**

ANEUPLOIDY is considered to be a numerical departure from the normal diploid complement of chromosomes, with a gain or loss of whole chromosomes. Variable chromosome numbers can occur, however, without apparent gain or loss of chromatic material by the process of centric fusion.

As the term implies, it is the fusion of two acro-centric chromosomes to form one chromosome with a more or less medianly placed centromere. The mechanism of centric fusion is as yet unknown, but because the reverse of centric fusion, or dissociation, can transform a meta-centric chromosome into two aero Gentries, it seems most reasonable to assume that terminal centromeres can unite with, or dissociate from, each other and without impairment of centromeric function.

The two processes, therefore, reduce or increase the chromosome number without a change in the number of major arms of chromatin, giving rise, within a species, to what has been termed a Robertsonian type of chromosomal polymorphism. Robertson's law states that the chromosome number may vary but the number of chromosome arms remains constant. For example, in the common English shrew, the total number of autosomal arms is 38, yet from individual to individual the diploid number of chromosomes ranges from 22 to 25 in females and 22 to 27 in males. Two karyotypes are depicted and it is evident that the smaller autosomes can exist as acro-centrics or meta-centrics. In the marine snail *Thais lapillus*, the haploid number ranges from 13 to 18. In the 18-chromosome form, all the chromosomes are acro-centrics whereas the 13-chromosome form possesses five meta-centrics and eight acro-centrics. Intermediate forms with one, two, three or meta-centrics have also been found in the same population, leading, of course, to a local chromosomal polymorphism.

In *Thais*, the 18-chromosome form occurs below the low-tide level, the 13-chromosome form at high-tide



Chromosome polymorphism in the marine snail Thais tapitlus.

levels and the intermediate-numbered individuals in the intervening tidal zone. It would appear, therefore, that the different chromosomal races exhibit ecological preferences, a condition not immediately evident in the shrew population. In the group of primates considered to be most closely related to man — the great apes — there is marked variation in the number of aero-centric chromosomes, although the diploid number remains constant. The evolutionary significance of this observation remains obscure, particularly since some groups, for example some species of the Felidae (cats), show remarkably little karyological variation.

Centric fusion can also unite X chromosomes and autosomes. When this occurs, there is a shift from autosomal to sex-linkage for the genes involved and in addition the creation of a new or neo-Y chromosome. This has occurred in at least 12 species of *Drosophila*, in certain phasmids, in the beetles *Tribolium confusum* and *Agrilus anxius* and on at least seven different occasions in the Morabinae — an Australian group of wingless grasshoppers.

The chromosomal situation in the rainbow trout, *Salmo irideus*, indicates that centric fusion and dissociation are responsible for the polymorphism existing not only among individuals of the species, but also in the tissues of a single individual. The rainbow trout has a diploid number of 104 chromosome arms, and *2n* numbers ranging from 58 to 104 have been reported. The 58-chromosomc form has 12 acro-centrics and 46 meta-centrics; the 104-chromosome form would, presumably, possess only acro-centric chromosomes.

Within a given individual, the chromosome number in different tissues can vary, with each tissue having a predominant, but not absolute, number of chromosomes. This is indicated in all instances of fusion, non-homologous chromosomes are involved and genetic imbalance in somatic cells is not a problem. Fusion of homologous chromosomes would, of course, lead to unbalanced complements in gametes if present in gonadal tissue and would be selected against in evolution.

What evolutionary advantage there is to fusion and dissociation of non-homologous chromosomes is, on the other hand, not immediately obvious, although chromosomal polymorphism may be a prelude to further karyological change and hence to evolutionary divergence within the species. Offsetting this possible evolutionary advantage is the fact that gonadal cells undergoing meiosis, and containing variable numbers of acrocentrics and metacentrics, would form multi-valents paving the way for irregularities of segregation. In *Salmo*, however, the species seems to be adjusted to this form of chromosome variability, for few unbalanced gametes are produced.

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