Nehru Bal Pustakalaya

THE FASCINATING WORLD OF BIOLOGY

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एकः सूते सकलम्

Nature's Incredible Phenomena and Science

Have you ever looked at a sunflower? Surrounded by the yellow petals are hundreds of tiny brown dots. From afar they look as if they have been arranged randomly in the middle. But if you look carefully, you will see that there is an order to the apparent randomness. They are arranged in a format known as 'Fibonacci numbers.'

I learnt Fibonacci numbers in school, but it never made much sense to me. Why do we need it? What is its use?

Now, when I look at the sunflower in my garden, I understand a bit. The Nature uses mathematics in her own fashion.

The world of biology uses mathematics, chemistry and physics. In the ten essays presented in this book, we will explore the 'Fascinating World of Biology' to see how some of the phenomena we observe can be explained by principles of mathematics, chemistry, physics, and of course biology.

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एकः सूते सकलम्

THE BEETLE BY THE MOONLIGHT

The divine dung beetle, Khepri,
rolls the Sun through the the sky.
-***Ancient Egypt***

The beetle was industriously rolling the dung ball. I stopped by to watch it.

The dung beetle is found across the world wherever there is dung as dung is its primary source of food. Some of the dung beetles are choosy; they prefer dung of only one species of animal. Other dung beetle species are less choosy; they feed on dung of many different species of animals.

But the question that persisted in my mind was: How do these beetles, especially the ones that are active in the night, navigate the dung ball, rolling it in a neat straight line when the light from the Moon is barely sufficient for us to see beyond our noses?

The answer is surprising: Studies done on the African dung beetle show that they use the polarization pattern of the light to navigate the dung ball.

Light, as we all have learnt, is described as an electromagnetic radiation, composed of massless particles called 'photons' that travel like a sea-wave with the speed of light. The photons, though they have no mass, possess energy. And depending upon how much energy it possesses we can differentiate them into X-rays, UV-rays, or visible light.

The visible light that is emitted from any source like the Sun or a light bulb is unpolarized because it can travel in all directions.

If you take a piece of a rope and move it up and down, it will travel up and down but only in one direction. If you made the light move like that, up and down, only in one direction, that light is now known as 'polarized.' How can an unpolarized light be converted into a polarized light?

The unpolarized light can be converted into polarized light by putting it in a filter such that the waves that emerge after passing through the filter can move only in one direction. What kind of filter? Crystals like calcite can function like filter (polarizer). So can plastic films that are coated with organic molecules in one direction. These plastic films are called 'polaroids' and are used in polaroid cameras.

Interestingly, the sky too is a polarizer. Our eyes cannot discern the polarized light but the eye of the beetle, can. Why? This is because of special structures that are present in the eye of the beetle.

The beetle possesses compound eyes. Each eye is composed of microvilli, which are small hair like cells that function as light absorbing particle. Each microvillus

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contains many light receiving pigments called 'rhodopsin'. And in each microvillus, these rhodopsins are aligned in one particular direction. Thus, all the microvilli face one direction and are maximally attuned to receive light polarized in a direction parallel to the direction in which the microvilli are arranged. These microvilli cannot receive any other light.

Does this mean that the beetle can receive only polarized light?

No. The microvilli are arranged in only one direction in the dorsal rim of the eye. In the rest of the region of the eye, the microvilli are placed in no particular pattern. So, in the rest of the region they can receive unpolarized light but in the dorsal rim they can perceive only the polarized light.

But what happens on moonless nights? How do beetles forage food on those nights? Well, the scientists have observed that the beetles tend to wander directionless on such nights. Many of them cease their activities 45-50 minutes after sunset as the amount of light available for navigation drops dramatically.

So, is this property unique to the dung beetles?

No.

Bees and ants and other insects as well as fish can perceive the polarization pattern of the sunlight. They too use polarized light for navigation, just like the dung beetle.

The difference is that they use the polarization pattern of the sunlight. As the Sun changes its position, the polarization pattern also changes.

Can we do it? No, we cannot, because the light receiving pigment, rhodopsin, is oriented randomly in our eyes and therefore, we are not able to detect the polarization pattern of the light.

The polarization pattern is simplest during twilight and the light of the whole sky is polarized in one direction. However, of all the animals known, only the dung beetle has figured out how to use this light for navigation when it forages for food!

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THE COURTSHIP OF THE PEACOCK

He approaches her, trailing his whole fortune,
Perfectly cocksure, and suddenly spreads
The huge fan of his tail for her amazement.
-David Wagoner

The peacocks enliven the early months of summer when they perform an inspired courtship dance. Through the months of March and April, the peacock performs, displays its magnificent tail, in the hope of attracting the peahen.

The peacock's plumage, despite its magnificence, is cumbersome. It hinders its movements. The peacock has to carry it everywhere. If he sees a predator, he cannot run away as fast as he would have been able to if he had no tail. Even flight is difficult. Then, why is the peacock endowed with an elaborate plumage?

The answer to this question lies in a theory known as 'Signalling Games.'

Signalling is a form of communication. There is a sender and a receiver. The sender possesses certain information, which he/she needs to communicate. And the receiver needs to interpret this information upon receiving. The most important point to remember in the signalling games is that the sender knows what information he/she possesses. However, the receiver does not know what information the sender possesses. So, the sender must decide how to communicate this information and the receiver has to decide how to respond to this information.

Sounds completely confusing, doesn't it?

Let us see if we can use the signalling games to understand the courtship of the peacock. In this example, the peacock is the sender and the peahen is the receiver. What information does the peacock communicate? Well, he communicates his fitness to mate. He is telling the peahen that he has more resistance to diseases, that he has sufficient fat reserves per unit body weight, and that their offspring have a good chance to survive. How does this peacock communicate this information? Why, by his plumage, of course!

If you look closely at the peacock's plumage, you will notice that each feather has, what is known as, an eyespot. Marion Petrie at Whipsnade Zoo, United Kingdom, has studied the courtship behaviour of the peafowl extensively and has documented that the number of eyespots directly correlates with the fitness of a peacock. That is to say, a physically-fit peacock will have a greater number of

eyespots than a peacock that is not physically fit. A physically-fit peacock might have more than 150 eyespots in his plumage.

When the peahen sees the plumage, she cannot sit and count the number of eyespots to determine which of her suitors possess more eyespots, and therefore, are more fit. So how does she figure out which peacock to mate with? Although we do not have any experimental proof, it appears that the peahen looks at the symmetry of appearance. A plumage will be most symmetrical if the number of eyespots in the right side is equal to the number of eyespots in the left. Therefore, instead of counting the eyespots, the peahen makes a quick assessment. How does the plumage look to her visually? Is it attractive? Is it symmetrical? If yes, then she would consider mating with that particular peacock.

Now, here is the dilemma. The peacock wants to pass the information that he is, indeed, a fit mate. But what if he truly is not? What if he communicates false information? How should the peahen assess this information?

This involves something known as 'Honest Signalling.' The question that a peacock has to ask himself is what he will get if he lies. In other words, what are the incentives of speaking the truth? What benefits will he get if he tells the truth and what happens if he tells a lie?

Suppose there is a peacock that is physically weak. If he has to grow a beautiful plumage, he will have to spend a considerable amount of energy to grow a tail.

Being physically weak, it is too costly an investment. Why should he do it? He might as well save that energy and use it to become physically stronger. Then there is also an additional problem. If he grows the tail, it will be difficult for him to flee from predators. When he thinks about these aspects, he decides that it is not worth it to grow a beautiful plumage. So, these factors act as a

deterrent and a physically weak peacock will have very little incentive to tell a lie. Therefore, peacocks are believed to be honest signallers. This implies that a peahen does not have to worry that the peacock dancing in front of her is telling a lie. All she has to observe is which peacock has more symmetrical plumage and therefore, with whom she should mate.

The peacock's job is over once the mating is done. The plumage moults and the peacock, a bird shorn of all his magnificence, moves about from July to March searching for food. In March, the plumage reappears, and the courtship cycle starts all over again.

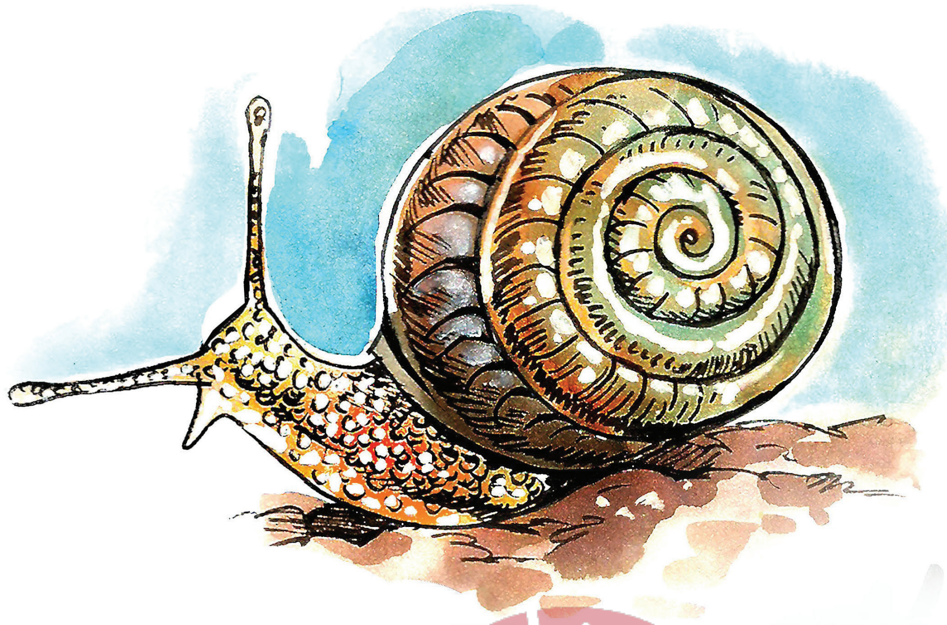
A HOUSE ON ITS BACK

And seeing the snail, which everywhere doth roam,
Carrying his own house still, still is at home,
Follow (for he is easy paced) this snail,
Be thine own palace, or the world's thy goal.
-John Donne

The snail slowly made its way across the pavement, slime oozing out. It was brown in colour and the shell glistened in the Sun. When I squatted down to get a better look of the shell, I could see the tiny spirals.

A spiral is just a curve in space, which runs around a centre. Spirals can be of different types: Archimedean spiral, logarithmic spiral, three-dimensional spiral, Fibonacci spiral, etc. This last one is what we are concerned with when we want to understand how a snail's shell grows.

We learn about Fibonacci numbers in school. Leonardo Fibonacci was an Italian mathematician and was born in 1170, long before the Renaissance period. As he travelled along with his father, who had a trading post in the port



of Algeria, he became acquainted with the Hindu-Arabic numerals and brought them into the European continent.

I remember that my mathematics textbook had a figure of rabbits. It was indeed with rabbits that Fibonacci began his observations as he was interested in understanding how fast the rabbits would breed under ideal circumstances. He started with an assumption that rabbits never die because they are neither killed nor starved. He then made a second assumption that the female rabbit always produces a pair of rabbits—one male and one female—from the second month. With these two assumptions, he said that if in the beginning there was one pair, then at the end of one month, there would still be only one pair. At the end of two months, the female rabbit produces one pair of rabbits so that the total is two pairs. At the end of the third month, the original female produces another pair making a total of three pairs. At the end of the fourth month, there will be five pairs. And at the end of the fifth month, there will be eight pairs and so on, producing a number series 1, 1, 2, 3, 5, 8, 13, 21, 34..., which is called as Fibonacci number.

The rabbit problem is not very realistic, but the Fibonacci number has numerous uses. We can use these numbers to create a series of rectangles. First, we draw a rectangle of unit 1. Adjacent to it, we draw another rectangle of

unit 1. Then we top them with a rectangle of unit 2. Now, we draw a rectangle of unit 3 keeping in mind that the longest side touches both the rectangle of unit 1 and 2 such that the sum of the longest side is 3. Once the unit 3 rectangle is ready, we can create a rectangle of unit 5. The trick is to remember that the size of the longest side is equal to the Fibonacci number.

Once we have the Fibonacci rectangle, we can create a Fibonacci spiral. To do so, take a pencil and draw a quarter of circle in each square. What you will get is a spiral, the kind you will see on a snail's shell.

Why did Nature choose Fibonacci spiral? Why not any other type of spiral?

A snail has to worry about two aspects. The first aspect is that the size of the body must be relative to the size of the shell. The two must grow at a similar rate because if the shell becomes too heavy, it will not be able to drag it along. In addition, the center of gravity would be altered and the poor snail would topple over. The second aspect is, of course, that the shell cannot be too small. It is not a decorative piece. The shell is a protective cover against threatening elements. The shell has to be big enough so that the snail can withdraw into it when the need arises.

The shell of the snail is made of calcium carbonate or lime. The shell is extended as the snail grows by depositing lime at the shell opening. Each new addition of lime, because of the above-mentioned constraints, tries to maintain more or less a constant relationship with the previous shell. The net result is a 'Fibonacci spiral.'

The snail shell provides a valuable lesson, not only in mathematics, but also for designing armours. For example, the scaly foot snail lives at the bottom of the Indian Ocean near vents that spew hot waters. In addition, this snail is preyed by crabs as well as by other snail species.

The scaly foot snail has evolved to combat both the hot water as well as predators by creating a shell that is composed of three layers. The outermost layer is made of iron-sulfide, the innermost layer of calcium carbonate. In between these two layers is present a thick organic layer. The iron-sulfide layer is the first line of defence against predators. It is brittle and can crack easily under pressure, but the jagged ends could possibly grind down the attacker's claws. The middle layer is soft and flexible, able to fill the cracks up and protect the inner layer from feeling pressure. The outer and the middle layer together protect the snail against the acidic nature of the hot springs. Finally, the inner layer is rigid providing structural support.

And this is what intrigues the defence specialists. Can they copy the snail while designing armours for the soldiers?

THE GLOW-WORMS

Among the crooked lanes, on every hedge,
The glow-worm lights his gem; and through the dark,
A moving radiance twinkle.
-James Thomson

Have you ever seen tiny speckles of light gleaming on the hedges on a dark night? They appear and disappear, lasting for just a few seconds. These are the fireflies. They are also known as 'glow-worms.' Quirkily enough, these are not flies but are beetles.

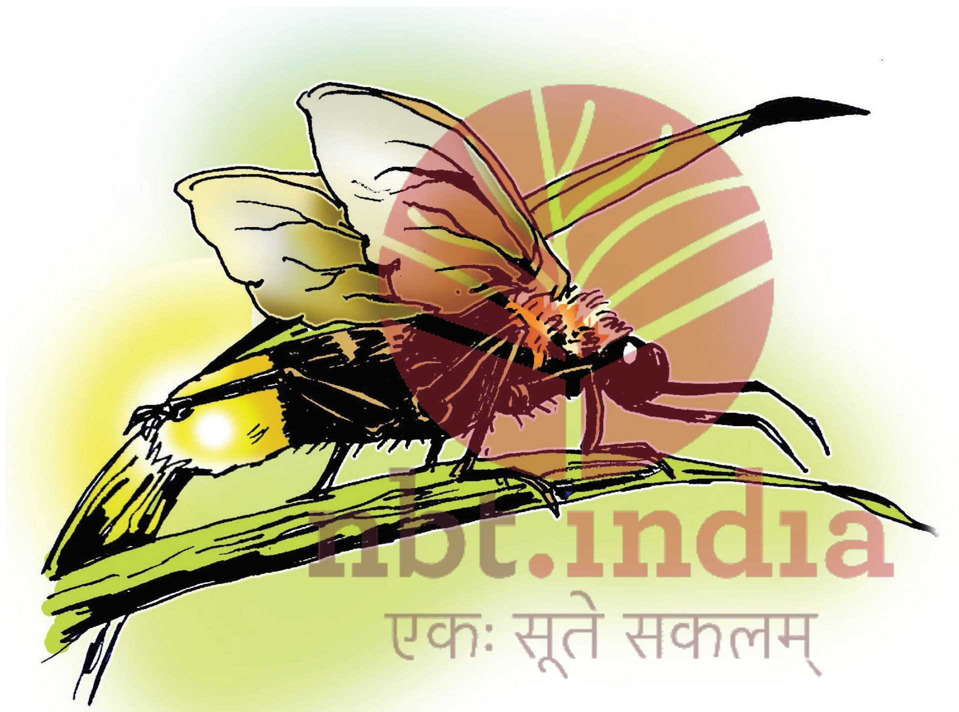
How do fireflies produce light?

The production of light in fireflies occurs through a process called 'bioluminescence.' Light is produced from an energy source. In fireflies, the energy source is a chemical reaction that takes place in their abdomen in a special organ known as lantern. The chemical reaction involves Adenosine Triphosphate (ATP) which is the energy source in all the living organisms. It involves an enzyme known as luciferase and a compound known as luciferin. The reaction requires oxygen. The reaction can be given as:

Luciferin + ATP + $O_2 \rightarrow$ oxyluciferin + AMP + light.

Luciferase catalyses this reaction. AMP stands for Adenosine monophosphate.

This light is emitted in the form of blue-green colour and in pulses. This is known as 'bioluminescence.' In this reaction heat is not produced. Have you ever touched a light bulb after it has been switched on for some time? It will be hot because the reaction produces heat. On



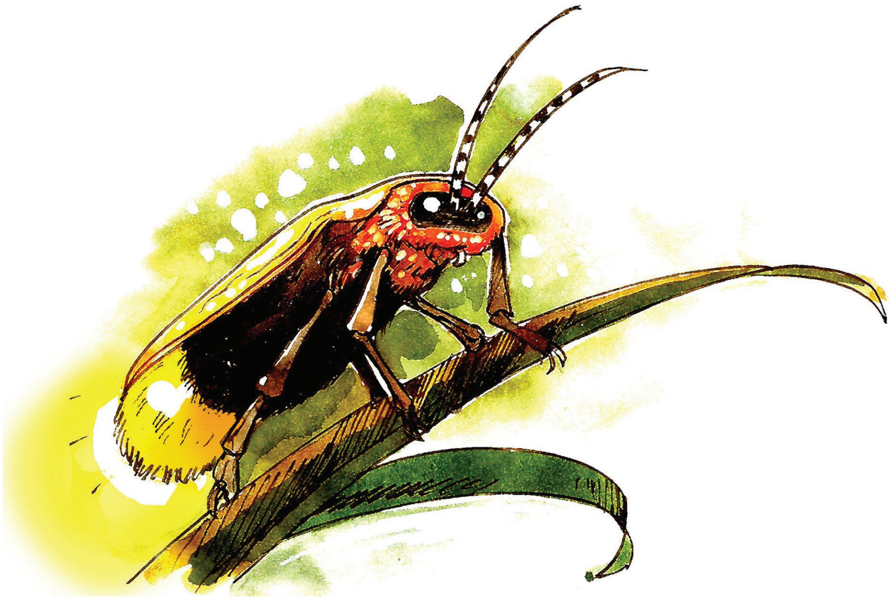
the other hand, the light that is produced by fireflies is called as 'cold light' because there is no heat generation. As there is no heat production, the light generated by these organisms is one of the most efficient methods of light production.

Why do fireflies produce this light? The adult fireflies produce this light to attract potential mates. However, the young or the larve of the fireflies do not emit light.

Are fireflies the only organisms that can produce this kind of light?

No. There are many organisms that can produce bioluminescence. There are bacteria that can emit light. There are glowing mushrooms. Tiny organisms called dinoflagellates residing in the deep ocean can also produce light. The light produced is mostly blue-green in colour though some can produce red, yellow, pink, violet and white coloured light too.

Dinoflagellates, unlike fireflies, produce light only when they are disturbed. One of the theories is that these organisms produce light to startle their predator. The copepods are small organisms that live on the ocean floor and prey on the dinoflagellates. Therefore, the dinoflagellate has to evolve strategies to escape the copepods. The production of a brief flash of light is one such strategy. An alternative theory is that production of light actually signals the enemies of copepods and thus, is



used to attract the organisms that prey on the copepods. Finally, there is a group of scientists, which believes that the light production has no value to the dinoflagellate.

In the ocean floors live tiny bacteria belonging to Photobacterium and Vibrio genera (e.g. Photobacterium phosphoreum, Vibrio fischeri) that can produce bioluminescence. These bacteria live in close association with other organisms like fish. The fish provides food and a place to live to the bacteria. In turn, the fish uses the light produced by the bacteria for hunting, or as a camouflage, or in attracting potential mates. This kind of association where both the organisms benefit from each other is known as 'symbiosis.'

Let us move from the ocean floors to the rain forests of Brazil. In some places the forest is so thick that sunlight never penetrates. In these dark forests, scientists have found new species of tiny glowing mushrooms. Just as the fireflies and dinoflagellates do, these mushrooms also use luciferase to convert luciferin into light in the presence of ATP and oxygen. The light, just as in the case of fireflies, is green in colour. There are 71 such species of mushrooms found not only in Brazil but in Japan too. Unlike dinoflagellates and fireflies, the mushrooms produce light continuously, which is visible only when it is dark. We do not know the reason why these mushrooms glow. It could be a signal to tell other organisms that it is poisonous and therefore, should be left alone. It could glow to attract insects, which would pick up the spores and help to spread them far and wide. Or just as in case of dinoflagellate, there might be no particular reason why the light is produced. Only further research will enable us to understand why these mushrooms produce light.

THE FLIGHT OF THE BIRDS

Stray birds of summer come to my window
To sing and fly away
-Tagore

The peahen landed gracefully on my patio. Using the patio as a runway, she braked in front of my rose plant, just as a plane would land on an airstrip. How do birds fly? Is it really similar to a flight of an aeroplane?

Let us first look at the flight of an aeroplane. To do so we need to understand Bernoulli's principle. Bernoulli was a Swiss mathematician who discovered that a slow-moving fluid (could be liquid or gas) exerts more pressure than a fast-moving fluid.

An aeroplane wing is rounded at the leading edge and sharp at the trailing edge. If we look at the cross-section of a wing, we would see that it is slightly curved. Due to this curvature, the airflow is faster on the upper surface as compared to the lower surface. Applying Bernoulli's

principle, we realize that the pressure will be more on the lower surface than on the upper surface, thus developing a pressure difference between the two surfaces. The higher pressure on the lower surface allows the aeroplane to be lifted.

Birds too follow Bernoulli's principle. Their wings are curved such that the airflow on the upper surface is more than on the lower surface allowing a pressure difference to develop. But there are differences between a bird and an aeroplane. The wings of an aeroplane are fixed whereas the wings of a bird are not fixed. The wings of a bird, unlike that of an aeroplane, have a sharp leading edge. The wings also contain many microscopic features like fold, gaps, and ridges. Besides, a bird can alter the dimensions of the wings by drawing them closer to their body or extending them fully outwards from the body.

Birds can glide and soar in the air as well as use flapping motion. During gliding, the wings do not flap. They are instead held out to the side of the body at a slight angle that allows the air to be deflected downwards. The downward movement of the air causes a reaction force, called lift, to be set up in the opposite direction. The lift allows the bird to glide through the air. The angle at which the wing is held is very critical. If the angle is too large, then it will produce a dragging force that will impede the motion of the bird. If the angle is too small, then the downward movement of air will not be sufficient to create lift.

Soaring is a kind of gliding and takes place only under certain specific conditions. During soaring the bird flies in a rising air current. For example, the Sun can heat up

warm air such that it rises up from the earth forming what is known as 'thermal.' Birds can use this rising air current to fly.

During flapping, the wings produce a downstroke and an upstroke. During downstroke, the wings beat down and forward creating lift. The upstroke involves lifting the wings up and extending it so that it is ready for the next downstroke.

Bats are the only mammalian species that can fly. Scientists in Lund, Sweden, used a wind tunnel created specifically to study animal flight. The field created by airflow during animal flight was recorded using a special tool called 'digital particle image velocimetry.' After recording the image, the scientists calculated the force generated by downstroke as well as upstroke. They found, much to their astonishment, that the force created by downstroke and upstroke was equal suggesting bats, unlike birds, use both downstroke and upstroke to create a lift.

One of the most intriguing flying patterns is created during migration of the birds. If you look at the birds, you will find that some of them fly in V-shape. Why V-shape? The V-shape helps in conserving energy as well as in better communication. The first bird, called 'the lead bird,' in the V-shape pushes against a wall of air, thus, reducing resistance. At the same time, the swirling air caused by the lead bird's movement helps the bird behind it to push forward. Hence, every bird behind the lead bird gets assistance and push to move forward. When the lead bird gets tired, it falls back, and another bird becomes the lead bird.

THE CAT'S TONGUE

The Owl and the Pussy-cat went to sea
In a beautiful pea-green boat.
-Edward Lear

My neighbour feeds two stray cats. One of them is striped and the other is black and white in colour. Both cats wait outside my neighbour's house for their daily ration of milk and chicken pieces. The striped cat is a male and the black and white is a female. Interestingly cats do not possess cheeks, which are essential for drinking. The cheeks provide suction power so that the liquid enters the mouth. If an animal does not possess cheeks, then how are they able to drink?

There are many animals that do not possess cheeks like we do. For example, dogs do not have cheeks so they drink water using a spoon-like action. They curl their tongue in such a manner that it forms a ladle and with this ladle they scoop up the liquid. This implies that the

tongue should be submerged into the liquid. Most of the animals lacking complete cheeks employ this trick. But not cats.

The tongue of a cat is known to be rough and for a long time scientists had assumed that the cats employ their rough tongue in the same way, as does a dog. However, one day, a researcher, Roman Stocker, was watching his cat, Cutta, drink milk and he wondered if the assumption that cats and dogs use the same method to drink was true.

To test this assumption, Roman Stocker and his colleagues used a high-speed camera to study the way cats drink milk. What they found was astonishing. The tongue of the cats does not penetrate the liquid. This implies that they do not form ladle like structure with their tongue. So how do they drink?

The cats extend their tongue towards the liquid and as it touches the surface of the liquid, the tip of the tongue is curled backwards. This movement allows it to pick a droplet. Now, the cat starts withdrawing the tongue from the liquid. As it does so, a column of liquid is pulled-up. The cat clamps its jaws close and the liquid is trapped inside the mouth.

This action of cats has a profound implication. When the column of liquid is being pulled up, it is being pulled against the gravity. Therefore, to understand the mechanism better, the researchers built a robotic tongue that could mimic the cats's tongue. Using this instrument, the researchers found that two forces play an important role in the drinking mechanism. One is the inertia of the liquid that tends to keep the liquid moving upwards. The other is the gravitational force that tries to pull the liquid downwards. Thus, the inertia and gravitational forces are acting on opposite directions. The cat must balance between these two forces such that it pulls up the liquid into its mouth before the gravitational force pulls it down. If it closes its jaws too early, it would miss the column of water as the inertia pulls it up. If it closes its jaws too

close, it will lose the water, as the gravitational force would pull it back towards the ground.

How do cats acquire this behaviour? Is it genetic? That is to say, are cats born with this instinct to balance inertial and the gravitational force? Or, is it learnt in the same way as birds learn to fly and we learn to walk? Researchers believe that cats learn this behaviour the same way as we learn to walk. So, the drinking behaviour is instinctive. It is not in-built but learnt through trial and error.

Is this only true of the cats? What about tigers, lions and other animals that belong to the feline genera along with the cats? Well, the researchers went to a zoo to study the behaviour of these animals and found that this behaviour extends to all the animals belonging to the feline genera. Thus tigers, lions, leopards, cheetahs, employ the same trick to drink liquids. The only difference is the timing. As these animals possess a longer tongue and are taller than cats, they lap much slowly so that the inertia and gravitational force could be balanced properly.

This study has helped in designing better robots. Robots are used for cleaning oil spills and scientists are now designing robots that would be able to clean up the oil spills using the same principle as the cat's tongue.

THE POWER OF SUGARS

Tardigrades don't care!
-Hank Green

Of all the animals abounding our Earth, I find the tardigrades the most fascinating. The name itself is mesmerizing. Tardi means 'slow' and grade means 'step.' The organism is a slow stepper and extremely hardy. It is found in hot springs as well as beneath layers of ice at the poles. It is found on the ocean floors where the pressure is 1000 times more than that on the Earth's surface. It is also found on the top of Himalayan peaks where the oxygen level is one-third of that found at sea level. How is it able to survive in such tough conditions?

Tardigrades, also known as water bear or moss piglet, are capable of going into suspended animation whenever they are faced with adversity. There are several organisms that can do this. For example, certain bacteria possess this behaviour. When these bacteria face lack of food supplies, they transform themselves into a form known as 'spores.' As spores, they can survive for a long time. When these

spores are provided plenty of food resources, they revert to their bacterial form.

Tardigrades, however, are not bacteria. Tardigrades, in fact, are closely related to cockroaches. They belong to a family known as arthropods. However, unlike cockroaches, which we can see with our naked eye, we need a microscope to observe tardigrades.

How do tardigrades go into suspended animation? The process of going into suspended animation is known as 'cryptobiosis.' During cryptobiosis, all the metabolic processes come to a standstill. It is a death-like state. However, under right conditions, the process can be reversed, and the organism can revive. Cryptobiosis takes place when there is lack of water (anhydrobiosis), lack of oxygen (anoxybiosis), low temperature (crybiosis) and increase in salt concentration (osmobiosis). Tardigrades undergo anhydrobiosis.

During anhydrobiosis, the tardigrades lose water and start drying up. However, each organism contains molecules that need to be present in hydrated form. If these molecules lose water, then they lose their structure and therefore, their function. So, the tardigrades had to evolve a mechanism by which these essential molecules would not lose their structure when water is lost. The tardigrades came up with an interesting solution. During anhydrobiosis, sugar molecules replace the lost water molecules. There are many kinds of sugar molecules. The sugar that we eat is one type. Glucose is another type and the sugar that tardigrades use is known 'trehalose.' Trehalose is an interesting molecule. It is classified as a disaccharide, which means two sugar molecules are linked together. Glucose is a monosaccharide as is fructose. These molecules contain one sugar residue. Sucrose is a disaccharide. It is made of glucose and fructose. Trehalose, on the other hand, is made up of two glucose units. It can retain a large amount of water.

Replacing trehalose with water appears to prevent structural deformities in tardigrades, though no one is sure how trehalose is able to do so. Some believe that the ability of trehalose to retain water molecules reduce the water loss. Some believe that it is because trehalose can interlink between various molecules. Whatever be the reason what we do know is that tardigrades can survive for a long period of time after cryptobiosis. The earliest observations were made by Anton van Leeuwenhoek in 1702, when he observed these animals under his microscope. He saw that by adding water, these animals could slowly be revived and the removal of water led to suspended animation.

The tardigrades are part of an important experiment. Can they survive in space and if they can, what features enable them to do so. The space has extreme conditions, it is extremely dry and creature in space will have to face harmful solar and ultraviolet radiations. The extreme dry climate implies that the organism needs to be equipped to survive under desiccating conditions. And we know that tardigrades are superbly equipped to do so. The first experiment was carried out in 2007 and it was found that tardigrades could indeed survive in space. In May 2011, they were carried in the space shuttle 'Endeavour' to understand further the ability of this organism to survive in the harsh environmental conditions of space. We have to wait and see what further surprise the organism reveals.

THE COLOURFUL CHAMELEON

We are like chameleons, we take our hue and the color of our moral character, from those who are around us.

-John Locke

The chameleon sat motionless on the bark of the tree. It was brown in colour. I moved slowly, trying to capture it on my camera. Alas, I was not very careful, and the chameleon moved. It now sat hidden amongst the leaves and as I watched it breathless, it turned from brown to pale green. Soon it was invisible.

How does the chameleon do this trick? Does it possess different pigments—brown, green, yellow... that it switches on, as the need be? How does it realize that the surrounding has changed and therefore, it should now change its colour? How many colours can a chameleon turn into?

Yes, the chameleons do possess different colour pigments. These creatures contain cells that possess the ability to make red, yellow or brown pigment. These

cells are called chromatophores (chroma: colour). The chromatophores are present just beneath the outer layer of the skin and are arranged in layers. Thus, the layer just beneath the outer layer of skin contains cells that can make red and yellow pigments. Beneath this layer further, is a layer of cell that has the ability to scatter light. Finally, is the layer of cells that has two characteristics. The first characteristic is the ability of these cells to make a brown pigment called 'melanin.' Melanin is universally present in all organisms and has the capacity to absorb all colours comprising light. However, the melanin that is produced in chameleons has the ability to move around the cell and thus, redistribute itself. The melanin can be present bunched together as a clump or widely distributed through the cell. The second characteristic of these cells is that they have branches and these branches extend upwards, invading the other layer of cells.

When melanin is bunched up together as a clump, the light that strikes the chameleon, is scattered by the scatter layer. The colour we see is the colour that is reflected by the yellow pigment. When melanin is distributed throughout the cell, all the colours are absorbed by this pigment and the chameleon appears dark in colour. When melanin is partially distributed, then the chameleon can adopt brown or green colour depending upon the extent of distribution.

How does the chameleon decide when it should change colour? The chameleon senses light, temperature and mood. For example, the chameleon that I was observing moved from the branch that was partially exposed to the sunlight into the thickset leaves, where the sunlight could not penetrate. The extent of light available as well as the temperature changed with the movement of the chameleon. And this change was sensed by it and accordingly it changed its colour. Besides, mood is also a determinant of the colour. A species of chameleon called 'Panther chameleon' becomes red when it is angry.

That brings us to the third question. Does each chameleon species possess the ability to change into any colour? The answer is 'no.' Each species possesses a set of colour pigments that is characteristic to that species. So, some can adopt exotic colours while others have more restricted range.

Why did chameleons evolve this ability? Was it because the ability to change colour helped it to hide better from its enemies? Or, was it to help in courtship? For a long time, scientists believed that, chameleons change their colour to blend into the surrounding and thus, be camouflaged. However, recent research has shown that this hypothesis is false. Researchers now believe that the chameleons evolved this ability to attract other chameleons and to warn potential rivals. Devi Stuart-Fox, a researcher at University of Melbourne, Australia, studied the chameleons in South Africa for four years and found that the males that possessed the ability to change into a wide of range of colours usually used the most eye-striking colour during courtship.

Chameleons are not unique in possessing the ability to change colours. There are other organisms like cephalopods, which reside in the oceans. These organisms, also called 'chameleons of the oceans,' possess a much wide colour palette than chameleons. Furthermore, cephalopods can change their colour within milliseconds.

ECHOLOCATING YOUR WAY IN DARK

Bumblebee bat, how do you see at night?
I make a squeaky sound that bounces
back from whatever it hits. I see by hearing.
-Darrin Lunde, Hello, Bumblebee Bat

During summers, in the night, I can sometimes see the bats flying about. I am not overtly fond of the bats and when they flap their wings as they sweep up and down, I have to control the urge to scream.

However, bats are special creatures. Along with dolphins and whales, they are one of the few mammals that use echolocation for navigation. Bats are nocturnal creatures and are of different types. For example, the Old World fruit bats have large eyes with good light-gathering capacity while the insect-eating bats possess small eyes and depend on echolocation to find their food. It was in 1799 that the Italian scientist Lazzaro Spallanzani discovered that bats do not use sight, but instead use hearing to locate preys.

What is echolocation? Sound, like light, travels as waves.

When we speak, a wave of air pressure is created that moves forward. When this wave hits a solid object, the object reflects back the sound wave, exactly as though it were a light wave. The reflected wave is known as 'echo.' You can get echo in canyons and in man-made structures. The Bara Imambara in Lucknow is famous for its echo. If you stand at end of the balcony and call out 'Hello', you will be able to hear the echo of the word 'Hello'. This is because the structure on the opposite end reflects back the sound waves. Bats use the same principle to locate their food. They produce a sound either through their mouth or through their nose. This sound creates waves

that traverse through the air until it hits a solid object like an insect. The insect reflects back the sound wave which the bat hears and thus, finds out the exact position of the insect.

How do bats use this property of the sound waves? Well, bats emit sound through their nose using their larynx or mouth by clicking their tongues. These sounds are made in the form of pulses. We cannot hear these sounds because these are very loud sounds in the range of 9 kHz to 200 kHz while the human ear can only hear sounds in the range of 20 Hz to 20 kHz. Hertz (Hz) is the unit of sound frequency, which merely means how many waves pass through a given point. Different species of bats emit different frequencies of sound. When a bat emits these sounds, the sound wave travels through the air until it hits the object, for example, an insect. The insect body reflects back the sound wave which is then received by the bat. The distance between the two objects is equal to the velocity of the sound multiplied by the time taken for the sound to be received. Thus, if a bat emits a sound and hears its echo back in 1 second, then the distance is given by:

$d = vt$ (where d is distance, v is velocity of sound in air, and t is the time taken for the bat to hear the echo).

$d = 343 \text{ m/s} \times 1 \text{ s}$

$d = 343 \text{ m}$

But, the time has to be divided by two because the bat emits a sound which travels through air to the object that then reflects back. Therefore,

$d = 172 \text{ m}$.

Thus, the bat can estimate the position of the insect accurately. Bats can emit sounds either at constant frequency or at varying frequencies. The calls also vary in repetition rate, intensity and length, hence allowing the bats to estimate not only the distance but also minute details such as size, hardness and the flutter of the prey's wings.

The ear of the mammal has a specialized structure known as cochlea to amplify and detect sound. The cochlea of bats is adapted to hear high frequency sounds.

Further, the auditory center in the brain appears to have become specialized to interpret the data received from echoes.

The discovery of echolocation in bats and dolphins is the basis of SONAR (Sound navigation and ranging) used for navigating, detecting and communicating with vessels/ objects under the surface of water.

Can humans use echolocation? A group of visually-challenged persons have been trained by scientists to use echolocation very successfully to navigate. Basically, these people actively create sounds, either by clicking their tongue, or by tapping their canes, or by lightly stomping their feet. Then they listen to the echo from the nearby objects to orient themselves and thus, navigate.

THE THIRSTY CROW

If men had wings and bore black feathers,
few of them would be clever enough to be crows.
-Henry Ward Beecher

Remember Aesop's fable about the thirsty crow? The crow finds a pitcher with water, but the level is so low that he cannot drink water from it. Then the crow decides to throw stones into the pitcher until the water level rises and it can drink water. The moral of the story is that where there is a will, there is a way or that necessity is the mother of invention.

For a long time, birds were believed to be of lesser intelligence than mammals. However, recent studies have shown that our traditional belief might be wrong.

The brain is a complex structure composed of neurons and glial cells. Of these two cells, neurons are considered most important. The brain is subdivided into many parts of which the neocortex is present only in mammals and is believed to be the seat of higher cognitive processes such as problem solving and memory formation. The

neocortex is absent in birds and therefore, for a long time it was believed that birds do not have the ability to solve problems or the skill to form concepts.

This view has now been challenged. Experiments done with many species of birds have begun to show that birds can indeed do problem-solving. The most amazing experiment came from a New Caledonian crow named 'Betty.' The New Caledonian crow is similar to our house crow, but it possesses an unusual ability to fashion tools. Three scientists from Oxford University studied Betty,

who was captured as a youngster and bred in captivity. However, Betty's ability to make tools was discovered by accident. The scientists were testing the ability of Betty and another New Caledonian crow named 'Abel' to retrieve food by using wires. The food was placed in a cage and the birds were provided with different kinds of wires to retrieve it. While Abel used a hooked wire to get the food, Betty took a straight wire, bent it into a hook shaped tool and used it to retrieve the food. This was the first time, a bird bred in captivity, had exhibited such power.

This ability was even more fascinating because Betty had no role model to learn from as it had been reared in a laboratory.

Betty is not the only example in the world of birds. Nor is the tool-making the only ability that birds display. One of the cognitive abilities that mammals possess is memory formation, a trait that corvids, the group to which crows belong, also display. Corvids live in large societal groups and in a study with Pinyon Jays, which are also corvids, it was found that these birds can recognize individuals within their group. Another member of the Corvidiae family is the Clark's nutcracker, which has a remarkable spatial memory. It can store its nuts in 20,000-30,000 separate places and yet, accurately retrieve each one of them months later.

So what region of the brain in birds provides this ability? It appears that the birds possess a region that goes by the tongue-twister name 'nidopallidium caudolaterale,' which functions in a comparable manner as neocortex in mammals. Furthermore, the birds also seem to possess similar neural substrates required for skills such as imagination and reasoning in neocortex and nidopalladium caudolaterale.

Do all birds possess cognitive abilities similar to mammals? We do not know. What we know is that the cognitive abilities seem to be maximal in birds that live in large complex societies. Further, a comparison of neural densities between different species of birds has shown that the 'intelligent' birds contain a higher neural density. However, it needs to be confirmed whether a higher neural density does indeed provides higher cognitive skills.

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Nature is endowed with creativity, so are wonderful its phenomena which we see around us. From the flight of birds to the light emitted by glow-worms to the chameleons changing their colour, they have always captured the imagination of humans. The present book explores the fascinating world of insects, birds and animals and explains in a lucid manner the principles of science and mathematics behind these various phenomena. An interesting read for young and curious readers who not only admire Nature but also wish to know more about it.

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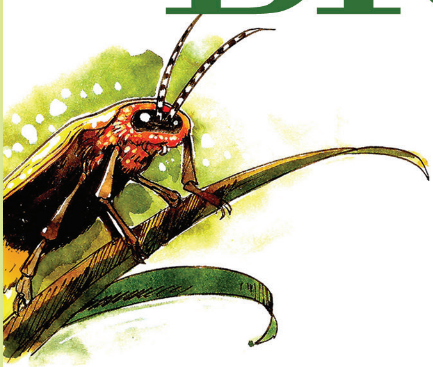

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