Unsuspected benefit of getting away

A STUDY SHOWS THAT REJUVENATION IS AN IMPORTANT FACTOR TO INDUCE TAKING A BREAK, WRITES **S ANANTHANARAYANAN**

The migratory behaviour of birds, fish, insects and even animals is fascinating to observe, both as a mystery of why it has evolved as well as the incredible endurance that many species exhibit during the movement, often over thousands of kilometres.

Mathematician Allison K Shaw of the University of Minnesota and naturalist Sandra A Binning of the University of Neuchâtel, Switzerland, describe in their paper in the journal *The American Naturalist* a mathematical analysis of the costs and a benefit of animal migration, as against staying put. Apart from climate and habitat, which are the reasons for migration that have been considered so far, they consider the benefit of escaping attacks by parasites as another major gain. Though migration has its costs of risk and hardship, they examine the conditions required for the exercise to still be viable as a method of escaping parasites. Their study shows that apart from escape, there is a degree of recovery from the effect of parasite attacks that brings the model closer to reality and allows partial migration to evolve.

Allison K Shaw and Sandra A Binning

Migratory movement, in this sense, is not just the dispersal or spread of animals when their numbers increase, but a seasonal movement of a group of animals to a new habitat at a distance. Instances are of birds in the northern hemisphere that fly south for the winter, antelopes and wildebeest in Africa that move 800 km seasonally for pasture or for calving, fish that move to spawning waters, often changing from salt water to fresh, or vice-versa, sea birds that come ashore to breed, and so on.

Avoiding harsh weather, seeking food and safety during the breeding season, to help optimise the chances of survival in the face of changing environment are good reasons for migration.

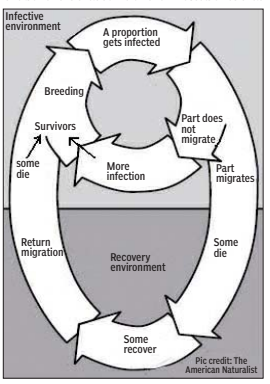
An additional reason, although not equally well studied, say Shaw and Binning in their paper, could be migration as a strategy to lower the risk and consequences of attack by infection or parasites. Parasites are often adapted to existing conditions of salinity, humidity, etc, and movement of the host to a different clime may make it difficult for the parasites to survive. However, as all factors that promote migration are usually active at the same time, it is difficult, in practice, to isolate the separate reasons why migratory behaviour has evolved.

Theoretical studies, however, are useful in considering how the influence of different factors may rise or fall in varying conditions, leading to insights into how migration may have evolved, the authors say.

Two mechanisms by which migration may deal with attack by parasites have been suggested. One is escape by getting physically away from the environment that harbours the parasite, the paper explains. The other is migratory culling, where the act of migration places stress on individuals infected by pathogens or parasites, so that many of the infected hosts do not survive. The authors suggest a third mechanism — of recovery from parasite attack during migration. "Many migratory species move between different habitat types or across strong environmental gradients (eg, temperature, humidity, salinity, altitude, dissolved oxygen). Parasites are often picked up and lost at different rates in these habitats," they say. Immersing fish in water of different salinity to get rid of parasites or skin infections is commonplace, and there are studies of the behaviour of some animals to seek a warm climate or of birds sunning themselves to free their feathers of parasites. The same effect of infection control, however, has not been considered so far as an explicit reason for migration, the paper says.

Mathematical model

The paper creates a model of a population of individuals that live in a parasite-infested environment from which a section of the individuals migrates for a period, while the rest do not. While migration is arduous and takes its toll, the benefit is that some of the infected ones that



migrate would get rid of the parasites, while infected individuals that do not migrate would continue to be affected and, hence, pay an infection-cost. And then, during the period of migration, some of the healthy ones that stayed back would get infected. Some of those that stayed behind would also die in the normal course and so would a somewhat higher percentage of those that migrated, because of the stress involved.

And finally, the migrants would return to the home habitat, which is the breeding ground. As the formula that has been developed gives a measure of how many healthy and infected individuals join in the breeding season, the model is able to give the number of offspring born, and the newborns are taken to be without infection. The model also provides for a fecundity-cost of the effect of infection on the ability of individuals to reproduce. The model, hence, works out the numbers of healthy and infected individuals at the beginning of the second year, based on the numbers at the start of the first year. This, of course, is according to the assumptions of the proportion of the population that gets infected in a given time, the proportion that migrates, as well as the rates taken for normal attrition, the infection cost, migration cost and fecundity rates.

Given this picture of change over the year, the proportion that migrates, as assumed in the model, is moved up or down till the numbers at the start of the second year come out the same as at the start of the first, which is to say that there is equilibrium. This then provides a measure of how evolutionary forces should result in the proportion that actually migrates for sustainability — the evolutionarily stable strategy.

The factors that were considered to affect the choices were the likelihood of infection in the home environment and of recovery during migration; the likelihood of survival even when not infected; survivals costs, both of infection and of migration; and the effect of infection on reproductive ability. In the case where there are very high chances of infection as well as of recovery, the best strategy simply works out to be a comparison of the cost of migration and that of staying put — and is a simple one-or-the-other strategy. But in real life, Shaw and Binning analyse, even if there were a low chance of infection and the cost of migration were high, never to migrate would mean that an individual would have no way of recovery once he/she was infected, as at some time he/she will be. The best strategy to evolve would hence be a mixed one, where a part of the population migrates and a part stays home so that the chances of survival and, hence, the annual reproductive potential are optimised.

This is relevant, of course, the authors add, mostly when the lifetime of the organism is more than a few seasons and mixed strategies are generally favoured when the chances of recovery are high and the infection rate is low. With higher infection rates, migration is generally the better choice. At the same time, they note, there are also counter-intuitive results when infection affects both survival as well as reproductive capacity. Migration may then become unlikely as the organism may not live long enough for occasional migration to help.

Researchers are increasingly recognising that parasite pressure can be a driver of the largescale movement of animals, the authors say. While there are known instances of specific life cycle history in response to parasites, parasite evasion has not been examined as the reason for the evolution of seasonal migration behaviour. On the other hand, researchers have paid more attention to the negatives of migration, like being susceptible to unknown pathogens, crowding at stopover points or the weakened condition on arrival at the destination, the authors say. However, as migration is a fact, these negatives must be getting offset by the benefits, they add.

Although there is little experimental data to support migratory recovery, there are instances of migrants benefiting from a loss of parasites, and migratory recovery is a valid mechanism that explains the evolution of partial migration, the authors say. The present model that has been developed based on long distance migration, but it could be modified to suit other conditions, they say. Shaw and Binning invite other researchers to take into account the loss of parasites as a factor while studying animal movements and also to improve the current model by refining the assumptions made.

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PHOTOSYNTHETIC REDUCTION

TAPAN KUMAR MAITRA EXPLAINS HOW LIGHT IS CONVERTED INTO CHEMICAL ENERGY BY PLANTS AND ALGAE

The process by which light energy is converted into chemical energy within a chloroplast or bacterium depends on the nature of light (electromagnetic radiation) and its interaction with molecules. Light is often regarded as a wave — the visible portion of the electromagnetic spectrum, for example, consists of light having wavelengths ranging from 380 to 750 nm. It also behaves, however, as a stream of discrete particles called photons, each one carrying a quantum (indivisible packet) of energy— the wavelength of a photon and the precise quantum of energy are inversely related.

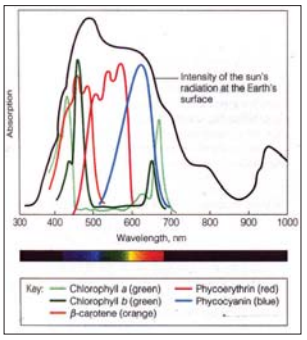
When a photon is absorbed by a pigment (light-absorbing molecule), such as chlorophyll, the energy of the photon is transferred to an electron, which is energised from its ground state in a low-energy orbital to an excited state in a high-energy orbital. The event, called photo excitation, is the first step in photosynthesis. The transfer of the photo excited electron to a high-energy orbital in another molecule is called photochemical reduction and the transfer is essential for converting light energy to chemical energy.

Chlorophyll, which is found in nearly all photosynthetic organisms, is the primary energy-transduction pigment that channels solar energy into the biosphere. The structures of two types of chlorophyll are designated *a* and *b*. The skeleton of each molecule consists of a central porphyrin ring and a strongly hydrophobic phytol side chain. The alternating double bonds in the porphyrin ring are responsible for absorbing visible light, while the phytol side chain interacts with lipids of the thylakoid or cyanobacterial membranes, anchoring the light-absorbing molecules in them.

The magnesium ion found in chlorophylls *a* and *b* affects the electron distribution in the porphyrin ring and ensures that a variety of high-energy orbitals are available. As a result, several specific wavelengths of light can be absorbed. Chlorophyll *a*, for example, has a broad absorption spectrum, with maxima at about 420 and 660 nm. Chlorophyll *b* is distinguished from chlorophyll *a* by the presence of a formyl group in place of one of the methyl groups on the porphyrin ring. That minor structural alteration shifts the absorption maxima toward the centre of the visible spectrum.

All plants and green algae contain both chlorophyll *a* and *b*. The combined absorption spectra of the two forms provide access to a broader range of wavelengths of sunlight and enable such organisms to collect more photons. Other oxygenic photosynthetic organisms supplement chlorophyll *a* with either chlorophyll *c* (brown algae, diatoms, and dino-flagellates), chlorophyll *d* (red algae), or phycobilin (cyanobacteria).

Most photosynthetic organisms also contain accessory pigments, which absorb photons that cannot be captured by chlorophyll. The feature enables organisms to collect energy from a much larger portion of the sunlight reaching the Earth's surface — two common types are carotenoids and phycobilins. Chlorophyll molecules, accessory pigments, and associated proteins are organised into functional units called photo systems, which are localised to thylakoid or photo-synthetic bacterial membranes. Each photosystem is generally associated with a light-harvesting complex, which collects light energy. The LHC does not, however, contain a reaction centre but instead passes the collected energy to a nearby photo system by resonance energy transfer. Plants and green algae have LHCs composed of about 80-250 chlorophyll *a* and *b* molecules, along with carotenoids and pigment-binding proteins.



In the 1940s, Robert Emerson and his colleagues at the University of Illinois in the USA discovered that two separate photo reactions are involved in the photo reduction process. Initially, they observed a dramatic drop in the rate of oxygen evolution above a wavelength of about 690 nm for photosynthesis by the green alga, chlorella. Emerson's group considered that odd because chlorella actually contains chlorophyll molecules that absorb a significant amount of light at wavelengths above 690 nm. When they supplemented the longer wavelengths of light with a shorter wavelength (about 650 nm), the drop was less severe. Indeed, photosynthesis driven by a combination of long and short wavelengths of red light exceeded the sum of activities obtained with either wavelength alone. This synergistic phenomenon became known as the Emerson enhancement effect.

In oxygenic phototrophs, it is the result of two distinct photo systems working in tandem. Photosystem I, with a maximum of 700 nm, absorbs both long and short wavelengths of red light, whereas photosystem II, with a maximum of 680 nm, absorbs only short wavelengths of red light. Each electron that passes from water must be photo excited twice — once each by PSI and PSII. When illumination is restricted to wavelengths above 690 nm, PSII is not active and photosynthesis is severely impaired. The special pairs of chlorophyll molecules within the reaction centres of PSI and PSII are designated, respectively, P700 and P680 to reflect their specific absorption maxima.

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'Maybe it's tricking us'

'THE UNIVERSE IS EXPANDING FAR FASTER THAN EXPECTED AND IS POTENTIALLY CAUSING HUGE PROBLEMS FOR PHYSICS.**ANDREW GRIFFIN** REPORTS

The universe is expanding far quicker than we'd have thought – and might throw up a problem with the most central parts of our understanding of physics. The discovery could prove a challenge to Albert Einstein's theory of relativity, which had for the last century stood unchallenged as one of the fundamental parts of our understanding of the universe. It could also upset our ideas of what sits in the 95 per cent of the universe that doesn't emit light or radiation, according to scientists.

The universe is expanding between five and nine per cent faster than expected, according to the National Aeronautics and Space Administration and the European Space Agency. "Maybe the universe is tricking us," said Alex Filippenko, a University of California, Berkeley, astronomer and co-author of an upcoming paper about the discovery.

The universe's rate of expansion does not match predictions based on measurements of the remnant radiation left over from the Big Bang explosion that gave rise to the known universe 13.8 billion years ago.

One possibility for the discrepancy is that the universe has unknown subatomic particles, similar to neutrinos, that travel nearly as fast as the speed of light, which is about 300,000 km per second. Another idea is that so-called "dark energy", a mysterious anti-gravity force discovered in 1998, may be shoving galaxies away from one another more powerfully than originally estimated.

"This may be an important clue to understanding those parts of the universe that make up 95 percent of everything and that don't emit light, such as dark energy, dark matter and dark radiation," physicist and lead author Adam Riess, with the Space Telescope Science Institute in Baltimore, Maryland, said in a statement. Riess shared the 2011 Nobel Prize in Physics for the discovery that the expansion of the universe was speeding up.

A speedier universe also raises the possibility that Einstein's general theory of relativity, which serves as the mathematical scaffolding for calculating how the basic building blocks of matter interact, is slightly wrong, Nasa said.

Riess and colleagues made their discovery by building a better cosmic yardstick to calculate distances. They used the Hubble Space Telescope to measure a particular type of star, known as Cepheid variables, in 19 galaxies beyond our own Milky Way galaxy. How fast these stars pulse is directly related to how bright they are, which in turn can be used to calculate their distances, much like a 100-watt light bulb appears dimmer the farther away it is.

The research will be published in an upcoming edition of *The Astrophysical Journal*.

THE INDEPENDENT

The Hubble Space Telescope shows the tattered remains of a supernova explosion known as Cassiopeia A. It is the youngest known remnant from a supernova explosion in the Milky Way.

PLUS POINTS

Human Genome Project

A team led by New York University's Jef Boeke, Harvard's George Church and Andrew Hessel of the California-based commercial design studio Autodesk Research has published its proposal to synthesise entire genomes from scratch, including those of humans. Called the "Human Genome Project-Write" (the authors refer to the original HGP as Human Genome Project-Read), the initiative could take 10 years and a minimum of $100 million just to get started, the researchers wrote in *Science* on 2 June.

"It's essentially a call to action," Hessel told *BuzzFeed News*. "We are suggesting it's time to consider a new genome project standing on the foundations of the Human Genome Project."

An underlying goal of the proposed project is to develop technologies to more efficiently and more cheaply write DNA. "Tangible products may be slow to follow at first, but writing DNA more cheaply and at large scale will make researchers more efficient and comprehensive in their work, leading to practically unlimited potential for indirect products," Danielle Tullman-Ercek, a biochemical engineer at the University of California, Berkeley, told *Nature*.

But the proposal was not universally praised. "My first thought was, so what," Martin Fussenegger, a synthetic biologist at the Swiss Federal Institute of Technology in Zurich, told *Nature*. "I personally think this will happen naturally. It's just a matter of price at the end."

THE SCIENTIST

Butterfly effect

Loved throughout the world for their striking and diverse colours, scientists at the University of Sheffield have identified the gene responsible for butterflies' colourful patterns. The study, led by Dr Nicola Nadeau from the university's

Department of Animal and Plant Sciences, has discovered that a gene called cortex controls some of the major differences in butterfly warning colour patterns.

The researchers studied the wing colour patterns of the Heliconius, also known as passion-vine butterflies — a brightly coloured species found in the rainforests of Latin America. Their colours warn predators that they contain toxins, which they get from the passion-vine plants they eat as caterpillars. Apart from being bright, their colours are also extremely variable, and the same species of butterfly often has very different patterns in different areas.

Nadeau said, "The wing patterns of butterflies have puzzled scientists and nature-lovers for generations. Their patterns are beautiful to look at but also amazing when you see how much they can change, sometimes within tens of kilometres, as you travel through the rainforest. What our study did was look for differences in the DNA of butterflies with different patterns to try to understand what it is that controls their colour patterns. We identified a fast-evolving gene called cortex, which we believe is responsible for butterflies changing colours and patterns in order to protect themselves from predators."

The study was published in the journal *Nature* on 1 June.

Electric sense

Bees use electric fields to help home in on flowers, but the mechanism by which the insects do so was a mystery. To find out, scientists used lasers to determine whether the antennae or tiny hairs on bumblebees' bodies moved in response to

an electric field. While both structures were deflected in the field, only the hairs produced neural activity, suggesting the latter may be responsible for the insects' electric sense, researchers at the University of Bristol, UK, reported in *PNAS*.

In the present study, the University of Bristol's Gregory Sutton and colleagues hypothesised that the bees used either their antennae or the tiny mechanosensory hairs on their bodies to sense these floral electric fields. To test this, the team measured the vibration of the insects' body hairs and antennae in an electric field using a laser Doppler vibrometer. Because bees are naturally positively charged, the researchers first gave the insects an electrical charge.

The electric field caused deflections in both the hairs and antennae, which increased with the charge of the bee. Sutton's team concluded that these tiny hairs were responsible for their electric sense.