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Letting the heat leak out

A BODY COVER THAT HELPS US STAY COOL IN WARM WEATHER WOULD REDUCE THE COST OF CLIMATE CONTROL, WRITES **S ANANTHANARAYANAN**

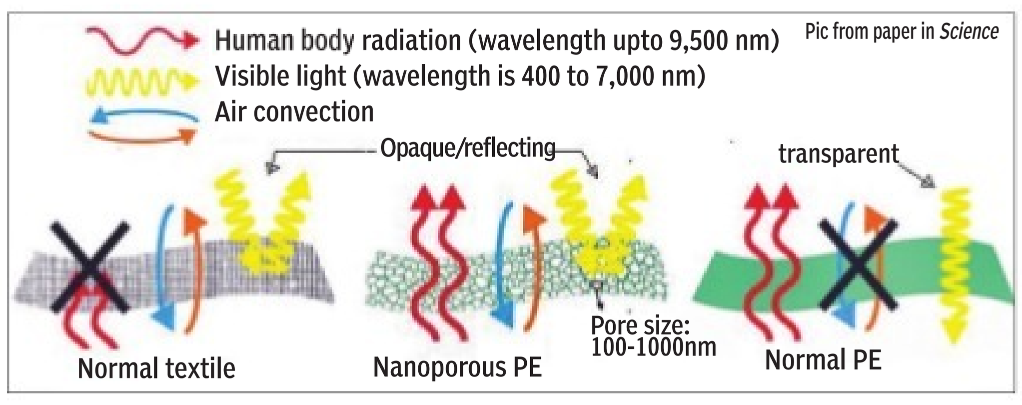
The principal purpose of clothing has been to protect the wearer from the cold. Better personal insulation could thus be one measure to help the Western world save on winter heating. But another large cost that the modern world faces, and one that would grow with global warming, is keeping the environment cool in warm weather. Clothing that does the opposite of insulating our bodies may be a way to economise on how cool we need the surroundings to be.

Po-Chun Hsu, Alex Y Song, Peter B Catrysse, Chong Liu, Yucan Peng, Jin Xie, Shanhui Fan and Yi Cui from the Departments of Material Science and Electrical Engineering at the University of Stanford and the Linear Accelerator facility at Stanford report in the journal *Science* that they have developed a material that does just that.

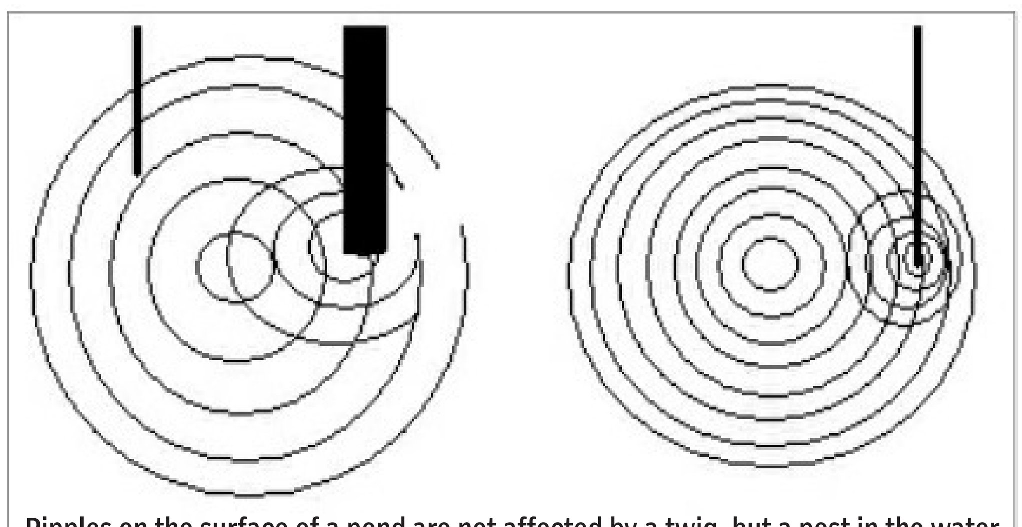
The way woolen or other fabrics help us keep body heat in is by being poor conductors of heat and impervious to winds. Insulating materials work by trapping pockets of air whose dimensions are nearly the same or less than the average distance that one molecule in the air moves before it encounters another. The thinner the fibres of the material and the closer the fibres are packed, the better the insulation. The reason why we need to conserve body heat in the winter is that the body is much warmer than the surroundings and would rapidly lose heat if exposed. But in warm weather, there is much heat coming in by radiation from warm surroundings and the body needs to lose heat. Any clothes we wear act as a blanket and create a warm layer around the body. And if we need to lose more heat because of exertion, the warmth can be oppressive.

When we need to cool rapidly, because of exertion or because of a warm environnThis is the way glands get active and cover the body with perspiration. This carries out some of the heat and, when it evaporates, it cools the body surface and draws out more heat. But if the body is covered by clothes and, of course, it usually is, perspiration collects and the discomfort multiplies. There is a way to treat fabrics so that they draw the perspiration out to the exterior, when it could dry and cause some cooling, but this treatment gets active only when there is perspiration, which is to say, when the body is pretty heated up already.

Yet another warm cover that we have is the atmosphere itself. The sun, which is very hot — some 6,000° Celsius — radiates mainly in visible light. The shortest light waves, towards the blue end of the spectrum, get scattered by the tiniest particles in the air but most of the energy, towards the red end of the spectrum, reaches ground level. The longer waves, the warm, infrared, do not get scattered by particles in the air but are absorbed by large molecules, like CO_2 or methane, in the air and warm up the atmosphere. These molecules also absorb the heat that the earth itself radiates and keeps our planet from cooling down at night.



The Stanford group took the lead from the atmosphere to create a fabric that would allow heat waves to pass through and still block light of the visible kind so that the fabric would perform the social role of clothing. The reason that light at the blue end of the spectrum is scattered by the atmosphere, which gives the sky its blue colour, is that the air contains particles that are of the dimensions — around 500 nanometres — of the wavelength of blue light. Infrared waves at more than 1,000 nanometres, are much longer than these particles and do not get affected.



Ripples on the surface of a pond are not affected by a twig, but a post in the water is able to scatter the waves. If the waves were closer together, however, even the twig would cause scattering.

The Stanford group examined an existing, normally transparent polyethylene fabric, but with the provision of nanopores from 50 to 1,000 nanometres in diameter. As the pores are of sizes comparable with the wavelength of visible light, visible light gets strongly scattered and the material is no longer transparent. The pores, however, are much smaller than infrared heat waves, which are able to freely pass through the material. The material, nanoPE, is found to allow 96 per cent of the heat waves to pass through, against only 1.5 per cent in the case of cotton fabric, which we usually wear in the summer. Normal polyethylene is also as good at allowing heat to escape, but it allows 80 per cent of visible light to pass through. NanoPE, on the other hand, is 99 per cent opaque. In trials conducted on a surface that mimics the temperature of human skin, it was found that a drape of nanoPE caused a rise in temperature of only 0.8° Celsius, as against 3.5° Celsius for cotton and 2.9° Celsius for commercially available fibrous PE textile.

Cotton clothing, despite the greater warming, is preferred to normal polyethylene because it soaks up any perspiration. Polyethylene garments, in contrast, allow perspiration to collect and can be quite uncomfortable in humid weather. One solution has been the use of "wicking" treatment, by a water repellent material that prevents the fabric in contact with the skin from getting soaked, along with a capillary structure that draws moisture to the outer side. This treatment has been found to help cotton fabric too. The use of this treatment could similarly increase the comfort of clothing made of nanoPE, whose porous construction also permits the permeation of air.

The paper by the Stanford group notes that nanoPE, or PE with nano-hole treatment, is commercially available as it is used in the manufacture of lithium-ion batteries. The team has also experimented with a cotton mesh sandwiched between layers of nanoPE and finds that this has mechanical strength and is suitable for use as clothing. The paper works it out that a drop in surface temperature by about two degrees Celsius implies that airconditioning in workplaces or homes can be set correspondingly, about three degrees Celsius, higher. The saving in cost is about 25 per cent for a two-degree Celsius raising of the AC temperature setting. The material could equally be used to check the temperature rise of tents, porta-cabins or vehicles.

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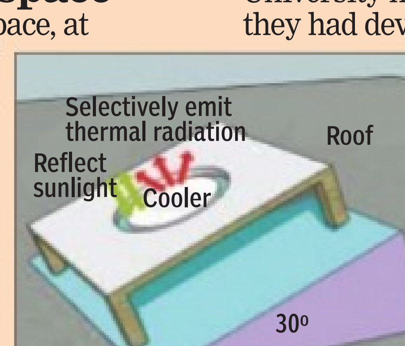
Sending it into space

Considering that outer space, at temperatures near absolute zero (-273° Celsius) is a cold place, it should be simple for things on earth to cool. Why this is not so is that the atmosphere keeps all infrared radiation from escaping from earth. Warm things that radiate hence end up warming their surroundings and getting warmed in turn.



Except that there is a small window of frequencies of the infrared to which the atmosphere is truly transparent. Linxiao Zhu, Aswath P. Raman, Marc Abou Anoma, Eden Rephaeli and Shanhui Fan, also of Stanford University had reported in 2014 that they had developed a surface, a photonic radiative cooler, that could radiate heat at the very frequency that has free passage through the atmosphere. An object covered with this surface could absorb heat from the sun and still grow cooler by radiating its own heat straight out to space.

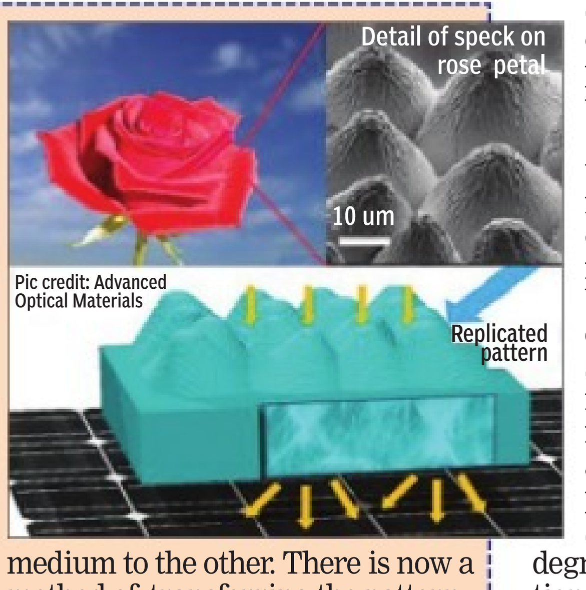
Some of the members of the same group reported, in 2015, the development of a transparent surface, a sliver of silica, which could do this. This discovery would have application for keeping solar cells cool and still admitting visible light that gives rise to the photo-current.

Perfect transparence

Even transparent surfaces like glass do not allow all light that falls on them to pass through — they reflect part of the light. The reason for reflection is that the electric and magnetic properties of media, which determine the speed of light waves, change when light passes from one medium to another.

A group at the Karlsruhe Institute of Technology, in Karlsruhe, Germany, and the Centre for Solar Energy and Hydrogen Research, Stuttgart, recently studied the structure of natural surfaces that are able to do better -- the cornea of the moth, a night-time creature that needs to capture all the light that it receives, and the surface of the rose petal, which needs to make the best use of light for photosynthesis.

The surfaces have microscopic, conical protuberances, of the dimensions of the wavelength of light, which affect the light waves and smooth the transition from one medium to the other. There is now a method of transferring the pattern to a film to lay on solar cells and ensure that all the light that falls on the cells is made use of for generating electricity and not reflected and lost.

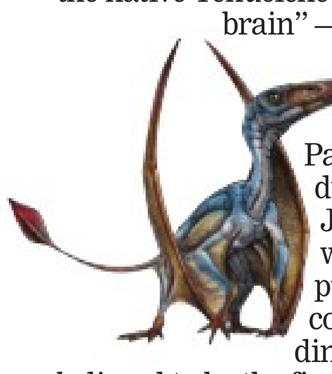


Coating the inner surface of nanoPE fabric with this pattern would make sure that heat radiation from the body actually goes out and is not reflected back in.

PLUS POINTS

Evolution of flight

A fossil of a previously unknown species of reptile that lived among the dinosaurs has been found in Argentina in a discovery that could help scientists work out how the first flying animals evolved. The "superbly preserved, uncrushed" skull of an Allkaruen koi — named after the native Tehuelche word for "ancient brain" — and other remains were found in Chubut province in Patagonia. It lived during the early Jurassic period and was a type of pterosaur, a close cousin of the dinosaurs that is believed to be the first kind of vertebrate capable of powered flight.



They had some extraordinary features to help them stay airborne, including hollow, pneumatic bones to reduce their overall weight and an elongated "finger" that supported the wing membrane. Dr Diego Pol, one of the researchers, said, "Allkaruen, from the middle lower Jurassic limit, shows an intermediate state in the brain evolution of pterosaurs and their adaptations to the aerial environment. As a result, this research makes an important contribution to the understanding of the evolution of all pterosaurs."

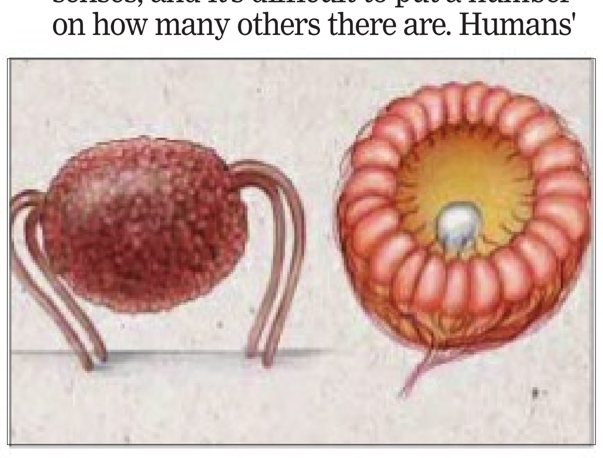
They described their findings in a paper in the open-access journal PeerJ, saying the "braincase was undistorted and superbly preserved". Previously palaeontologists knew of two major pterosaur body plans: a long-tailed primitive version and then the more familiar, short-tailed pterodactyl-like shape. "These two groups differ considerably in their general anatomy and also exhibit a remarkably different (brain anatomy) and inferred head posture, which has been linked to different lifestyles and behaviours and improved flying capabilities in these reptiles," the paper said.

It added that the features of the Allkaruen skull — in particular the inner ear, which is important for balance — "fills an important gap" in the evolution from the early form of pterosaur to the pterodactyls. Pterosaurs were neither birds nor bats, but reptiles that learned to fly, according to the American Museum of Natural History. "They were also the first animals after insects to evolve powered flight -- not just leaping or gliding, but flapping their wings to generate lift and travel through the air," according to the museum's website. "They evolved into dozens of species; some were as large as an F-16 fighter jet, and others as small as a paper airplane."

IAN JOHNSTON/THE INDEPENDENT

Sensory biology

Growing up, we learn that there are five senses: sight, smell, touch, taste and hearing. For the past five years, The Scientist has taken deep dives into each of those senses, explorations that revealed diverse mechanisms of perception and the impressive range of these senses in humans and diverse other animals. But as any biologist knows, there are more than just five senses, and it's difficult to put a number on how many others there are. Humans'



vestibular sense, for example, detects gravity and balance through special organs in the bony labyrinth of the inner ear. Around the animal kingdom, numerous other sense organs aid the perception of their worlds.

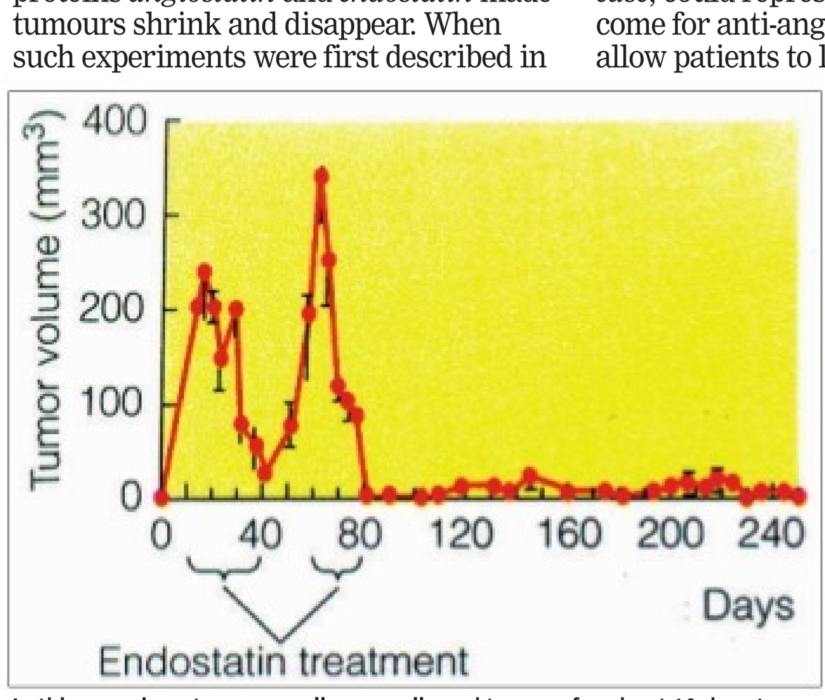
The ability to detect gravity and the body's motion may be one of the most ancient senses. In vertebrates, the complex vestibular system handles this task via the otolith organs and semicircular canals of the inner ear. Invertebrates rely on a simpler structure known as a statocyst to sense their own movement and body position relative to the earth's gravitational pull. Even comb jellies (ctenophores), which may have been the first multicellular animals to evolve, have a rudimentary statocyst — essentially, a weight resting on four springs that bend when the organism tilts in the water.

The comb jelly's single statocyst sits at the animal's uppermost tip, under a transparent dome of fused cilia. A mass of cells called lithocytes, each containing a large, membrane-bound concretion of minerals, forms a statolith that sits atop four columns called balancers, each made up of 150-200 sensory cilia. As the organism tilts, the statolith falls towards the earth's core, bending the balancers. Each balancer is linked to two rows of the ctenophore's eight comb plates, from which extend hundreds of thousands of cilia that beat together as a unit to propel the animal. "They're the pacemakers for the beating of the locomotor cilia," says Sidney Tamm, a researcher at the Marine Biological Laboratory in Woods Hole, Massachusetts, who has detailed the structure and function of the ctenophore statocyst.

USEFUL ANTI-CANCER AGENTS

TAPAN KUMAR MAITRA EXPLAINS HOW ANTI-ANGIOGENIC THERAPIES ACT BY ATTACKING A TUMOUR'S BLOOD SUPPLY

Sustained tumour growth depends on *angiogenesis* – that is, the development of new blood vessels that supply nutrients and oxygen to the tumour and remove waste products. It is, therefore, logical to expect that inhibitors of angiogenesis might be useful agents for treating cancer. Initial support for the concept of *anti-angiogenic therapy* came from the studies of Judah Folkman, who reported that treating tumour-bearing mice with the angiogenesis-inhibiting proteins *angiostatin* and *endostatin* made tumours shrink and disappear. When such experiments were first described in 1998 on the front page of the *New York Times*, a distinguished scientist was reported as having said, "Judah is going to cure cancer in two years."



In this experiment, cancer cells were allowed to grow for about 10 days to form a large tumour in mice. The mice were then injected with an angiogenesis inhibitor, endostatin, until the tumour regressed. After allowing the tumour to grow again in the absence of endostatin, a second treatment cycle was given. After the second treatment was stopped, the tumour no longer grew again.

Needless to say, such sensational news coverage led to unrealistic expectations concerning the prospects for a quick cancer cure. Applying the results of animal studies to human patients takes many years of testing, and there are several potential obstacles to overcome. First, many of the early human trials of anti-angiogenic drugs were carried out on cancer patients with late stage disease, and anti-angiogenic therapy may work better at earlier stages. Second, the optimal dose for angiogenesis-inhibiting drugs may need to be tailored to each patient based on the concentration of angiogenesis-stimulating molecules produced by their tumours. And, third, the effectiveness of anti-cancer drugs is usually measured by assessing their ability to make tumours shrink or disappear.

While this might be an appropriate expectation for a drug that kills cancer cells, inhibiting blood vessel growth may simply stop tumours from becoming larger. This condition, called *stable disease*, could represent an acceptable outcome for anti-angiogenic drugs if they allow patients to live with cancer as a chronic but manageable disease condition, especially in view of the minimal side effects associated with the use of such drugs.

The complexities raised by these issues mean that it will take many years to assess the effectiveness of the dozens of anti-angiogenic drugs that are currently being tested on cancer patients. Nonetheless, signs of progress are already evident. For example, in 2004 *Avastin* became the first anti-angiogenic drug to be approved for routine medical use in cancer patients. Avastin is a monoclonal antibody that binds to and inactivates the angiogenesis-stimulating growth factor, *VEGF*. In tumours that depend on VEGF to stimulate angiogenesis, Avastin would be expected to inhibit angiogenesis and thereby inhibit tumour growth. Human clinical trials have shown that patients with metastatic colon cancer who received standard chemotherapy plus Avastin lived longer than patients who received standard chemotherapy without Avastin. Such results represent one of the first signs that anti-angiogenic therapy may one day become an integral component of human cancer treatment.

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How songbirds island-hopped

CHRIS CONNEY REPORTS ON HOW RESEARCHERS USED GENETIC AND FOSSIL DATA TO RECONTRUCT THE EVOLUTIONARY FAMILY TREE TO CONFIRM THAT THESE BIRDS ORIGINATED IN AUSTRALIA MORE THAN 30 MILLION YEARS AGO

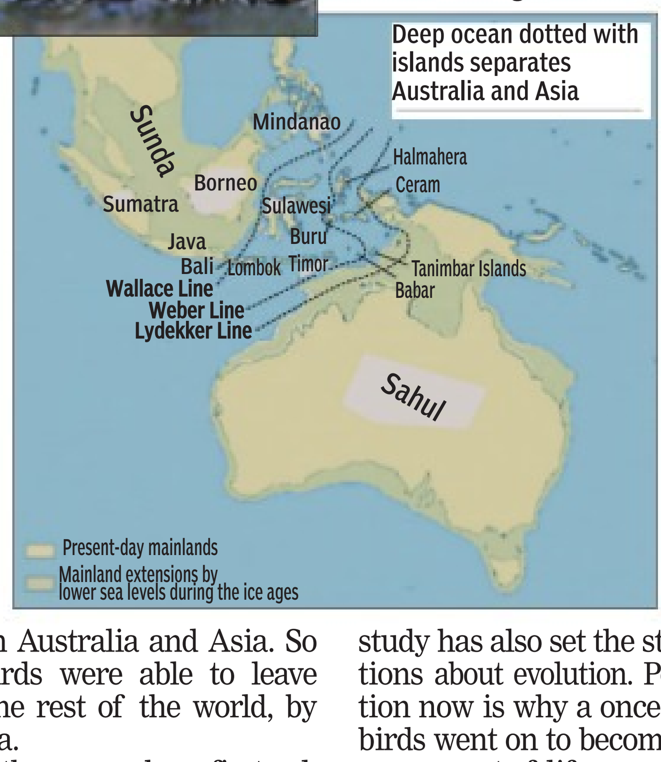
The songbirds that are common in gardens all across the world have a surprisingly distant origin - they all evolved from a common ancestor that emerged from what is now Australia around 24 million years ago. How they managed to leave that isolated part of the world and spread all over the planet has long been a mystery to scientists, but a new study suggests they began spreading just as the islands in and around Indonesia were being formed, creating a pathway for them to cross what had previously been thousands of kilometres of open ocean. Songbirds are a tremendously diverse group of small perching birds, made up of over 5,000 known species distributed worldwide. Common examples include the European robin (*Erithacus rubecula*) and the North American song sparrow (*Melospiza melodia*). Together, songbirds account for almost half of all avian species alive today.

Although fossils of birds are rare, the ancestor of all songbirds is thought to have originated in Australia at a time when that landmass was separated from all other land by a vast ocean in all directions. So despite the birds' extensive evolutionary spread, it remained unclear how this diverse and cosmopolitan family arose from a single ancestral species on an isolated continent.

Songbirds are categorised as small perching birds including the song thrush.

However, a recent study published in the journal *Nature Communications* sheds new light on this question. Using genetic and fossil data, the authors reconstructed the evolutionary "family tree" for songbirds. They then linked this to information on different species' geographic locations to understand how early songbirds spread between different continents over the course of millions of years.

This confirmed that songbirds originated in Australia just over 30 million years ago. But the most eye-catching finding is that songbirds started to spread out of Australia much more recently than previously thought. This process appears to have started approximately 24 million years ago, at the same time as the formation of Wallacea, a group of islands bridging the ocean-filled gap between Australia and Asia. So this may explain how songbirds were able to leave Australia and radiate across the rest of the world, by island-hopping their way to Asia.



To gain these novel insights, the researchers first collected DNA from many songbird species across the world. DNA molecules are the building blocks of life and bear the imprint of our evolutionary past. Close relatives tend to have more similar DNA to each other than to distant relatives. So by comparing DNA between songbird species that are related by different amounts, it is possible to reconstruct their evolutionary past and generate a family tree for the entire songbird group.

By mapping the geographic location of living species on to this family tree, the authors were then able to reconstruct where and when new songbird species evolved. The first songbirds originated in the landmass that would eventually become Australia. More surprisingly, though, the first major burst of evolution within songbirds coincided with a period of tectonic collision when islands began forming in the waters north of Australia. This provided the first land link between Australasia and the southeastern tip of Asia (Sundaland).

These novel insights have at least three interesting implications. The first is that it resolves the longstanding question of how and when songbirds arrived in Asia. Previous attempts to date the spread of the birds from Australia pointed to a much earlier time, when the landmass was isolated by thousands of kilometres of open ocean. We now know that the islands of Wallacea provided the first plausible corridor out of Australia, resulting in waves of songbird expansion through Asia to the rest of the globe. This colonisation of previously uninhabited regions seems to have then triggered the evolution of many new songbird species, as the group began to adapt to these novel environments and habitats.

This leads to the second important conclusion: the role of chance in evolution. Paleontologist Stephen J Gould argued that if the tape of life were rewound and allowed to run again from the start, the chances were we would see a very different set of evolutionary outcomes. Features of songbird evolution appear to support this message. Without the chance collision of two tectonic plates millions of years ago, songbirds may have never left Australia and the world's garden bird feeders may now be playing host to a very different set of species than they do today.

The third and perhaps most striking conclusion is that the common ancestor of all modern songbirds is likely to have lived just over 30 million years ago. In evolutionary terms, this is surprisingly recent, especially compared to the probable age of the ancestor of all birds (about 95 million years). By resolving these issues, the study has also set the stage for new and important questions about evolution. Perhaps the most intriguing question now is why a once-small group of Australian songbirds went on to become such a diverse and widespread component of life on earth.

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