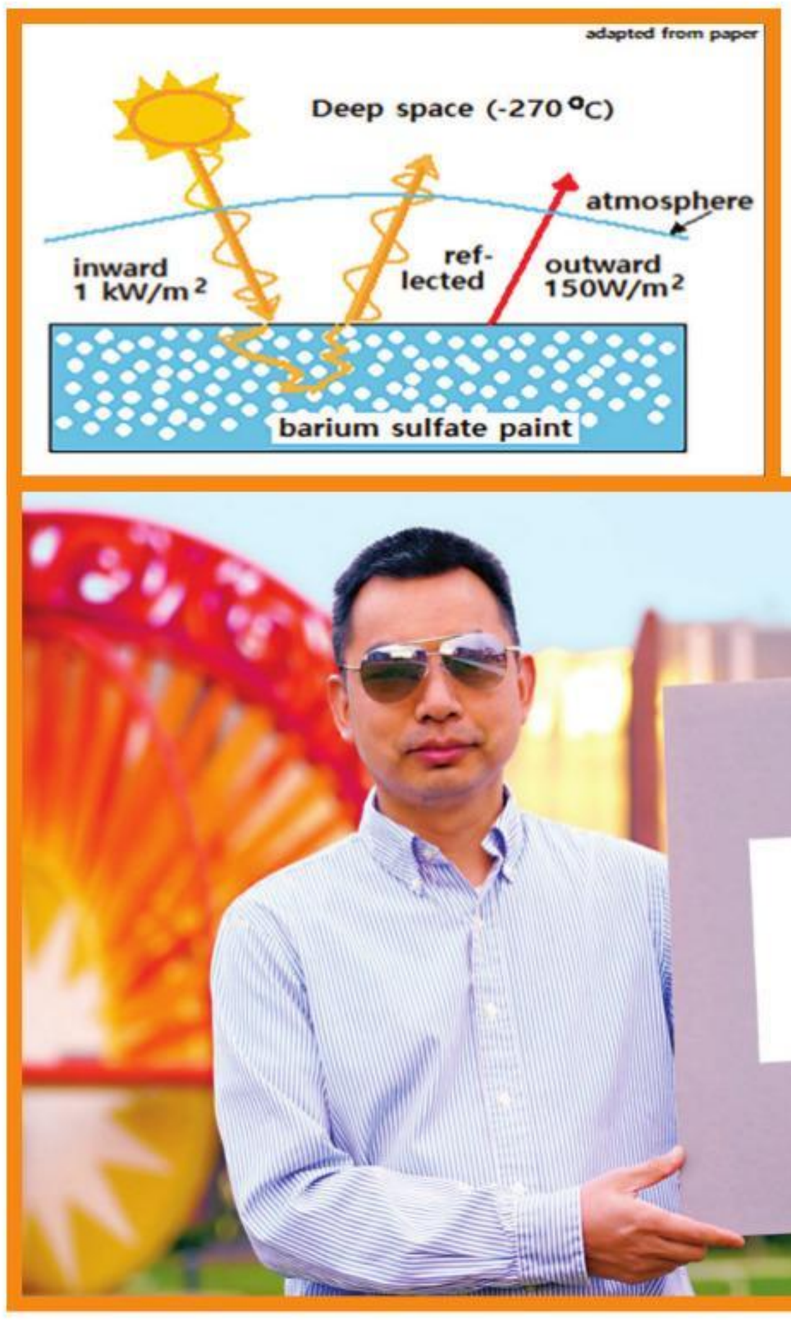
Climate control without the AC

A recent paper describes a material that can reflect away the heat that falls on it, as well as cool by radiating in that special way

S ANANTHANARAYANAN



Rising carbon dioxide in the air and rising temperatures have driven up the use of air conditioning in homes and workplaces, and hence the consumption of electricity. As much of our electricity comes from burning coal, the increased load leads to more carbon dioxide in the air and, in turn, greater need for air conditioning. Homeowners and architects would welcome a way out of the spiral.

The last few decades have hence seen several groups working on methods of "passive cooling", or cooling things down without conventional refrigeration units. One approach has been with surfaces that reflect, in place of absorbing heat from sunlight or the surroundings. Another approach is with special surfaces that radiate in such a way that heat travels not just out from the warm object but passes through the atmosphere as well.

Xiangyu Li, Joseph Peoples, Peiyan Yao and Xiulin Ruan (*in photo*), from Purdue University, Indiana, U S, in a paper in the journal, *Applied Materials and Interfaces*, of the American Chemical Society, describe a material that can reflect away the heat that falls on it, as well as cool by radiating in that special way.

It is well known that wearing white or painting buildings white would reflect heat and help things stay cooler. Buildings even use a complex, multi-layer covering, to promote reflection, or use a reflective metal layer. But those are expensive procedures and are not even possible for many applications. Single-layer paints have been used, but they often need thick coats and are only partially effective. The best high reflection paints, the paper says, are only 91 per cent reflective.

While warm objects do cool by radiation of heat, most of the heat that is sent out is absorbed by the surrounding air and the ambient temperature goes up, which sends the heat right back, and reduces the cooling that radiation brings about. There is, however, a special band of wavelengths of radiation which does not heat the surroundings and is able to pass through the atmosphere, and away to outer space. Radiation at this band would thus cause real, net cooling, of the object and the Earth as well. This radiation band, known as the "sky window", is in the infra-red region, in the wavelength range of eight to 13 micrometres, a band of wavelengths at which none of the components of the atmosphere can absorb radiation.

A first material that favoured radiation of heat in this wavelength band was silicon, the material of electronics and solar cells. A group at Stanford University created a composite film, made of silicon dioxide and hafnium dioxide. Silicon dioxide emits strongly at nine micrometres and hafnium dioxide at nine to 13 micrometres. The film, when laid over an object, would thus warm by the heat of the object and radiate at those wavelengths. Combined with an arrangement for reflectivity of 97 per cent, the Stanford group reported cooling by four to five °C, of an object placed in open sunlight. The system also works with a comparatively cheaper material, titanium dioxide, in place of hafnium dioxide.

What the group at Purdue University has now reported is a far simpler arrangement, an "ultra-white" paint, which results in high reflectivity as well as emission in the special band of frequencies. A reason why existing high reflectivity paints, which contain a suspension or film of titanium dioxide particles for selective emission, have not resulted in cooling of more than two °C, is mainly that titanium dioxide particles absorb ultraviolet light, the paper says. The way materials absorb light when photons fall on them is that photons knock about the electrons of atoms in the material and pass on their energy to the material.

The quest has hence been for materials where electrons are more firmly bound, and photons of ultraviolet light cannot knock them loose. Using such materials, however, leads to less reflectivity and what we gain by the better materials gets set off by their effect, the paper says.

The arrangements the Purdue team report are a film with nanoparticles of an alternative material, barium sulphate, and an acrylic paint that contains barium sulphate. With barium sulphate, the paper says, it takes higher energy for electrons to be separated from atoms. The result is that photons of the ultraviolet are not absorbed, while they are still reflected by the film or paint. By choosing a proper distribution of particle sizes, the team has achieved reflectivity of 97.6 per cent, the paper says.

Another property of barium sulphate particles is that their internal, mechanical vibrations are strong at the frequency that corresponds to the wavelength of nine micrometres. It is within the "sky window' of nine to 13 micrometres. The particles in a film or paint, hence, convert a large fraction of heat energy in an object at nine micrometres and send it out, to pass through the atmosphere and away from the Earth!

During trials conducted, the temperature of a sample dropped 10.5 °C below the ambient temperature during the nights and stayed 4.5-10 °C below the ambient temperature during daytime. Whereas the temperature of a control test with commercial paint increased 6.8 °C above the ambient temperature between 2 p.m. and 3 p.m. Overall, the barium dioxide film achieved an average cooling power of 117 W over every square metre. The cooling capacity of a one tonne AC unit is about 3.5 kW. In comparison, a film-covered rooftop with an area of 50 square metres could provide 570 W of cooling.

The cooling by a conventional AC unit is during the time it is on and working, whereas the cooling film would work continuously. And the cooling could be twice as much, as the walls would also be painted. Most of the area under the roof could, hence, be fairly well cooled, with no power consumed.

Three of the authors of the paper are in the process of obtaining a patent for the technology. The material, therefore, may soon be commercially available.

The writer can be contacted at response@simplescience.in

PLUS POINTS

Malaria vaccine

A malaria vaccine developed by the same team behind the Oxford coronavirus jab has been found to be 77 per cent effective in providing protection against the mosquito-borne disease, in what is a major scientific breakthrough for the world.

This is the first time that a vaccine for malaria has surpassed the 75 per cent efficacy goal set by the World Health Organisation, raising fresh hope that the disease can be one day eradicated. The findings come from the first 12 months of an ongoing phase two trial, which was first launched in Burkina Faso in May 2019 and involves 450 children, aged five to 17 months.

Professor Adrian Hill, whose work at Oxford University's Jenner Institute set the foundations for the Oxford Covid jab, designed and developed the malaria vaccine. He said the latest results, published in *The Lancet*, "support our high expectations for the potential of this vaccine".

–THE INDEPENDENT

Covid & heart diseases

Individuals are often born with defects in their hearts and they are called congenital heart diseases. Examples of CHD include a wide spectrum of diseases including atrial septal defect and ventricular septal defect (commonly referred to as "hole in the heart"). Currently, advanced surgical options help repair such defects during childhood. However, some aspects of the disease processes still linger well into adulthood and sophisticated care is needed for such individuals.

There are only a handful of leaders whose clinical research focus has emphasised on enhancing the quality and care of outcome in adult congenital heart disease patients. Dr Mahesh Aradhya (*in photo*) has enhanced community health literacy to understand the healthcare needs of this emerging population and examine the impact of quality of care on their outcomes. Originally from Kempegowda Institute of Medical Sciences in Bangalore, he is a fellow of the American College of Cardiology.

Dr Aradhya pointed out that lack of access to quality speciality ACHD care is associated with increased mortality in such patients. He is one of the pioneers in establishing such services in the southern U S state of Arkansas in his role as staff cardiologist at the North East Arkansas Baptist Hospital.

The improvement of CHD care has increased the number of patients surviving into adulthood. There are more than 1.5 million patients, and the initial surgeries for CHD are often not curative as the patients have residual abnormalities, remarked Dr Aradhya.

An important reason for discussing this ACHD population during the coronavirus pandemic is related to the increasing number of emergency room visits for such patients due to exacerbation of their heart ailments. The ACHD patients, depending on the complexity of their original heart lesions, often present with sudden acute decompensated heart failure, pulmonary hypertension, arrhythmia and develop the necessity for implantation of a pacemaker or cardioverter defibrillator or for cardiac catheterisation. All of those are important co-morbidities that worsen outcomes due to coronavirus or flu infection. Adults with CHD have worse perioperative outcomes from non-cardiac surgery. Moreover, such patients have multiple neuropsychological issues, liver and kidney dysfunction, blood-related problems and endocrinopathy. The abnormal cardiac physiology predisposes unique challenges during pregnancy and poses a great risk for common age-related or acquired co-morbidities like hypertension, warned Dr Aradhya.

Those co-morbidities, including development of heart failure and lung edema, make such adult patients with congenital heart diseases highly vulnerable to a downhill clinical trajectory during Sars-CoV-2 infection. Additionally, 20-30 per cent of people with severe CHD have congenital physical, developmental or cognitive disorders resulting in increased healthcare resource utilisation. The trail-blazing work of Dr Aradhya ensures higher quality of life in this special populace of patients with debilitating heart diseases from birth.

– SUBHENDU MAITI

THEY ARE ALMOST THE SAME

You don't have a male or female brain – the more brains scientists study, the weaker the evidence for sex differences

LISE ELIOT

Everyone knows the difference between male and female brains. One is chatty and a little nervous, but never forgets and takes good care of others. The other is calmer, albeit more impulsive, but can tune out gossip to get the job done.

These are stereotypes, of course, but they hold surprising sway over the way actual brain science is designed and interpreted. Since the dawn of magnetic resonance imaging, neuroscientists have worked ceaselessly to find differences between men's and women's brains. The research attracts lots of attention because it's just so easy to try to link any particular brain finding to some gender difference in behaviour.

But as a neuroscientist long experienced in the field, I recently completed a painstaking analysis of 30 years of research on human brain sex differences. And what I found, with the help of excellent collaborators, is that virtually none of those claims has proven reliable.

Except for the simple difference in size, there are no meaningful differences between men's and women's brain structure or activity that hold up across diverse populations. Nor do any of the alleged brain differences actually explain the familiar but modest differences in personality and abilities between men and women.

MORE ALIKE THAN NOT

My colleagues and I titled our study "Dump the Dimorphism" to debunk the idea that human brains are "sexually dimorphic." That's a very science-y term biologists use to describe a structure that comes in two distinct forms in males and females, such as antlers on deer or the genitalia of men and women.

When it comes to the brain, some animals do indeed exhibit sexual dimorphism, such as certain birds whose brains contain a song-control nucleus that is six times larger in males and is responsible for male-only courtship singing. But as we demonstrate in our exhaustive survey, nothing in human brains comes remotely close to that.

Yes, men's overall brain size is about 11 per cent bigger than women's, but unlike some songbirds, no specific brain areas are disproportionately larger in men or women. Brain size is proportional to body size, and the brain difference between sexes is actually smaller than other internal organs, such as the heart, lungs and kidneys, which range from 17 to 25 per cent larger in men. When overall size is properly controlled, no individual brain region varies by more than about one per cent between men and women, and even those tiny differences are not found consistently across geographically or ethnically diverse populations.

Other highly touted brain sex differences are also a product of size, not sex. They include the ratio of grey matter to white matter and the ratio of connections between, versus within, the two hemispheres of the brain. Both of those ratios are larger in people with smaller brains, whether male or female. What's more, recent research has utterly rejected the idea that the tiny difference in connectivity between left and right hemispheres explains any behavioural difference between men and women.

A ZOMBIE CONCEPT

Still, "sexual dimorphism" won't die. It's a zombie concept, with the latest revival using artificial intelligence to predict whether a given brain scan comes from a man or woman.

Computers can do this with 80 to 90 per cent accuracy except, once again, this accuracy falls to 60 per cent (or not much better than a coin flip) when you properly control for head size. More troublesome is that these algorithms don't translate across populations, such as European versus Chinese. Such inconsistency shows there are no universal features that discriminate male and female brains in humans – unlike those deer antlers.

Neuroscientists have long held out hope that bigger studies and better methods would finally uncover the "real" or species-wide sex differences in the brain. But the truth is, as studies have gotten bigger, the sex effects have gotten smaller.

This collapse is a tell-tale sign of a problem known as publication bias. Small, early studies which found a significant sex difference were likelier to get published than research finding no male-female brain difference.

SOFTWARE VERSUS HARDWARE

We must be doing something right, because our challenge to the dogma of brain sex has received pushback from both ends of the academic spectrum. Some have labelled us as science "deniers" and deride us for political correctness. On the other extreme, we are dismissed by women's health advocates, who believe research has overlooked women's brains – and that neuroscientists should intensify our search for sex differences to better treat female-dominant disorders, such as depression and Alzheimer's disease.

But there's no denying the decades of actual data, which show that brain sex differences are tiny and swamped by the much greater variance in individuals' brain measures across the population. And the same is true for most behavioural measures. About a decade ago, teachers were urged to separate boys and girls for mathematics and English classes based on the sexes' alleged learning differences. Fortunately, many refused, arguing the range of ability is always much greater among boys or among girls than between each gender as a group.

In other words, sex is a very imprecise indicator of what kind of brain a person will have. Another way to think about it is every individual brain is a mosaic of circuits that control the many dimensions of masculinity and femininity, such as emotional expressiveness, interpersonal style, verbal and analytical reasoning, sexuality and gender identity itself.

Or, to use a computer analogy, gendered behaviour comes from running different software on the same basic hardware. The absence of binary brain sex features also resonates with the increasing numbers of people who identify as n on-binary, queer, non-conforming or transgender. Whatever influence biological sex exerts directly on human brain circuitry is clearly not sufficient to explain the multidimensional behaviours we lump under the complex phenomenon of gender.

Rather than "dimorphic," the human brain is a sexually monomorphic organ – much more like the heart, kidneys and lungs. As you may have noticed, those can be transplanted between women and men with great success.

The writer is professor of neuroscience, Rosalind Franklin University of Medicine and Science, U S. This article first appeared on www.theconversation.com