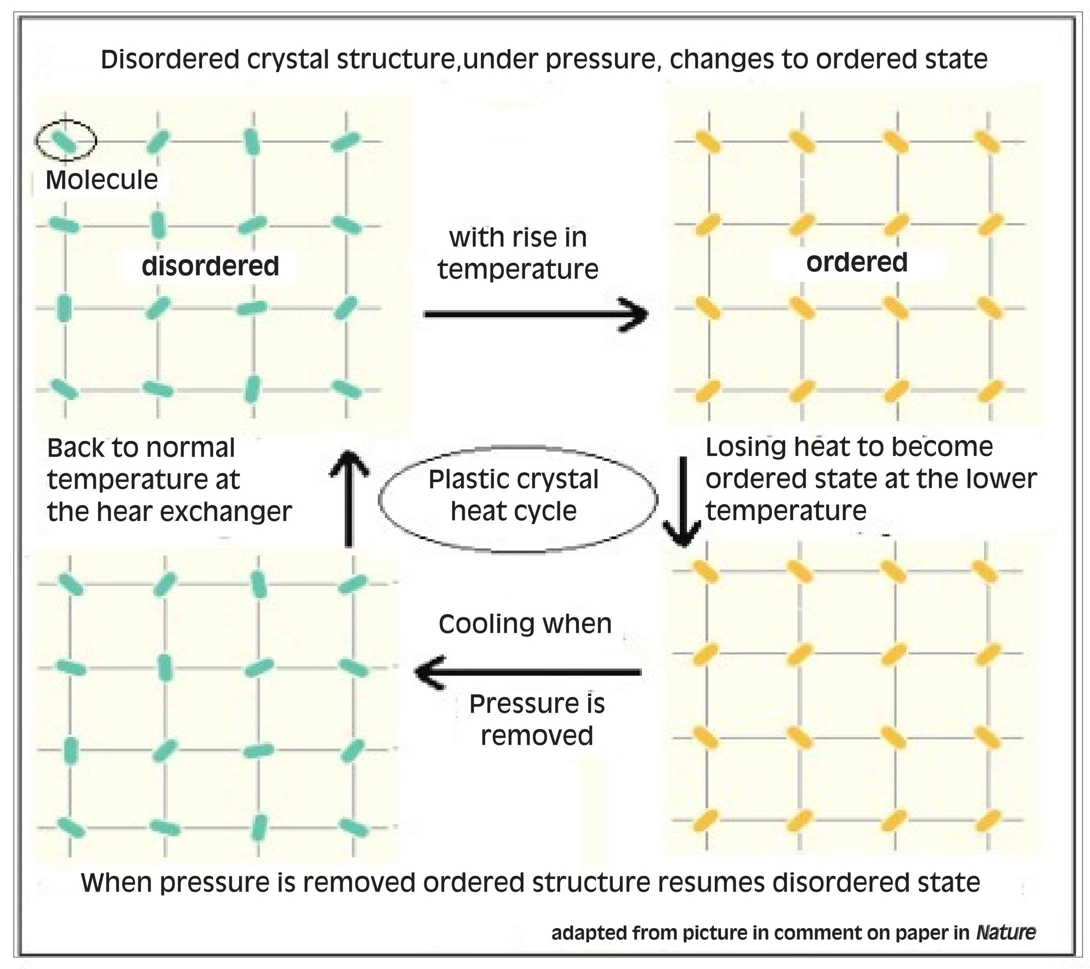
Green cooling on the anvil

The growing use of refrigeration and air conditioning has a dire impact on the environment owing to the widespread use of greenhouse gases. But scientists may have found an alternative



adapted from picture in comment on paper in *Nature*

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While hot things naturally lose heat and come down to the temperature of the surroundings, extracting heat, to get them any cooler, takes energy. The demand of energy is the first impact of the cooling industry. The second is that the industry uses volatile chemicals. Those get released into the atmosphere and cause pollution.

While the need for cooling will increase through the rest of the century, a report in the journal, *Nature*, holds out the promise of mitigating at least the second environmental cost of artificial cooling. Bing Li, Yukinobu Kawakita, Seiko Ohira-Kawamura, Takeshi Sugahara, Hui Wang, Jingfan Wang, Yanna Chen, Saori I Kawaguchi, Shogo Kawaguchi, Koji Ohara, Kuo Li, Dehong Yu, Richard Mole, Takanori Hattori, Tatsuya Kikuchi, Shin-ichiro Yano, Zhao Zhang, Zhe Zhang, Weijun Ren, Shangchao Lin, Osami Sakata, Kenji Nakajima and Zhidong Zhang, from universities and institutes in Shenyang, Changsha, Beijing, Hefei and Shanghai in China; Tokai, Osaka and Sayo in Japan; Irvine and Tallahassee in the US, report their trials with an effective, climate-friendly and abundant alternative to the powerful greenhouse gases that conventional cooling systems use.

Cooling things below the ambient temperature essentially means inducing flow of heat, from a cool object to the surroundings, which are warmer. The outward flow of heat from a cool object, however, is the opposite of what normally happens. This has, hence, to be managed through a two-step combination of otherwise natural processes.

The first step is to increase the internal energy of a system, typically a gas, by compression, so that the additional energy shows as a rise in temperature. Once the system is at a higher temperature, natural processes reduce its total energy content by cooling to the ambient temperature. We then have a system, which has energy stored in its internal composition, which, in the case of a gas, is the pressure, but which is at the same temperature as the surroundings. The internal energy is then released. In the case of a gas, this is done by allowing expansion.

The result of expansion is that the system loses energy and there is cooling, below the initial temperature. We can see that heat had earlier been released to the surroundings, when the gas cooled down. Now, when the gas comes back to normal pressure, it amounts to giving up the same heat, resulting in cooling. The heat released at first came from the external work done, during compression. Now, it is the system that does work, in expansion, which depletes its own energy and leads to cooling.

This process, however, is not feasible in the case of a normal gas, as heat capacity of normal gases is too low. To be more effective, the substance needs more heat capacity, typically an extreme greenhouse gas. And further, a gas that would change state, turning into a liquid, releasing large energy as heat, when compressed. As we may know, when liquids vapourise, they take in a large quantity of heat, as "latent heat". When the vapour is liquefied, by applying pressure, the energy is released as heat. When the liquid evaporates, the energy has to be recouped, resulting in cooling.

A substance that has these qualities in ample measure is the chlorofluorocarbon, sold under the brand name of Freon. Freon was the refrigerant fluid of choice for many decades, before it was realised that its release into the atmosphere caused depletion of the ozone layer. An international effort, the Montreal Protocol, resulted in CFCs being replaced by hydrofluorocarbons, or HFCs. HFCs do not affect the ozone layer but like CFCs, they are extreme greenhouse gases. When the dangers of greenhouse gases were realised, so also was the environmental downside of HFCs. And a serious downside is as a kilogram of a typical CFC has the heat storing capacity of two tones of CO_2.

Alternative

An alternative to using gases in refrigeration are some metals that absorb energy when they are magnetised. Just as the molecules of a gas become more confined when the gas is compressed, randomly oriented magnetic crystals, called domains, within some solids undergo a phase change to get aligned when the solid is magnetised. And there is absorption of energy and warming in the process. Now, if the solid is allowed to cool to the ambient temperature and the electric current inducing the magnetism is stopped, the solid de-magnetises. The magnetic domains then disorient, and in the process, they absorb thermal energy. And as thermal energy is absorbed, the object cools.

This method, of magnetic refrigeration, has the advantage of using no fluids of gases, which could leak to the atmosphere, nor the need for compressors, valves and sealed units. The arrangements can be compact, even miniaturised, for use in chip-based instruments or equipment, and is energy efficient and scalable.

The problem, however, is that most substances that undergo such phase changes under magnetic or electric fields do not have substantial heat capacity for practical applications. Their temperature of working is also often removed from ambient conditions. Another serious disadvantage is that the materials get denatured by repeated cycles of magnetisation. The methods are effective no doubt, in niche areas, like attaining very low temperatures, for research, but the limitations have come in the way of solid state refrigeration making a mark in the industry.

The development reported in the journal appears to be the answer sought for — a solid material, not a vapour, which undergoes internal phase transition by the application and removal of pressure, just like in the case of a gas. Some organic and some inorganic substances take a soft and easily deformable form — and are hence called, "plastic crystals" — where the molecules take fixed positions, as in crystals, but the molecules themselves are randomly oriented. When the substance is cooled, however, the molecules orient themselves, with a large change in the total energy of the system. This transition, which is from a highly disordered to an ordered state, is hence associated with the large energy change.

But what is significant is this transition can be brought about by a small change in pressure. This is to say that like a vapour can be made to condense by increasing the pressure, the structure of a plastic crystal can be changed to the ordered state by pressure of just one to 10 atmospheres. And by applying this pressure, the energy change is of the same order as traditional refrigerant materials, like CFCs, and 30 to 40 times the change in materials that respond to magnetic or electric fields. And this effect comes about at the normal ambient temperature for usual applications.

There are, however, some negatives. One is that organic materials have low melting points, sometimes as low as 25°C, which would be a disadvantage. Another is that the materials have limited mechanical strength, to withstand continued use. The crystal structure may also undergo changes that reduce the cooling performance. These, of course, are challenges to be overcome. This instance of an effective, solid state alternative to CFCs, however, may mark the beginning of ways to prevent refrigeration and air conditioning from becoming a cause of concern because of their existence.

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Cellular identity

For decades, scientists erroneously believed that DNA could not contain genetic information

TAPAN KUMAR MAITRA

Cellular structure and function has a sense of predictability, order and control. Organelles, and other cellular structures, will have a predictable appearance and function; metabolic pathways will proceed in an orderly fashion in specific intracellular locations, and all of a cell's activities will be carried out in a carefully controlled, highly efficient and heritable manner. Such expectations express our confidence that cells possess a set of "instructions" that specify their structure, dictate their functions, and regulate their activities, and that these instructions can be passed on faithfully to daughter cells.

More than a hundred years ago, the Augustinian monk Gregor Mendel worked out rules accounting for the inheritance patterns he observed in pea plants, although he had little inkling of the cellular or molecular basis for these rules. These studies led Mendel to conclude that hereditary information is transmitted in the form of distinct units that we now call genes. We also now know that genes consist of DNA sequences that code for functional products that are usually protein chains, but in some cases they consist of RNA molecules that do not code for proteins.

A preview of how DNA carries out its instructional role in cells and, at the same time, provides a framework for describing how this set of chapters on information flow is organised. The figure highlights the fact that the information carried by DNA flows both between generations of cells and within each individual cell. During the first of these two processes the information stored in a cell's molecules undergoes replication, generating two DNA copies that are distributed to the daughter cells when the cell divides.

Instructions stored in DNA are utilised in a two-stage process called transcriptiot and translation. During transcription, RNA is synthesised in an enzymatic reaction that copies information from DNA. During translation, the base sequences of the resulting messenger RNA molecules are used to determine the amino acid sequences of proteins. Thus, this information initially stored in DNA base sequences, is ultimately used to code for the synthesis of specific protein molecules. It is the particular proteins synthesised by a cell that ultimately determine most of a cell's structural features as well as the functions it performs.

When Mendel first postulated the existence of genes, he did not know the identity of the molecule that allows them to store and transmit inherited information. But a few years later, this molecule was unwittingly discovered by Johann Friedrich Miescher, a Swiss physician. Miescher reported the discovery of the substance now known as DNA in 1869, just a few years before the cell biologist Walther Flemming first observed chromosomes as he studied dividing cells under the microscope.

Miescher's discovery of DNA led to conflicting proposals concerning the chemical nature of genes. Miescher was interested in studying the chemistry of the nucleus, which most scientists guessed was the site of the cell's genetic material. In his initial experiments, Miescher isolated nuclei from white blood cells obtained from pus found on surgical bandages. Upon extracting these nuclei with alkali, he discovered an unusual substance, which he called "nuclein" and which we now know to have been largely DNA.

Miescher then went on to study DNA from a more pleasant source, salmon sperm. Fish sperm may seem a somewhat unusual source material, until we realise that the nucleus accounts for more than 90 per cent of the mass of a typical sperm cell and therefore DNA accounts for most of the mass of sperm cells. For this reason, Miescher initially believed that DNA is involved in the transmission of hereditary information. He soon rejected this idea, however, because his crude measuring techniques incorrectly suggested that egg cells contain much more DNA than sperm cells. Reasoning that the sperm and egg must contribute roughly equal amounts of hereditary information to the offspring, it seemed to him that DNA could not be carrying hereditary information.

Although Miescher was led astray concerning the role of DNA, in the early 1880s a botanist named Eduard Zacharias reported that extracting DNA from cells causes the staining of the chromosomes to disappear. Since evidence was already beginning to suggest a role for chromosomes in transmitting hereditary information, Zacharias and others inferred that DNA is the genetic material. This view prevailed until the early 1900s, when incorrectly interpreted staining experiments led to the false conclusion that the amount of DNA changes dramatically within cells. Because cells would be expected to maintain a constant amount of the substance that stores their hereditary instructions, these mistaken observations led to a repudiation of the idea that DNA carries genetic information.


Gregor Mendel

As a result, from around 1910 to the 1940s, most scientists believed that genes were made of protein rather than DNA. The chemical building blocks of both proteins and nucleic acids had been identified by the early 1900s, and proteins were perceived to be more complex and hence more likely to store genetic information. It was argued that proteins are constructed from 20 different amino acids that can be assembled in a vast number of combinations, thereby generating the sequence diversity and complexity expected of a molecule that stores and transmits genetic information. In contrast, DNA was widely perceived to be a simple polymer consisting of the same sequence of four bases (like the tetranucleotide ATCG) repeated over and over, thereby lacking the variability expected of a genetic molecule. Such a simple polymer was thought to serve merely as a structural support for the genes, which were in turn made of protein. This view prevailed until two lines of evidence resolved the matter in favour of DNA as the genetic material.

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PLUS POINTS

Underwater spies

The US military is turning to fish and other sea life to help them monitor the activity of their enemies in the oceans. Marine creatures are well adapted to their environment, and scientists want to employ their sensory abilities to pick up signals that might be missed by conventional technology. This could mean anything from monitoring fluctuations in schools of sea bass to microbes responding to the magnetic signatures emitted by submarines.

The Persistent Aquatic Living Sensors programme will make use of this information to transform these creatures into self-sustaining populations of underwater spies. "The US Navy's current approach to detecting and monitoring underwater vehicles is hardware-centric and resource intensive," said programme manager Lori Adornato as the initiative was launched last year.

"As a result, the capability is mostly used at the tactical level to protect high-value assets like aircraft carriers, and less so at the broader strategic level.

"If we can tap into the innate sensing capabilities of living organisms that are ubiquitous in the oceans, we can extend our ability to track adversary activity and do so discreetly, on a persistent basis, and with enough precision to characterise the size and type of adversary vehicles."

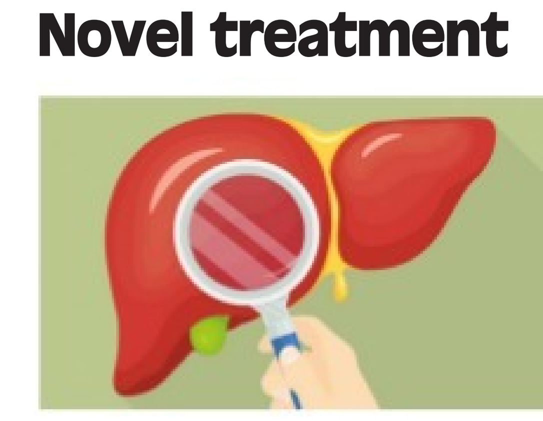
A total of \$45m has now been distributed to five research teams, each of which is working on a particular organism and developing technologies to monitor them and beam information back to the scientists. One team is analysing the "booms" made by territorial fish known as goliath groupers, which they think could provide information about approaching drones or submarines. Another is examining the noises made by snapping shrimp, 200-decibel pops that could work as a natural form of sonar. "It has the potential to detect even the quietest vehicles that might be there," project leader Alison Laferriere of Raytheon BBN Technologies told *Scientific American*.

Findings from these studies are expected to be published across the next few years, and should contribute to basic research into animal behaviour as well as its military uses. The programme is administered by the federal Defense Advanced Research Projects Agency and it is not their only initiative involved living creatures. One project is creating genetically modified plants that, like fish in the Pals programme, are capable of acting as environmental sensors.

Another project being developed by the agency involves using insects loaded with synthetic viruses to spread genetic changes to plants growing in fields. That initiative, dubbed Insect Allies, has faced controversy as scientists raised concerns that instead of being used in agriculture it could lead to the development of "a new class of biological weapon".

The independent

Novel treatment



Singapore researchers have succeeded in coaxing the body's own cells to kill a strain of liver cancer in two patients, by finding a way to control the behaviour of HBV-specific T cells, a type of immune cell. Researchers say this new treatment is a potential game-changer for sufferers of Hepatocellular carcinoma, a form of liver cancer common in Asia. According to the National Cancer Centre Singapore, liver cancer affects 24 out of every 100,000 people here. HCC is currently the most common type of primary liver cancer.

The treatment was developed in collaboration between the Duke-NUS Medical School, the Singapore General Hospital, and biotechnology firm Lion TCR. In it, white blood cells from a cancer patient are extracted and infused with receptors through a process lasting 10 to 14 days. Akin to putting spectacles on a person, these receptors boost the white blood cells, which are injected back into the patient, where they will identify cancer cells and attack them.

The treatment is tailor-made for each patient, taking into account an individual's varying medical condition. This project is a successful example of cell therapy, a field of study in which intact living cells are injected or implanted into a patient to restore tissue or organ function, or combat diseases such as cancer.

The straits times/ann