Helping the brain recover

When did living things learn to sleep and how is it different from other states of restfulness?

S ANANTHANARAYANAN

'Sleep that knits up the ravell'd sleeve of care…chief nourisher in life's feast… and, "…downy sleep, death's counterfeit…", said William Shakespeare of the nature of sleep. Yet the nature of this state of being that all living things must have to sustain their wakeful hours has evaded understanding.

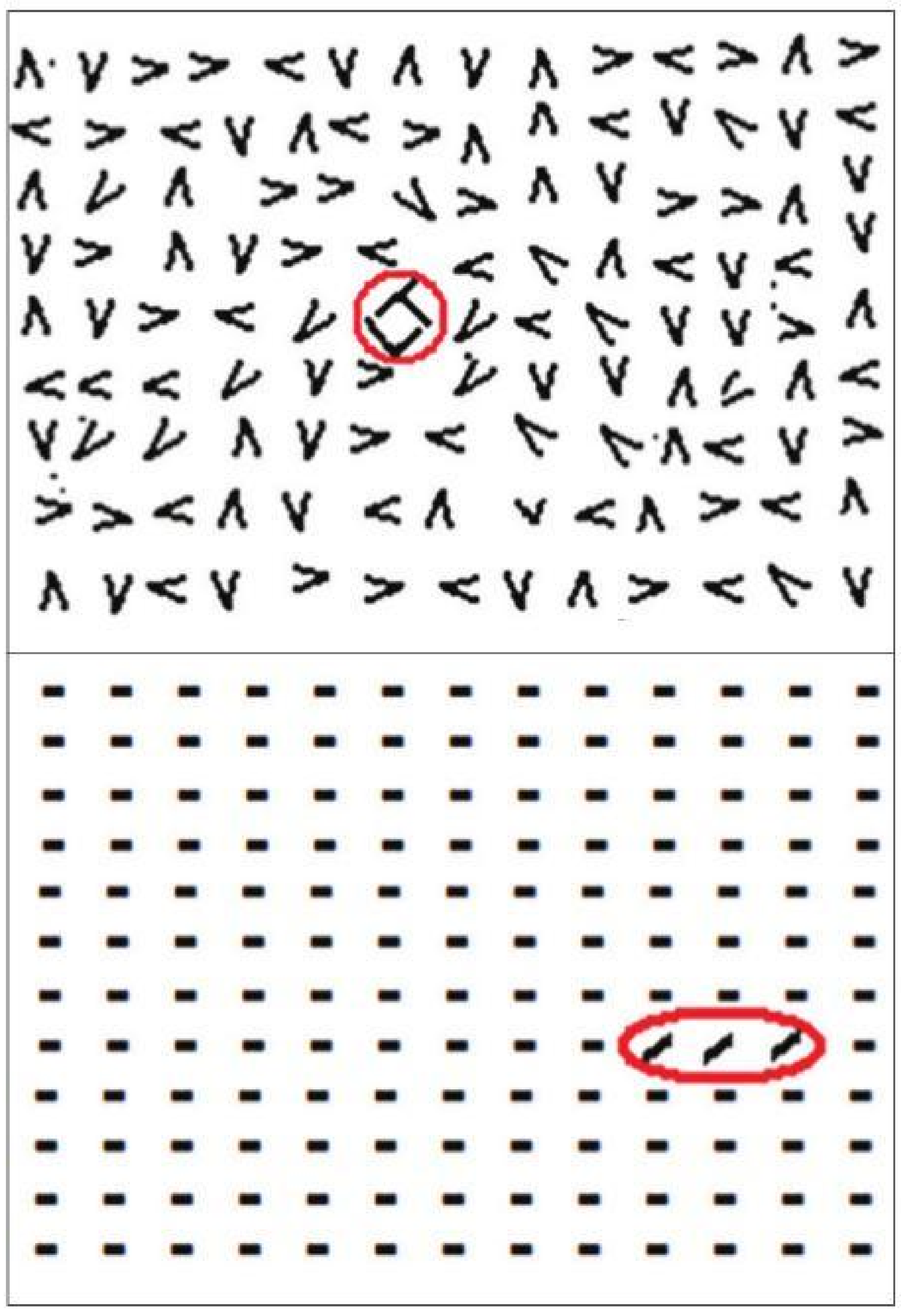
Christoph Nissen, Hannah Piosczyk, Johannes Holz, Jonathan G Maier, Lukas Frase, Annette Sterr, Dieter Riemann and Bernd Feige, from the Universities of Bern, in Switzerland, of Surrey in the UK, and of Freiburg and of Applied Police Sciences, Villingen-Schwenningen, in Germany, write in the journal *Sleep* of the Sleep Research Society, of trials that show that sleep is a distinct state that affects the reorganisation of neurons in the brain in a way that mere restfulness cannot.

In another study published in the same month in the journal, *Science Advances*, Hiroyuki J Kanaya, Sungeon Park, Ji-hyung Kim, Junko Kusumi, Sofian Krenenou, Etsuko Sawatari, Aya Sato, Jongbin Lee, Hyunwoo Bang, Yoshitaka Kobayakawa, Chunghun Lim, Taichi Q Itoh, from Kyushu University, Japan, Ulsan National Institute of Science and Technology, South Korea and Agro-Paris Tech, Paris, go into the origin of the phenomenon of sleep – did it evolve as behaviour to help maintain the brain or was it there before the brain came to be?

The trials reported in the journal Sleep are related to the nature of learning, where neurons, or brain cells, consolidate connections which form during experience. Thus, if a response to a stimulus, out of possible responses, proves to be correct, the neuron circuit that corresponds to the correct response is strengthened and grows stronger with repeated use, while connections of incorrect responses weaken by disuse.

While sleep is seen to promote reorganisation of neurons, the paper says, it is not clear whether it is activity in the brain during sleep, or the lack of diverting stimuli during periods of sleep, that bring it about. Trials were hence designed to see if learning during a spell of activity was strengthened by a period of sleep, compared to the same period spent in normal activity, or in non-sleep inactivity, with minimal stimulation, so-called "passive waking".

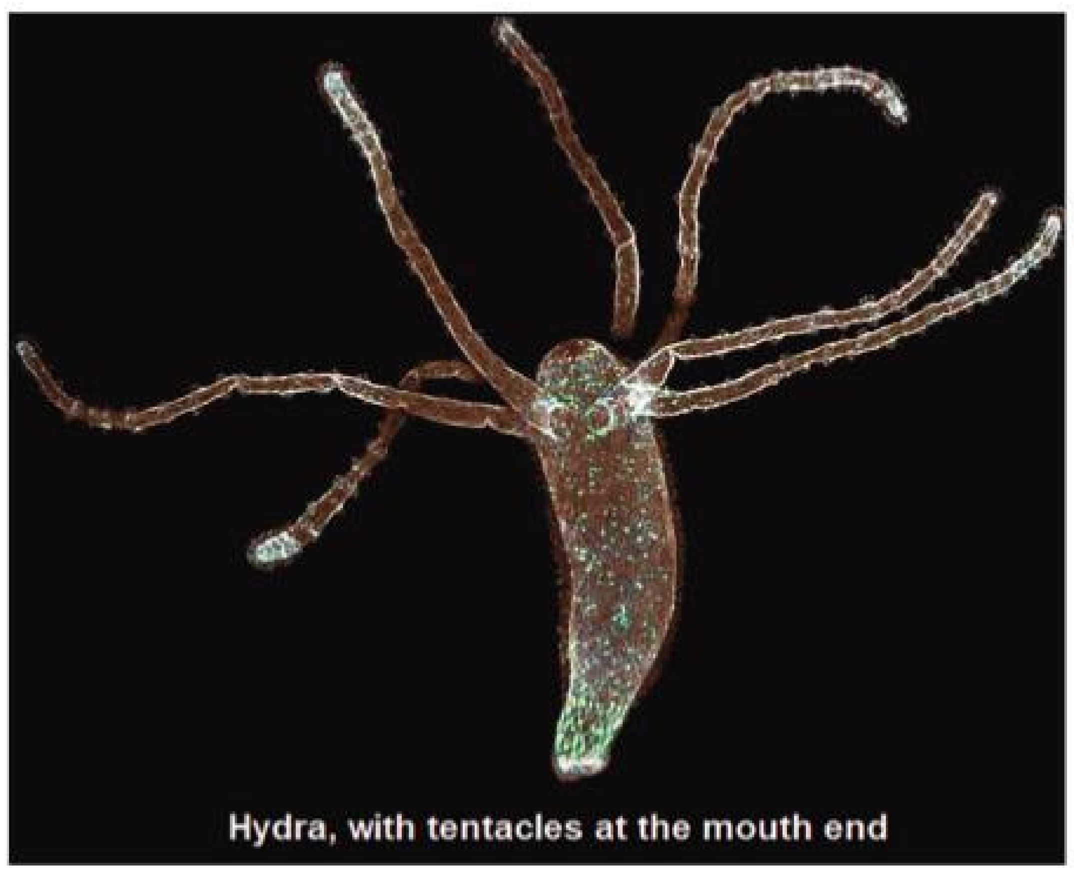
The trials, called "texture discrimination tasks", were to identity patterns embedded in visuals that were flashed before participants. The participants had to first concentrate on the centre of the screen and then activate the first image. The first image was an array of randomly oriented "Vs", with a letter "L" or "T", at some angle of orientation, in the centre. This image remained for less than a third of a second, and the next image was shown. The second image was an array of horizontal dashes, except for a series of three diagonal dashes, horizontal or vertical, somewhere off centre. This image stayed for a tenth of a second. The task was to identify the letter, "L/T" and then say whether the texture target was horizontal or vertical. There was immediate feedback on the "L/T" response, but not on the texture response.



This trial was conducted with 62 participants, who were trained during the morning, till they could get the answers right most of the time. The trial was then repeated later in the day, when the participants, in three groups, had spent the intervening period in (a) usual activities (b) sleep or (c) resting without activity in a darkened room. The principle was that the texture discriminating task was one where the learning that took place in the morning session would get consolidated, through "synaptic plasticity" or the formation of connections between neurons, during the period between the trails. Now, if there were differences in the learning of the three groups, it would reveal whether sleep, or passive wakefulness, made a difference.

The result was unequivocally that the group that had been asleep did better than the two others. There was, in fact, no difference between the active group and the "passive waking" group. Which shows that the sleeping state is one that specifically leads to consolidating learning, and formation of memories, quite apart from other physiological effects of sleep, and in a way that is not possible just by being well rested.

The second paper, in *Science Advances*, is about how this role of sleep, in preserving or restoring the effects of experience on the brain, could have evolved. The paper notes that sleep or states exactly like sleep are seen in practically all animals -- vertebrates, animals with shells, even in worms. How this spectrum of species, which have central nervous systems that range from rudimentary to complex, have the same mechanisms of sleep regulation, is still a mystery, the paper says. The authors hence consider a group of animals with complexity just below that of animals with central nervous systems. This is the category of cnidaria, a group of water-dwelling animals that consist of a non-living, jelly-like substance, sandwiched between two thin layers of tissue. These animals have just one orifice to take in food, which they capture with the help of stings that protrude from around the mouth.



Hydra, with tentacles at the mouth end

The feature of interest, however, is that the body movements of these animals are controlled by a net of interconnected nerve cells, with no centralised brain or brain-like organ. The nerve net allows them to respond to the environment, that is food or chemicals, but not to make out where a stimulus has come from. An instance of cnidarians is the hydra, a one cm long, cylindrical creature, with the mouth at one end, which produces the same motor action regardless of where it receives a stimulus.

The paper says that the diffuse, nerve net probably represents the ancestral organisation of the nervous system. The interesting thing, however, is that cnidarian species (corals and jellyfish are other instances) display periodic suspension of activity, sometimes different daytime and night behaviour. These states, which can be considered sleep-like, are similar to those of animals which have a distinct central nervous system. The similarities for instance, are the reduced response to stimuli and the physiological effects of sleep-inducing drugs.

The authors considered the case of *hydra vulgaris* or the common hydra, one of the simplest cnidarians, as the cnidarian model of sleep. The study was to photo-record the hydra's activity every five seconds, with a definition of what its quiescent or reduced activity state was, in terms of the level of activity. It was found that when hydra entered this state, they could be jerked out of it by a pulse of light. If they had been in the state for over 20 minutes, however, it took substantially longer for them to be aroused. The same reduced response was seen when hydra that had been in the quiescent state for more than 20 minutes were exposed to chemical feeding signals.

Further, hydra were seen to display day-night regularity in entering the sleep state, and other features, like similar genes that regulate sleep, the nature of nerve signals, and physiological changes, as found in other animals. What we find is evidence that sleep is a state that was in existence before the nerve activity was centralised in the brain. These observations of cnidarians "provide important insights into how ancestral sleep has evolved with developing central nervous systems and how sleep-regulatory pathways have been reorganised accordingly," the paper says.

The writer can be contacted at response@simplescience.in

PLUS POINTS

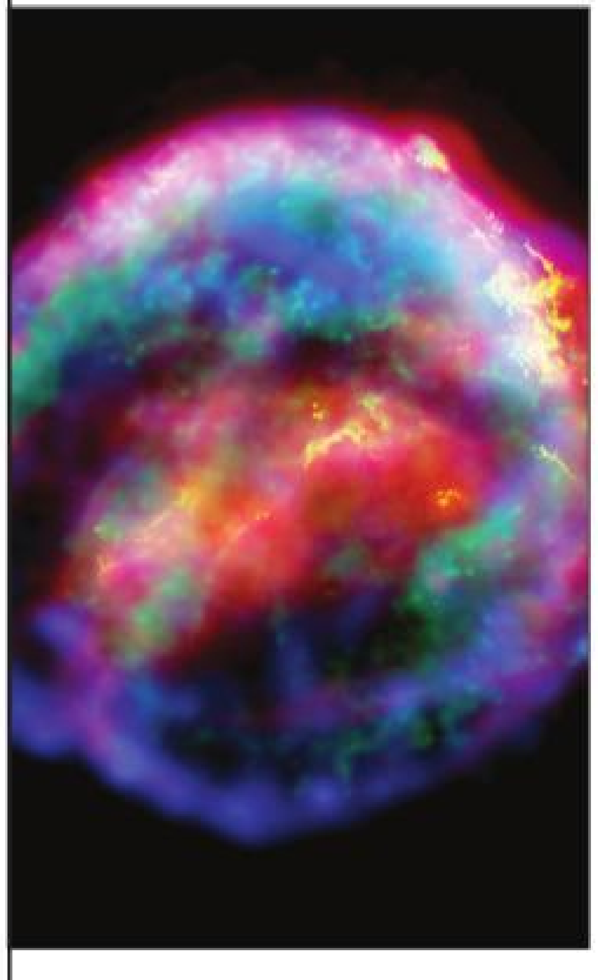
Flavours of supernovae

Researchers from the Indian Institute of Technology-Guwahati, in collaboration with researchers from Max Planck Institute for Physics, Munich, Germany, and Northwestern University, US, have revealed important clues to understand the death of massive stars and the problems with existing models. They found that all three species of the neutrinos from the supernovae are important, contrary to the common treatments with only two flavours.

The results of this crucial work have been recently published in the journal, *Physical Review Letters*. It has been carried out by Sovan Chakraborty, assistant professor, department of physics, IIT-Guwahati, along with research scholar, Madhurima Chakraborty, in collaboration with Francesco Capozzi, post-doctoral fellow, Max Planck Institute for Physics, and Manibrata Sen, post-doctoral fellow, Northwestern University.

The super explosions during the death of massive stars are considered to be the cradle for new stars and synthesis of the heavy elements in nature. At the end of their life, stars, especially massive ones, collapse resulting in an immense shock wave that causes it to explode, briefly outshining any other star in its host galaxy. The study of supernovae and the particles they release helps us understand the universe because almost all matter that makes up the universe is a result of these massive explosions.

During the core collapse supernova explosion, neutrinos are created in several particle processes. Due to their neutral nature and extremely weak interaction with stellar matter, neutrinos



escape and carry 99 per cent energy of the collapsing star. Thus, tiny neutrinos are the only messengers with information from the deepest interiors of the star. The Nobel Prize for Physics in 2002 was shared by Masatoshi Koshiba for the detection of neutrinos from the Supernova SN1987A at the Kamiokande neutrino detector situated in Japan.

Supernovae are the only natural source where neutrinos and antineutrinos of all three species (electron, mu and tau "flavours") are produced in substantial amounts. This creates additional complexities. However, existing supernovae models predicted that the mu and tau neutrinos, and antineutrinos have very similar properties and are considered a single species. This simplified the supernova neutrino problem and most studies are done under the assumption that all types behave the same way when ejected from the star's dying core.

Chakraborty said, "Our information is crucial for the reason that in the extremely dense supernovae core, neutrinos interact with other neutrinos and may interchange flavours. This conversion may happen rapidly (in nanosecond time scale) and flavour interchange can affect the supernovae process as different flavours are emitted with different angular distributions. These 'fast' conversions are nonlinear in nature and are not confronted in any other neutrino sources but supernovae. We, for the first time, did a non-linear simulation of fast conversion with 'all' the three neutrino flavours."

This becomes possible as new simulations show the presence of muons in the supernovae and in turn produce asymmetry between muon neutrinos and antineutrinos, taken to be zero otherwise, implying three flavour effects. Capozzi said, "The models used in our research work too have some simplifications, more generic studies are being done by our team and other competing groups. The clearer answers will need more precise muon supernova simulations, which are appearing to be one of the most promising solutions to the problems of core collapse mechanism".

Meanwhile, these new results give a clear message that the differences between the three flavours of neutrinos are all relevant, and ignoring the presence of any gives us an incomplete picture of fast flavour exchange. Chakraborty said, "Three flavour studies are essential as fast oscillations may actually influence the solution to the question – why and how some massive stars die as supernovae and some don't."

THE NECESSITY FOR SCIENCE DIPLOMACY

It provides instruments that allow policymakers to better decide between competing collaborative research for the benefit of humanity

BIJU DHARMAPALAN

The globe has become one intricate web where problems, afflictions and sufferings are the same for everyone. In order to address the challenges faced by humanity we require collaborations between all nations. In cases where we need collaboration for the sake of humanity, scientists and policymakers must come together to address a specific problem. Therefore, the concept of science diplomacy is gaining importance in diplomatic circles these days. Increasingly, the world requires effective partnerships among scientists, policymakers and diplomats.

The pandemic has necessitated the importance of science diplomacy. Every country across the globe, irrespective of their political affiliations, has come forward to tackle this menace. There were also concerted efforts between nations in developing vaccines and life-saving medicines. The pandemic has shown that science is for global public good but our current international science-policy interface structures and institutions are inadequate to address the challenges facing human and planetary health. The pandemic has exacerbated profound geopolitical shifts, created new tensions, and catapulted science and health diplomacy to the front pages. The crisis is forcing us to rethink, reimagine, and reconstruct how we live, communicate and work.

A crucial task in a post-Covid world will be to examine the connections between science, policy and society, as well as our relationship with Nature. Building science diplomacy systems and structures that can prevent or effectively respond to the next global crisis requires broad-based creative coalitions between the global scientific community, governmental and intergovernmental institutions, industry and philanthropy.

While Covid-19 discoveries are currently the top priority of the global scientific enterprise, issues pertaining to Nature, food, energy and non-infectious diseases also persist. Here a few areas where the world needs greater cooperation.

* Food and agriculture constitute a priority area where nations should work together. Many countries are badly affected by malnutrition problems where molecular breeding and gene modification technologies should be incorporated to maintain food security. Providing food to every human is the fundamental duty of every country and only through scientific collaboration can it be achieved.

* Environmental issues affecting one part of the globe, can influence another part also. The common adage, "think globally act locally" is highly relevant in many problems pertaining to Nature. A flood in Bangladesh would also badly affect India. Similarly, global warming may cause the melting of polar ice caps and its effect may be felt in islands like the Maldives or Lakshadweep. People affected by natural disasters like cyclones, floods or droughts outnumber those displaced by war. According to one estimate, by 2050, more than one billion people may get displaced by natural disasters.

* Exploitation of natural resources is rampant as nations are competing for natural gas and oil, water and forest products. Providing potable drinking water to its citizens is the top priority of each nation. It is also estimated that there is a vast resource of natural gas and oil in the polar caps. Similarly, glaciers are rich sources of potable water. The judicious use of such resources needs collaboration between all nations.

* Oceans, which harbour a rich biodiversity, are getting polluted by the dumping of waste. Dumping waste in one part of the ocean will badly affect marine resources in another. Only through active dialogue between scientists and policy makers can this practice be prevented.

* In the world today, knowledge has become a shared resource. Due to the pandemic, information sharing become openly accessible with many journals removing the paywall from their websites. Digital educational resources like *coursera* have also been opened for all during the lockdown period. People have understood the value of knowledge sharing and many countries are providing scholarships for students to go and learn. In all diplomatic offices now, there is a special wing for education and scholarships.

* When scientists come together for complex multi-national projects in astronomy or physics, their nations devise diplomatic agreements on management and financing. Especially in extra planetary space research, we need stringent international rules and regulations. Countries are vying to build space colonies but the rockets and satellites we put out there also create lots of debris, which in the long run may affect human survival, even on Earth. With space travel and tourism set to become active in a couple of decades, we need more regulations to control pollution in space. At present, the need for science diplomacy in space research is growing as more countries are strategically incorporating space science into their foreign policy.

But fragmented governmental responses in many countries have revealed "catastrophic failures of the science-policy interface". What lessons can we learn about how to effectively incorporate scientific advice in national and international policy decision-making for future trans-boundary crises? How and where have scientists been effectively engaged in national and international policy structures? How do we train and deploy the next generation of science diplomats to anticipate and better manage future crises? These are questions worth our time.

Notably, the next generation of scholars are promulgating the need for responsible innovation focused on how regions and nations can gain access to scientific datasets, and if the access can actually be of importance in shaping societal and developmental challenges. Science diplomacy can have an oversized impact in achieving the 2030 UN Sustainable Development Goals, the need for human and planetary health, and calls for racial justice to rebuild a foundation of diversity, equity and inclusiveness.

The recently published *Madrid Declaration on Science Diplomacy* has highlighted that it "has long been a tool to develop bilateral and multilateral relationships, (its) definition and applications (…) broadened considerably in recent years. This conceptual broadening coincides with the growing understanding that science and technology underpin so many of the challenges and opportunities that current societies face, whether as a driver or a potential solution."

Science diplomacy is a device to propel scientific collaborations across borders. It pays greater attention to societal and global challenges by providing instruments that allow policymakers to better decide between competing collaborative research for the benefit of humanity.

The writer is a science communicator and research scholar, CSIR-NISCAIR, New Delhi