Staying together without being led

Independent individuals sometimes move in concert without being conducted

A swarm of auklets

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A well-known instance is the collective behaviour, which is seen in groups of insects, birds, fish, and even bacteria. While there are no indicators that individual members of the groups are aware or conscious of more than a few neighbours, the whole group self-organises with coordination and cohesiveness, as if enclosed in an envelope, or a containing surface, and the group moves like a single, sentient being.

The phenomenon is of interest both in the study of the animal kingdom as well as one to mimic while managing groups of machines, or in robotics. A step to help understand the mechanism that translates the relationship among a handful of individuals into orchestration of the whole assembly may be finding the smallest size of the group that shows such behaviour. James G Puckett and Nicholas T Ouellette from Yale University, Connecticut, have examined this question and they report in Interface, the journal of the Royal Society, that it takes just 10 individuals of one species of insect to act essentially in the same way as a swarm of many more.

Swarming behaviour is seen most markedly in the movement of hordes of locusts, in the coordinated, short flight of thousands of birds, usually from one large perching area, like a set of trees to another, and in shoals of fish. Bacteria are found, when present in sufficient numbers, to slide en masse across surfaces and even microscopic plants, like phytoplankton, form themselves into vast rafts called "blooms". The characteristic is that the individuals in the groups are self-propelled and are not subject to any centralised control. "The group-level dynamics emerge spontaneously as a consequence of the low-level interactions between individuals," Puckett and Oullette say in the paper.

A mathematical model of a swarm could consist of several basic units, capable of motion, placed together and subject to simple rules. The rules, for instance, could be that a unit should move the same way as its neighbour and stay close to neighbours, and yet a little away, so that it does not touch a neighbour. It is easy to imagine that if the members of a large group all follow these rules, there will be random shuffling and lead to general movement of the group in some direction, which may veer and swerve as individuals make their decisions to keep following the rules.

Another example of large numbers of individual particles following specific rules in bulk is that of the molecules of a gas. Here, the thermodynamic equilibrium, which is the pressure and volume given the temperature, is decided by the rules of statistics, of the number of different, equivalent combinations there can be of the molecules of the gas, distributing themselves in, for a given total energy. It works out that the distribution where the gas has the same pressure and temperature at all parts of the container is the distribution that can be arrived at in the most number of ways, and this distribution becomes more likely when the number of molecules increases. This is then the actual distribution, as different ways, like with the molecules on one side of the container moving faster than on the other side, in even a small volume of gas, are unlikely.

The units in swarms of animals, however, are capable of self-propulsion, unlike molecules whose speed and direction depends on collisions with other molecules. Collective movements of animals hence cannot be treated in a straightforward statistical way like a gas, but can still be viewed as the "large number" tendency as more and more self-propelled and mutually interacting units come together.

When the group is very large, the paper says, it is reasonable to suppose that one part of the swarm is not different from another and that the group behaviour represents a state that is shared by all units. This assumption, however, is not valid when the group is small and small groups would not have the cohesion and resilience of large groups. Discovering how large a group needs to be before it reaches the stage when adding numbers does not bring about appreciable change would help one understand the "low number" behaviour of groups, Puckett and Oullette say in the paper. This would impact bio-inspired engineering applications by setting the smallest number that must be there for group behaviour to emerge, they say.

Another way of looking at swarm behaviour is that the disorganised movement of smaller groups of individuals appears to become ordered and follow a pattern when the group reaches a threshold number. The transition is then seen as a kind of "phase change", like we see when water vapour condenses to liquid or when liquid water freezes to ice. Finding the threshold numbers for swarming would show the stage at which uniting effects of the rules of interaction overcome the fissiparous nature of groups of individuals, and hence keep the group together.

Puckett and Oullette considered the movements of swarms of midges, the annoying collection of flying insects that form a cloud around people's heads when they are out in the open. These swarms do not move over distances, like swarms of fish or birds, but the midges, in rapid motion themselves, stay together over a limited defined area, as a group.

"As collisions are disadvantageous and the sharp manoeuvres required to avoid a collision when two individuals come close together are energetically costly, midges tend to arrange themselves to maintain some empty space in their local neighbourhood," the researchers say. The researchers then used rapid, high speed photographs of 344 swarms of midges in motion, to analyse the changes in statistical features of the midges' local surroundings as the groups changed in size. With groups ranging from a single midge to groups of 60, a main feature analysis was of the average volume, as a fraction of the volume of the swarm, which each midge occupied in its flight, on the average, over a period.

The study has shown that while the statistics change as the number of participants increases, they settle down to a steady figure at the level of just 10 individuals. Thus, while one midge may roam freely around a central average position, two midges are somewhat more united and three midges even more so. But when we reach 10 midges, they form a swarm that stays basically unchanged as the numbers increase, even to thousands.

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PLUS POINTS

Spacesuits crunch

Nasa is running low on spacesuits and might not have a replacement for many years. The agency is quickly running low on the kit, which is absolutely necessary for any future space travel. And its plans to make a next generation space suit are going too slowly, according to a new report from the agency's Office of Inspector General.

A lack of a formal plan and destinations for travel have held back development, according to the report. Nasa has also had funding for such work slashed, leaving it without the resources to develop new suits.

Nasa is left with only 11 of the 18 original suits that include life-supporting backpacks. That might not be enough to carry it through until the station's retirement in 2024, let alone a possible extension until 2028, the report stated. And already, astronauts have been experiencing problems with suits. One of those was almost fatal, when an astronaut almost drowned after the cooling system in his backpack leaked into the helmet and flooded it with water.

That was one of 3,400 mostly minor incidents with the suits, some of which have also included astronauts feeling burning or stinging in their hands and eyes during spacewalks.

As the spacewalking suits age, "Nasa must deal with a dwindling number of flight-ready spacesuits and with mitigating risks related to their design and maintenance", the report said.

Nasa needs a formal plan, especially if it hopes to test a new suit before the space station ends operation in 2024, the report concluded. It also needs to compare the cost of maintaining the current crop of suits with developing new ones.

Nasa's next spacewalk is set for 12 May. Veteran spacewalker Peggy Whitson will venture outside with newcomer Jack Fischer.

Andrew griffin/the independent

Checkpoint pathways

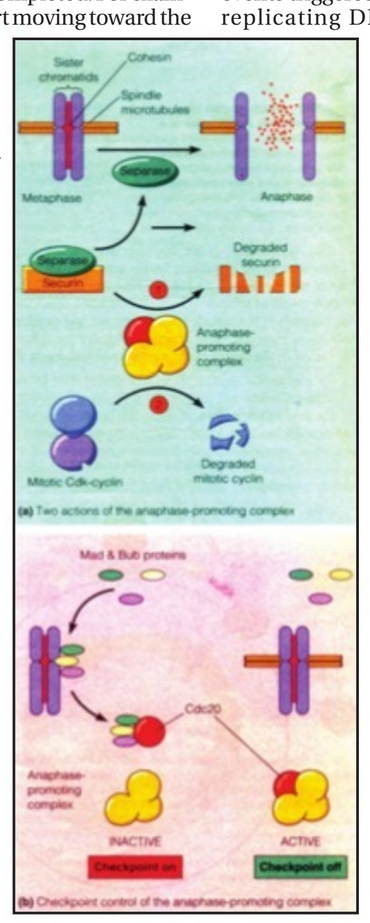
Cells use a series of mechanisms to monitor conditions within them

TAPAN KUMAR MAITRA

It would obviously create problems if cells proceeded from one phase of the cycle to the next before the preceding phase had been properly completed. For example, if chromosomes start moving toward the spindle poles before they have all been properly attached to the spindle, the newly-forming daughter cells might receive extra copies of some chromosomes and no copies of others.

Similarly, it would be potentially hazardous for a cell to begin mitosis before all of its chromosomal DNA had been replicated. To minimise the possibility of such errors, cells utilise a series of checkpoint mechanisms that monitor conditions within the cell and transiently halt the cell cycle if conditions are not suitable for continuing.

The checkpoint pathway that prevents anaphase chromosome movements from beginning before the chromosomes are all attached to the spindle is called the spindle checkpoint. It works through a mechanism in which chromosomes whose kinetochores remain unattached to spindle microtubules produce a "wait" signal that inhibits the anaphase-promoting complex.



As long as the anaphase-promoting complex is inhibited, it cannot trigger destruction of the cohesins that hold sister chromatids together. The "wait" signal responsible for inhibiting the anaphase-promoting complex is transmitted by proteins that are members of the Mad and Bub families. The Mad and Bub proteins accumulate at unattached chromosomal kinetochores, where they are converted into a multi-protein complex that inhibits the anaphase-promoting chromosomes that have become attached to the spindle. This "wait" signal ceases and the anaphase-promoting complex becomes active.

A second checkpoint mechanism, called the DNA replication checkpoint, monitors the state of DNA replication to ensure that DNA synthesis is completed prior to permitting the cell to exit from G2 and begin mitosis. The existence of this checkpoint has been demonstrated by treating cells with inhibitors that prevent DNA replication from being finished. Under such conditions, the final de-phosphorylation step involved in the activation of mitotic Cdk-cyclin is blocked through a series of events triggered by proteins associated with replicating DNA. The resulting lack of mitotic Cdk-cyclin activity halts the cell cycle at the end of G2 until all DNA replication is completed.

A third type of checkpoint mechanism is involved in preventing cells with damaged DNA from proceeding through the cell cycle unless the DNA damage is first repaired. In this case, a multiple series of DNA damage checkpoints exist that monitor for DNA damage and halt the cell cycle at various points — including late Gl, S, and late G2 — by inhibiting different Cdk-cyclin complexes. A protein called p53, sometimes referred to as the "guardian of the genome," plays a central role in these checkpoint pathways.

When cells encounter agents that cause extensive DNA damage, the altered DNA triggers the activation of an enzyme called ATM protein kinase, which in turn catalyses the phosphorylation of p53 (and several other target proteins). Phosphorylation of p5i prevents it from interacting with Mdm2, a protein that would otherwise mark p53 for destruction by linking it to ubiquitin (just as the anaphase-promoting complex target proteins for degradation by linking them to ubiquitin) ATM-catalysed phosphorylation of p53 therefore protect it from degradation and leads to a buildup of p53 in the presence of damaged DNA.

The accumulating p53 in turn activates two types of events — cell-cycle arrest and cell death. Both responses are based on the ability of p53 to bind to DNA and act as a transcription factor that stimulates the transcription of specific genes. But if the damage cannot be successfully repaired, p53 then activates a group of genes coding for proteins involved in triggering cell death by apoptosis. A key protein in this pathway, called Puma ("p53 unregulated modulator of apoptosis"), promotes apoptosis by binding to and inactivating a normally occurring inhibitor of apoptosis known as Bcl-2.

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Would it really work?

The controversial Italian neurosurgeon, Sergio Canavero, has successfully carried out a full head transplant on rats during an experiment in China ahead of the first human head transplant being planned for later in the year

BEN KENTISH

Scientists have carried out a successful head transplant on rats ahead of plans to attempt a similar operation on a human later this year.

During the procedure, the head of a smaller rat was attached to the body of a larger rodent. Rather than simply replacing the head, the team attached the donor head to the body of the larger rat, creating an animal with two heads.

The operation involved three rats in total — the donor, the recipient and a third used to maintain the blood supply to the transplanted head.

A pump was used to transfer blood from the third rat to the donor head in order to ensure the brain was not starved of oxygen. After the procedure, the rat whose head had been transplanted was able to see and feel pain, showing the brain was functioning despite having been detached from its original body.

The experiment, reported in the journal *CNS Neuroscience and Therapeutics*, was designed to investigate issues relating to blood flow to the brain and the possibility of the immune system rejecting the new organ — problems that could arise during a human transplant.

The procedure was carried out by a team including Sergio Canavero, the controversial Italian neurosurgeon who has pledged to carry out a human head transplant by the end of 2017. Canavero had previously announced that his patient would be Valery Spridonov, a Russian man who suffers from the degenerative muscular condition Werdnig-Hoffman's disease, but the doctor has since said it is actually likely to be an, as yet unselected, Chinese person. The reasons for the change are unclear.

The neurosurgeon and his collaborator, Xiaoping Ren from the Harbin Medical University in China, have between them previously carried out a series of experiments involving head transplants. Their method involves using a very sharp knife to cut the spinal cord and then placing the body in a state of hypothermia to allow it to heal.

Sergio Canavero

In one, they claimed to have severed 90 per cent of a dog's spinal cord before re-attaching it. In another, a head transplant was reportedly carried out on a monkey, and a third experiment saw the spinal cords of mice being cut and then reattached in such a way that the animals were able to recover their ability to move.

The pair also claims to have experimented with human head transplants using dead bodies. None of the experiments were peer reviewed and Canavero has a number of critics in the scientific community who accuse him of sensationalism.

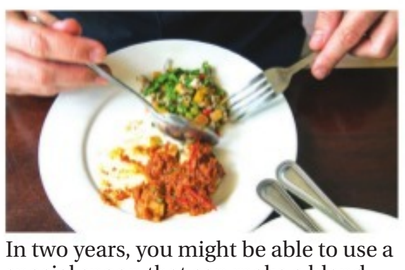
His latest studies have been announced via press releases before they were published in the journals to which they had been submitted. The editor of one of the journals, *Surgery*, said that significant work was needed on the draft paper before it could be published.

Other experts say there is not sufficient evidence that a human head transplant would work. Hunt Batjer, the president elect of the American Association for Neurological Surgeons, has criticised Canavero's plans to transplant a human head.

"I would not wish this on anyone," he said. "I would not allow anyone to do it to me as there are a lot of things worse than death."

The independent

Goodbye bland food



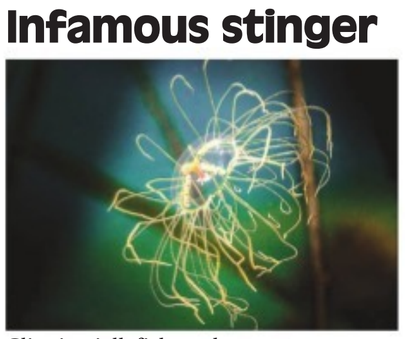
In two years, you might be able to use a special spoon that can make a bland scoop of porridge taste sweet, sour or even bitter. The base of the spoon would have two electrode strips, which when in contact with your tongue, send electric pulses to stimulate your taste buds to mimic the different tastes.

At the same time, a light-emitting diode will flash a colour associated with the desired taste. This would be red for bitterness, blue for saltiness and green for sourness. The same concept has been applied to chopsticks, a soup bowl and a beverage bottle.

Nimesha Ranasinghe, the lead researcher behind the technology, said the inventions could benefit people on restricted diets due to medical conditions. Ranasinghe and his team from the National University of Singapore's Keio-NUS Cute (Connective Ubiquitous Technology for Embodiment) Centre believe their technology can also be used to enhance digital interactions as well as virtual and augmented reality technologies. The team is in talks with an industry partner to manufacture some of these utensils to start field trials and hopes to get the products commercialised in two years.

Samantha boh/the straits times

Infamous stinger



Clinging jellyfish are known to cause severe sting reactions. The jellyfish are found along coastlines in the Pacific and Atlantic oceans, particularly in waters near Vladivostok, Russia.

Now, the first genetic study of the diversity of clinging jellyfish populations around the globe, led by the Woods Hole Oceanographic Institution in the United States, has discovered some surprising links among distant communities of the jellyfish and also revealed that there may be more than one species of the infamous stinger.

The straits times/ann