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There are 5 essays in this test with a total score of 100%. Each essay contains a text followed by questions. Please **answer questions in Chinese or English pointedly according to the text.**

1. Why great ideas come when you aren't trying

History is rich with 'eureka' moments: scientists from Archimedes to Isaac Newton and Albert Einstein are said to have had flashes of inspiration while thinking about other things. But the mechanisms behind this psychological phenomenon have remained unclear. A study now suggests that simply taking a break does not bring on inspiration — rather, creativity is fostered by tasks that allow the mind to wander.

The discovery was made by a team led by Benjamin Baird and Jonathan Schooler, psychologists at the University of California, Santa Barbara. The researchers presented 145 undergraduate students with two 'unusual uses' tasks that gave them two minutes to list as many uses as possible for everyday objects such as toothpicks, clothes hangers and bricks.

After the two minutes were over, participants were given a 12-minute break, during which they rested, undertook a demanding memory activity that required their full attention or engaged in an undemanding reaction-time activity known to elicit mind-wandering. A fourth group of students had no break. All participants were then given four unusual-uses tasks, including the two that they had completed earlier.

Those students who had done the undemanding activity performed an average of 41% better at the repeated tasks the second time they tried them. By contrast, students in the other three groups showed no improvement.

Participants who engaged in the undemanding task did not do any better than others on unusual-uses tasks that they encountered for the first time in the second round. "The implication is that mind-wandering was only helpful for problems that were already being mentally chewed on. It didn't seem to lead to a general increase in creative problem-solving ability," says Baird.

As well as revealing that breaks on their own do not encourage creative thinking, Baird's work suggests an explanation for one of psychology's great mysteries: why we zone out.

From an evolutionary perspective, mind-wandering seems totally counterproductive and has been viewed as dysfunctional because it compromises people's performance in physical activities. However, Baird's work shows that allowing the brain to enter this state when it is considering complex problems can have real benefits. Zoning out may have aided humans when survival depended on creative solutions.

Q 1-1: What is mind-wandering? Please give an example out of you own experience. (10%)

Q 1-2: What are the benefits of mind-wandering? What are the conditions for mind-wandering to be beneficial? (10%)

(背面仍有題目,請繼續作答)

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2. Blind mole rats may hold key to cancer

There's more than one way for long-lived subterranean rodents to avoid cancer, and they might hold cellular clues to effective treatments in humans.

Cell cultures from two species of blind mole rat, *Spalax judaei* and *Spalax golani*, behave in ways that render them impervious to the growth of tumours, according to work by Vera Gorbunova at the University of Rochester and her colleagues. The creatures seem to have evolved a different way of doing this from that observed in their better known and similarly cancer-resistant cousin, the naked mole rat.

Some 23% of humans die of cancer, but blind mole rats — which can live for 21 years, an impressive age among rodents — seem to be immune to the disease.

"These animals are subject to terrific stresses underground: darkness, scarcity of food, immense numbers of pathogens and low oxygen levels. So they have evolved a range of mechanisms to cope with these difficulties," explains co-author Eviatar Nevo, who has published papers on the creatures since 1961.

Three years ago, Gorbunova was involved in another study that described the unusual way in which the cells of the naked mole rat behave in the lab. This hints at how the rats resist cancer. When cells from most animals are grown in a culture dish, they divide until they form a single layer of cells covering the base of the dish. At this point, healthy cells stop dividing, whereas cancerous ones continue. But the cells of naked mole rats behave as if they are 'claustrophobic', ceasing to divide much sooner than cells from other species.

On the other hand, rather than ceasing to divide, the cells of blind mole rats reach a point at which they die en masse in a bout of cell suicide that Gorbunova and her co-authors call "concerted cell death". This seems to be triggered by the collective release of a signalling molecule called interferon-beta, although what causes this is unclear.

No biologist has yet worked out how to keep the cells of blind mole rats alive long-term in culture. "If we apply the same technique that works for 20 other species of rodent, for some reason that's not good enough for blind-mole-rat cells — they always die," says Gorbunova. But, counter-intuitively, this mass cell death might be the very thing that makes the animals so long-lived: it could be a natural mechanism their bodies use to clear precancerous cells, stopping tumours in their tracks.

Q 2-1: What are the unique features shared by the naked mole rats and blind mole rats? (5%)

Q 2-2: How do cells of the naked mole rats and blind mole rats behave differently in culture? (10%)

Q 2-3: What is the potential mechanism for the blind mole rats to be long-lived? (5%)

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3. How to learn in your sleep

It sounds like every student's dream: new research results show that we can learn entirely new information while we snooze. Anat Arzi of the Weizmann Institute of Science and her colleagues used a simple form of learning called classical conditioning to teach 55 healthy participants to associate odours with sounds as they slept. They repeatedly exposed the sleeping participants to pleasant odours, such as deodorant and shampoo, and unpleasant odours such as rotting fish and meat, and played a specific sound to accompany each scent.

It is well known that sleep has an important role in strengthening existing memories, and this conditioning was already known to alter sniffing behaviour in people who are awake. The subjects sniff strongly when they hear a tone associated with a pleasant smell, but only weakly in response to a tone associated with an unpleasant one.

But the latest research shows that the sleep conditioning persists even after they wake up, causing them to sniff strongly or weakly on hearing the relevant tone — even if there was no odour. The participants were completely unaware that they had learned the relationship between smells and sounds. The effect was seen regardless of when the conditioning was done during the sleep cycle. However, the sniffing responses were slightly more pronounced in those participants who learned the association during the rapid eye movement (REM) stage, which typically occurs during the second half of a night's sleep.

In 2009, Tristan Bekinschtein, a neuroscientist at the UK Medical Research Council's Cognition and Brain Sciences Unit in Cambridge, and his colleagues reported that some patients who are minimally conscious or in a vegetative state can be classically conditioned to blink in response to air puffed into their eyes. Conditioned responses such as these could eventually help clinicians to diagnose these neurological conditions, and to predict which patients might subsequently recover. It remains to be seen if the neural networks involved in sleep learning are similar to the ones recruited during wakefulness.

The findings by Arzi and her colleagues might also be useful for these purposes, and could lead to 'sleep therapies' that help to alter behaviour in conditions such as phobia.

"We are now trying to implement helpful behavioural modification through sleep-learning," says Arzi. "We also want to investigate the brain mechanisms involved, and the type of learning we use in other states of altered consciousness, such as vegetative state and coma."

Q 3-1: What is the evidence provided by the new study to show that we can learn in sleep? (10%)

Q 3-2: Are same mechanisms involved in sleep-learning and learning while one is awake? (5%)

Q 3-3: What does "sleep therapy" mean? (5%)

(背面仍有題目,請繼續作答)

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4. How to print out a blood vessel

A tissue-engineering group has succeeded in creating functional blood vessels and cardiac tissue, using a 'printer' that dispenses cells instead of ink. The work is among the first to produce functional three-dimensional tissue using a printer, and a milestone to the goal of printing out whole organs.

Gabor Forgacs from the University of Missouri and his colleagues printed various tissue structures, including blood vessels and sheets of cardiac tissue. When they printed out cardiac and endothelial cells, the cells fused into a tissue after 70 hours, and began beating in time like regular heart tissue after 90 hours. Their work relies on the innate capacities of the cells to create capillaries and other finishing touches on their own.

What makes this work different from that done in most other tissue-engineering labs is that Forgacs's team does everything without a scaffold — they don't start with an object shaped like the tissue or organ they are aiming to create, but instead plan to print the whole thing from scratch, from the vasculature up. This should make it easier to print any type of organ, they say, as they don't have to develop different scaffolds for each tissue type. The work also uses a printer that dispenses blobs (or 'spheroids') of cells, rather than spraying out one cell at a time. This is faster, can be gentler on the cells, and seems to encourage them to fuse together.

The team demonstrated their technique after their paper first appeared online. The centrepiece of the lab is the 2-metre-wide printer, a custom-made device from a company called nScrypt, which specializes in printers that make microelectronics. The printer has three heads, each of which is controlled by an attached computer, that can lay down spheroids of cells much as a desk printer would lay down ink.

Two of the heads print out tissue cells (e.g. mixtures of cardiac and endothelial cells), while the third prints a 'gap-filler' (e.g. collagen) that fills a space temporarily until the other cells have fused. So to make a blood vessel, for example, lines of cells are laid down with lines of collagen in the middle, which will later be extracted to make way for blood. After all the lines are laid down, the result is a tiny, flaccid-looking white tube.

Once branched tubes are printed, the tubes can be left on their own to arrange their cell types in the right orientation and grow basic vasculature including capillaries, following the same internal instructions that produce complex tissues when an embryo develops. "It is tissue engineering based on developmental biology," says Forgacs. The team is now working on ways to exercise the muscle in their resulting blood-vessel tubes to make them tough enough to sew onto natural blood vessels as a graft. They are focusing on vessels narrower than 6 millimetres, as there are synthetic grafts that work quite well for larger vessels.

Q 4-1: How does this tissue-engineering team create cardiac tissue? (10%)

Q 4-2: What are unique in the approach of Forgacs's team to produce a tissue? (10%)

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5. Fathers bequeath more mutations as they age

In the 1930s, the pioneering geneticist J. B. S. Haldane noticed a peculiar inheritance pattern in families with long histories of haemophilia. The faulty mutation responsible for the blood-clotting disorder tended to arise on the X chromosomes that fathers passed to their daughters, rather than on those that mothers passed down. Haldane subsequently proposed that children inherit more mutations from their fathers than their mothers, although he acknowledged that "it is difficult to see how this could be proved or disproved for many years to come".

That year has finally arrived: whole-genome sequencing of dozens of Icelandic families has at last provided the evidence that eluded Haldane. Moreover, a study published in *Nature* finds that the age at which a father sires children determines how many mutations those offspring inherit. By starting families in their thirties, forties and beyond, men could be increasing the chances that their children will develop autism, schizophrenia and other diseases often linked to new mutations.

Haldane, working years before the structure of DNA was determined, was also correct about why fathers pass on more mutations. Sperm is continually generated by dividing precursor cells, which acquire new mutations with each division. By contrast, women are born with their lifelong complement of egg cells.

Kári Stefánsson, whose company maintains genetic information on most Icelanders, and his team compared the whole-genome sequences of 78 trios of a mother, father and child. The team searched for mutations in the child that were not present in either parent and that must therefore have arisen spontaneously in the egg, sperm or embryo. The paper reports the largest such study of nuclear families.

Fathers passed on nearly four times as many new mutations as mothers: on average, 55 versus 14. The father's age also accounted for nearly all of the variation in the number of new mutations in a child's genome, with the number of new mutations being passed on rising exponentially with paternal age. A 36-year-old will pass on twice as many mutations to his child as a man of 20, and a 70-year-old eight times as many.

Most such mutations are harmless, but Stefánsson's team identified some that have been linked to conditions such as autism and schizophrenia. The study does not prove that older fathers are more likely than younger ones to pass on disease-associated or other deleterious genes, but that is the strong implication.

Previous studies have shown that a child's risk of being diagnosed with autism increases with the father's age. And a trio of papers published this year identified dozens of new mutations implicated in autism and found that the mutations were four times more likely to originate on the father's side than the mother's.

The results might help to explain the apparent rise in autism spectrum disorder: this year, the US Centers for Disease Control and Prevention in Atlanta, Georgia, reported that one in every 88 American children has now been diagnosed with autism spectrum disorder, a 78% increase since 2007. Better and more