

Scientific and Technological Achievements that Contribute to Daily Life

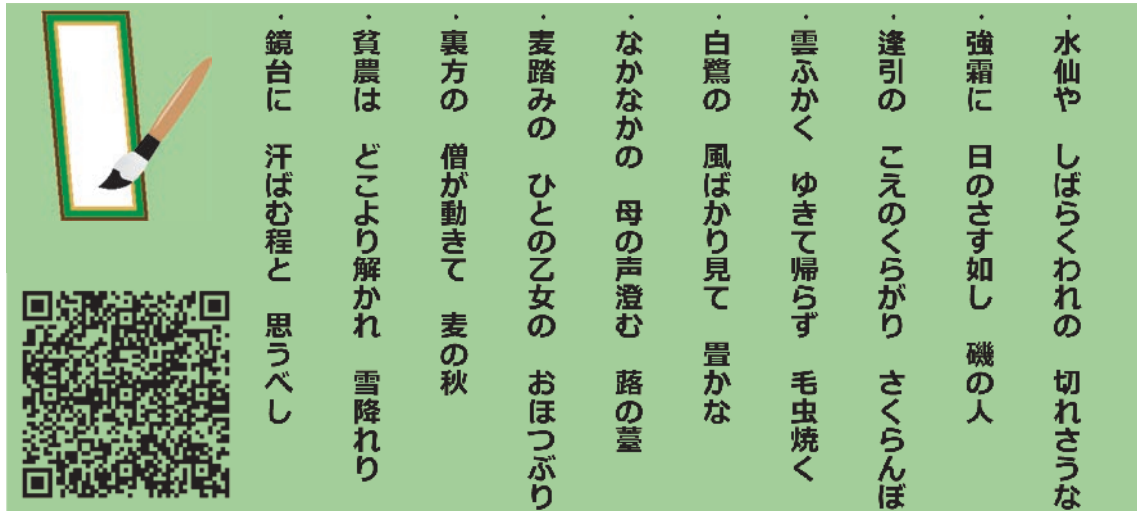
In this segment, we describe R&D achievements and topics that are already having an impact on our daily lives or that are expected to in the near future.

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Scientific and Technological Achievements that Contribute to Daily Life ①

Haiku Composition by AIs:
Can Machines Enjoy Poetry?

Contributor: Hokkaido University



A haiku composed by an AI developed by Harmo Lab, Hokkaido University

To view poems selected and reviewed by haiku poet Gai Otsuka, please scan the QR code on the left.

(Outline)

- Haiku—said to be the world’s shortest poetic form—originated in Japan and has been popular since the Edo period (early 17th to late 19th century CE). Haiku poets derive joy not only from the process of creation, but also from a mutual learning process in which they develop their skills by reading their haiku poems in groups and commenting on them.
- In haiku poems, poets creatively express their observations and feelings using only a small number of words. Many haiku poets enjoy sharing their work with others. Hokkaido University Professor KAWAMURA Hidenori and his team have been researching the use of the latest artificial intelligence (AI) technology to generate and evaluate haiku poems.¹
- The attempt to generate and evaluate haiku poems using AI requires the development of “strong AI”² through various R&D efforts.
- Even if AI becomes capable of generating haiku poems, certain elements, such as human values and philosophies of life, still need to be incorporated to give the poems life. Is it really possible to develop AI capable of truly understanding the human mind and enjoying haiku in the same way that humans do?³ This quest will continue in future AI research.

(Commentary)

1. Newly developed haiku-generating AI: 70,000 haiku poems previously created by prominent haiku poets were used to train the AI. The AI generates haiku poems by selecting haiku-like word combinations. Specifically, the AI generates a number of haiku by first breaking down training haiku data into individual words and entering them in the order of their appearance into a deep learning structure called long short-term memory. The AI then inspects generated haikus for several criteria (a 5-7-5 syllable structure, inclusion of words related to the changing seasons and “cutting words” (a type of verbal punctuation mark used in haiku poetry to signal separation) and sufficient originality when compared to training haiku data) and selects qualifying haiku poems. Deep learning software capable of distinguishing between artificial and human works is then used to guide the final selection of appealing haiku poems.
2. Strong AI: Unlike “weak AI” which is capable of performing only narrow tasks, “strong AI” is equipped with more sophisticated capabilities, including the ability to link physical qualities—such as images and sound—with words, the ability to understand and express concepts (e.g., emotions), the ability to detect the implicit meaning of words and the ability to recognize factors that humans find emotionally moving.
3. Development of strong AI: It may be feasible to develop AI that behaves like humans by giving the appearance of “understanding” and “enjoying” haiku poems in the way that humans do. However, it would be difficult to determine whether AI experiences haiku poetry in the same manner that humans do (see “How Will We Treat AI/Robots that Appear to Possess Consciousness?” on p. 230).

AI Increases Office Work Efficiency: Document Summarization

Contributor: Fujifilm Holdings Corporation

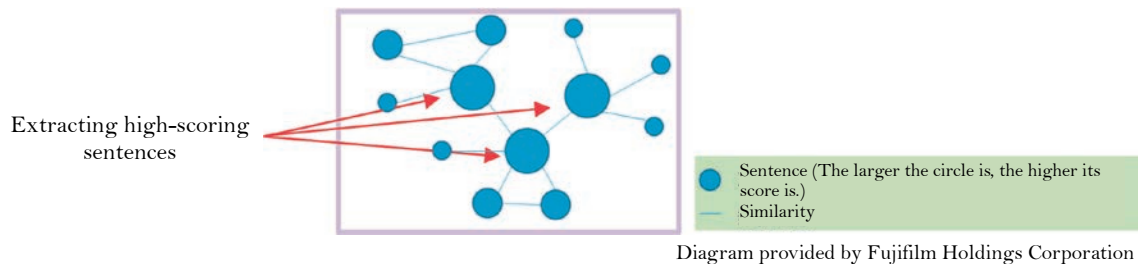


Figure. Conceptual representation of the summarization technique. Similar sentences are identified and linked. Higher scores are assigned to sentences that are similar to many other sentences and to sentences that are similar to a high-scoring sentence.

(Outline)

- The document summary example below was composed using an AI technique capable of identifying key sentences in a document. First, the document is broken down into individual sentences. Scores are assigned to individual sentences based on their importance and the sentences are then arranged in descending score order from high to low. A so-called PageRank technique is used to calculate the scores. Google's search engine uses this technique to rank and display webpages based on scores assigned to them on the basis of key words they contain.
- After breaking the document down into individual sentences, similar sentences are linked to form a network. The degree of similarity between the sentences is determined on the basis of the number of matching words they contain. Scores are calculated for individual sentences in the network.
- A high-scoring sentence has the following characteristics:
 - It is similar to many other sentences or to another high-scoring sentence.
- Sentences are then extracted in descending score order from high to low. Users can specify the number of sentences to be included in a summary.
- Key sentences extracted to compose a summary sometimes lack a natural flow from one sentence to the next. To address this problem, research has been conducted to develop a new alternative to the sentence extraction technique in which AI is trained using a large number of previously composed document summaries to improve this natural flow.

(Example of a document summary generated by AI)

In other words, the achievement of the SDGs and social implementation of STI are two sides of the same coin. It is important to conduct initiatives to resolve various social challenges by linking together research results across the boundaries of various stakeholders, including universities, research institutions, the private sector and non-profit organizations (NPOs).

As a pioneer in developing sustainable economy, society and environment—as an advanced problem-solving country, so to speak—Japan has made cumulative achievements whereby it sets an example for the international community in implementing the SDGs. (partially omitted)

The Sustainable Development Goals (SDGs) Implementation Guiding Principles, decided by the SDGs Promotion Headquarters in December 2016, prescribe 140 domestic and foreign measures related to individual goals under the SDGs together with benchmarks. The first check and review of the implementation status of initiatives are scheduled to be conducted by 2019, when a summit meeting to conduct a follow-up review of SDGs is scheduled to be held.

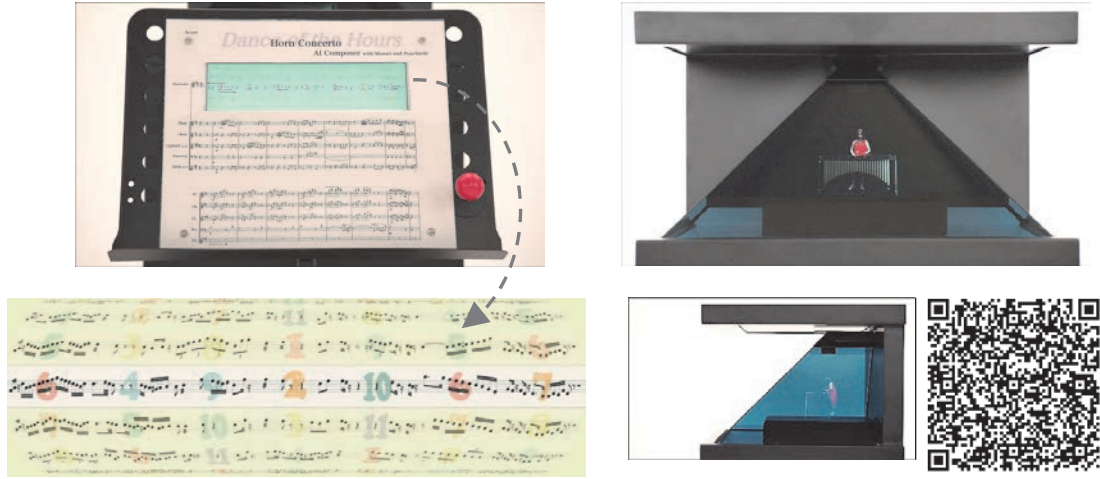
It is not necessarily easy to achieve all those goals, but STI is the essential key to the achievement of the lofty goals, so it is important to promote STI for SDGs in an effective manner.

The 84-sentence feature section of the 2018 White Paper on Science and Technology was summarized in 10 sentences.

Scientific and Technological Achievements that Contribute to Daily Life ③

Can AI Help People Become Music Composers?: Melody Composition Experience

Contributor: RIKEN Center for Advanced Intelligence Project



Images provided by the RIKEN Center for Advanced Intelligence Project

Left: Device that allows users to enjoy an experience composing a melody. Users can select melodies they like by simply turning the dial. They can also connect different melodic sequences by pulling a lever to spin different melody combinations on the display, just like playing a slot machine.¹

Right: Holographic display of a marimba player. When a melody is modified, the marimba player changes its performance accordingly. You can view video clips of the marimba player performing by scanning the QR code above.

(Outline)

- HAMANAKA Masatoshi (Team Leader, RIKEN Center for Advanced Intelligence Project) and his team have been developing a technique that can be used to analyze musical works and uncover the steps taken during the process of creating them.² This analysis is a reverse-engineering process, which can be viewed as the opposite of the music composition process.
- Formerly, only experienced music composers who had studied music composition methodology at a music university were capable of accomplishing this type of reverse-engineering analysis.
- After 15 years of research, Hamanaka's team discovered that this analysis can be carried out very effectively using deep learning, an artificial intelligence (AI) technique.
- Once the melody composition procedures are identified, they can be shared publicly to make the process of musical composition more efficient. However, it should be noted that the effective use of these procedures is likely to be difficult for most people, allowing traditional music composers to continue to do their job.

(Commentary)

1. Melody slot machine: GTTM (generative theory of tonal music) analysis is a technique being developed to uncover the procedures used to compose musical works. The performance of this analytical technique has been improving in recent years. When fully realized, it may make melody composition easier. The melody slot machine was designed to allow the public to experience the taste of composing music.
2. Music structure analysis: GTTM, a musical analysis theory proposed in 1983, is unique for its concept to extract structurally important melody components from musical works. The world's first computer-based GTTM analyzer was developed in Japan in 2005, although its performance was unsatisfactory for practical use. A different GTTM analyzer has been in development since 2016 using deep learning and its analytical performance has been rapidly improving.

How Will We Treat AI/Robots that Appear to Possess Consciousness?

Contributors: Kanazawa University and GROOVE X, Inc.



Left photo provided by GROOVE X, Inc.

Left: “Lovot,” a domestic robot designed to provide loving companionship
Right: The penguin on the left may appear to be depressed, with its shoulders drooping in sadness.

(Outline)

- Is it possible for robots and artificial intelligence (AI) to achieve consciousness? A more fundamental question might be, “How do we know that others possess consciousness?”
- Consciousness is said to have two components: functional consciousness, which controls responses to external stimuli (e.g., a person withdrawing his/her hand when it is subjected to heat), and phenomenal consciousness, which is experiential (e.g., the experience of sensing a hot object).¹
- When we see something react in a way that represents functional consciousness, we sense that it is conscious. For example, when we see another person smiling or a happy-looking dog, we equate this with a joyful state of consciousness. The photo at upper right is a counter example of a creature that appears to be depressed.
- If robots capable of exhibiting human-like facial expressions are created, some questions may arise. Would we perceive them as conscious beings? Lovot in the photo at upper left is a robot designed to adjust its behavior in response to external stimuli and express affection.² Should we accept robots as members of our “moral community”?³
- If we choose to accept robots as members of our moral community, how should we treat them? This and related issues may need to be addressed soon.

(Commentary)

1. Functional and phenomenal consciousness: Consciousness is said to have two components: functional consciousness, which controls responses to external stimuli, and phenomenal consciousness, which is represented by subjective, internal experiences unobservable to others. The existence of phenomenal consciousness is generally thought to be impossible to prove scientifically and objectively because metaphysics is incapable of proving that different people can undergo similar experiences.
2. Lovot: This domestic robot was developed by GROOVE X in the hope of making the concept, “a little love can change the world,” a reality. Its behavior was not preprogrammed. It perceives external stimuli using more than 50 sensors distributed throughout its body. The sensed stimuli are then processed by AI. A Lovot takes real-time actions based on this processed information.
3. Moral community: According to this concept, all members of a community share equal rights and obligations. Assume the existence of robots that appear to have consciousness based on their abilities to express such emotions as joy and disappointment in response to external stimuli. Should they be given the same rights and obligations given to other community members? This moral issue in the context of AI/robot research should be carefully discussed in advance.

Scientific and Technological Achievements that Contribute to Daily Life ⑤

Robotic Alter Ego Enables Bedridden Patients to Participate in Society Virtually

Contributor: OryLab Inc.



Photos provided by OryLab Inc.

Left: The OriHime robot (yellow object) can be remotely controlled using a tablet computer or even eye movement. This robot may fulfill the needs of severely disabled people and people who want to enjoy long-distance communications in the manner of a face-to-face conversation.

Right: OriHime (blue) being used by people who are remotely participating in a conversation taking place at a different location

(Outline)

- OriHime is a robot developed by YOSHIFUJI Kentaro, a founder of OryLab Inc. Physical issues he experienced during early childhood inspired him to create a robot capable of serving as his “alter ego.”¹
- Patients with greatly limited mobility due to severe illness, such as ALS (amyotrophic lateral sclerosis), can remotely operate OriHime as a “second self” by simply moving their eyes or clicking a switch. By manipulating OriHime, the patients can engage in various activities, including expressing their thoughts, using social media services, drawing pictures and remotely participating in various events.²
- In addition, workers who are obliged to stay at home (e.g., parents raising young children) can operate OriHime placed in their workplaces using any type of computer, thereby helping them work from home. Moreover, hospitalized children can use OriHime to remotely attend school and participate in school events (e.g., cultural festivals) with their friends.³

(Commentary)

1. Robotic alter ego: OriHime was developed to help people with severely limited mobility enjoy life by allowing them to visit places, meet other people and participate in social activities.
2. Remote communication that gives users the feel of face-to-face interaction: OriHime is equipped with a camera, microphone, speaker and motor and can be remotely operated using any type of PC. By operating an OriHime placed in a desirable location, users can observe their surroundings, converse with others and use gestures to express their emotions, allowing them to experience face-to-face interaction.
3. Example applications: Stationary OriHime models have been used as a means of remotely attending classes and teleworking. They have also been used by patients with severe illnesses to communicate with others. More recently, a moving model, OriHimeD, is being developed. Experiments open to the public have demonstrated that a bedridden patient was able to remotely work in a café by operating an OriHimeD robot placed in the shop using eye movement and other means.

Electric Wheelchair that Makes Outings a Pleasure

Contributors: WHILL, Inc. and New Energy and Industrial Technology Development Organization (NEDO)



Photos provided by NEDO

Left: Anti-vibration omni-wheel is equipped with 24 large and small tires capable of rotating perpendicular to the direction of a wheel's rotation.

Right: WHILL Model C commercialized by WHILL, Inc. in 2017. This electric wheelchair uses a pair of anti-vibration omni-wheels as its front wheels.

(Outline)

- Conventional electric wheelchairs are difficult to use on rough surfaces, such as paths with shallow steps and gravel roads. In addition to these physical obstacles, some users of electric wheelchairs have a mental resistance to using them. WHILL, Inc. has developed new personal mobility vehicles—the WHILL models—which are completely different from conventional wheelchairs.
- The WHILL Model C¹ is a new electric wheelchair model developed by WHILL, Inc. Its front wheels consist of a pair of anti-vibration omni-wheels², each equipped with 24 small tires, enabling the wheelchair to change direction within a 76 cm radius circle. In addition, the WHILL Model C is equipped with a powerful motor developed jointly by WHILL, Inc. and Nidec Corporation which allows the wheelchair to drive over steps up to 5 cm in height and climb 10 degree slopes.
- WHILL vehicles are distinctly different in design from conventional electric wheelchairs: they are compact and light, allowing users to load/unload them without assistance, highly maneuverable and resistant to vibration when traveling on rough surfaces, resulting in a comfortable ride. These features make WHILL personal mobility vehicles enjoyable and exciting to drive.
- Several thousand WHILL vehicles have already been shipped globally. People all over the world will hopefully enjoy these personal mobility devices developed in Japan.

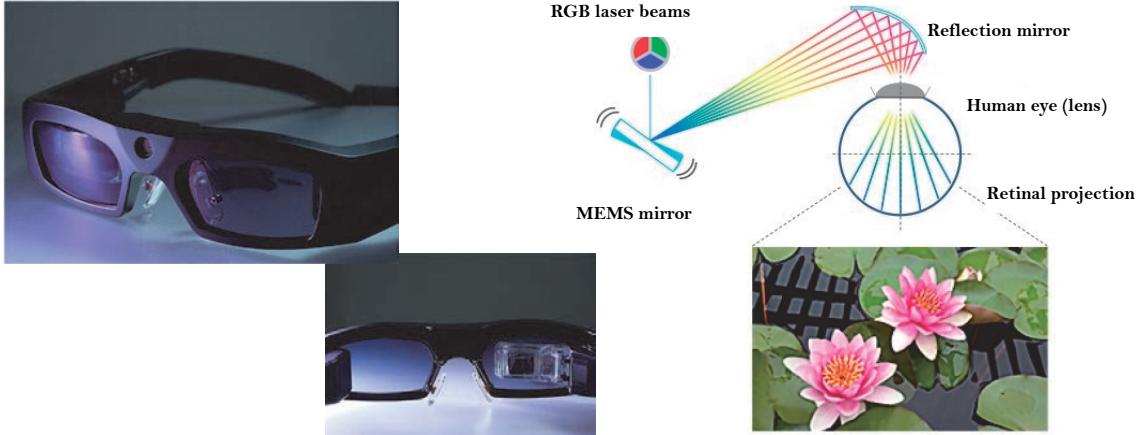
(Commentary)

1. WHILL Model C: WHILL, Inc. developed the front wheels and motor, enabling the creation of powerful lightweight electric wheelchairs. This project was supported by NEDO's Development Promotion Project for Practical Use of Welfare Equipment (FY2015–2016). WHILL Model C is a product of this effort and has been commercialized.
2. Anti-vibration omni-wheel: This omnidirectional wheel is capable of moving the wheelchair in every direction without changing the axle orientation. The wheel had been used mainly in electric dollies and small robots and WHILL, Inc. made modifications to increase its durability and vibration absorption for use in wheelchairs.

Scientific and Technological Achievements that Contribute to Daily Life ⑦

Correcting Near- and Far-Sightedness with Retinal Projection Technology

Contributors: QD Laser, Inc. and New Energy and Industrial Technology Development Organization (NEDO)



Images provided by QD Laser, Inc.

Upper left and middle: Laser eyewear that resembles eyeglasses. The device on the right lens projects laser beams. Right: Images viewed by an eyewear user (e.g., flowering plants) are converted into red, green and blue laser beams, which are then projected onto the user's retina via a series of mirrors.

(Outline)

- People with lazy eye (amblyopia)—a condition that can result from eye diseases and other causes—suffer from significantly reduced visual acuity that cannot be corrected using eyeglasses or contact lenses. 1.5 million Japanese people are said to have this condition.
- Some with amblyopia manage to read text with the aid of magnifying lenses and other means, but they are still forced to experience various inconveniences in daily life. For example, it may be difficult for them to recognize facial expressions of people immediately in front of them and they may be unable to go out alone.
- QD Laser, Inc. has been researching and developing eyewear intended to reduce these visual inconveniences using semiconductor laser technologies and optical design techniques.¹ In 2016, the company succeeded in putting the retinal scanning laser eyewear it developed into practical use.
- The laser eyewear frame is internally equipped with a tiny laser projector. Images viewed by an eyewear user (e.g., the flowering plant photo at lower right) are converted into weak laser beams which are then projected onto the user's retina via a series of mirrors. This method enables people with abnormalities in their anterior eye components (the cornea and lens) to experience clear vision.²
- The feasibility of using the laser eyewear for eye exams is being studied in addition to its use as a visual aid. This technology may significantly contribute not only to the medical treatment of amblyopia but also to the advancement of ophthalmology more generally.

(Commentary)

1. Eyewear R&D: QD Laser, Inc. evaluated the advantages of head-mounted displays capable of projecting laser beams onto the retina and identified functions required for the device. The company also worked to reduce the size of the eyewear and to improve the quality of the images it forms. These efforts were made in order to put the technology into practical use and establish it as a standard technology. These R&D projects were supported by NEDO's Clean Device Society Promotion Program and another NEDO's Development Promotion Project for Practical Use of Welfare Equipment.
2. Retinal projection technology: This technology projects images of visual objects directly onto a user's retina. As long as the user has a normally functioning retina, this technology enables him/her to clearly see objects irrespective of the eye's focal point or ability to focus (i.e., the eye does not need to actively focus). Moreover, the technology may be applicable even to people with partially impaired retinas if images can be effectively projected onto an undamaged portion of the retina.

Converting Unpleasant Memories into Pleasant Ones: Rewriting Memory-storing Cells through Neuronal Manipulation

Contributors: RIKEN Center for Brain Science and former RIKEN-MIT Center for Neural Circuit Genetics



(Outline)

- Approximately 1.27 million people in Japan are estimated to be undergoing treatment for depression and other emotional disorders, including lack of motivation and bipolar disorder, according to injury and illness statistics compiled from a 2017 Patient Survey conducted by the Ministry of Health, Labour and Welfare.
- Medication, psychotherapy and other treatment methods have been used to treat these conditions. However, because these treatments vary in effectiveness among individuals and conventional drugs often induce side effects, it is desirable to develop new treatments and drugs that take neuronal characteristics into account.
- A research team led by Joshua Kim and TONEGAWA Susumu (former director of the RIKEN Brain Science Institute) carried out research on memory rewriting inspired by some of the specific symptoms of depression: inability to recall pleasurable experiences and loss of interest in previously enjoyed activities.
- Based on experimental research, the team found that unpleasant memories stored in memory traces (engrams) can be rewritten into pleasant ones.¹
- In addition, the team confirmed that depression can be improved by activating pleasant memories.²
- The team also discovered that pleasant and unpleasant memories interact to suppress one another.³
- These findings may lead to the development of more effective ways of treating depression.

(Commentary)

1. Converting unpleasant memories into pleasant ones: In mouse experiments, when a group of hippocampal neurons in which unpleasant memories (engrams) were stored was activated, the treated mice retrieved unpleasant memories. However, when the mice were allowed to experience pleasure while the same hippocampal cell group was activated, the same cells stored the pleasurable memory. The research team then conducted similar experiments targeting a different brain region responsible for memory called the amygdala. Unlike the first experiment, the memories of the treated mice were unaffected by the new experience regardless of whether they were pleasant or unpleasant. These results indicate that the link between the hippocampus and the amygdala cannot be easily modified—a possible cause of depression symptoms.
2. Facilitating pleasurable memory recall: Artificial techniques (e.g., activation of hippocampal neurons that become active when mice experience pleasure (engrams)) may be used to help depression sufferers retrieve pleasurable memories. This response has been found to be caused by the activity of a neuronal network that extends from the hippocampal dentate gyrus to the nucleus accumbens shell (a brain region responsible for cognitive processing of rewards and pleasure, etc.) via the basolateral amygdala.
3. Cells that respond to pleasant/unpleasant experiences: When mice experienced pleasant or unpleasant events, neurons in different areas of the basolateral amygdala became active. These neuron groups have been found to inhibit one another in an antagonistic manner. Moreover, when the activities of neurons that store pleasant/unpleasant memories were suppressed, the behavior of the mice changed, exhibiting reduced activity linked to these memories.

Scientific and Technological Achievements that Contribute to Daily Life ⑨

New “Benchmarks” for Doping Tests to Ensure Good Sportsmanship

Contributor: National Institute of Advanced Industrial Science and Technology (AIST)



Images provided by AIST

Left: Nuclear magnetic resonator used for quantitative magnetic resonance spectroscopy
 Right: AIST-certified reference testosterone, one of many prohibited substances

(Outline)

- Doping tests targeting athletes participating in international sporting events are carried out by WADA (World Anti-Doping Agency)-authorized organizations capable of analyzing doping samples. These tests concern a list of prohibited substances publicized by WADA. Concentrations of prohibited substances in urine and other samples must be accurately determined (i.e., by determining whether their concentrations are below (negative) or above (positive) allowable levels), as a false positive may, in the worst-case scenario, destroy an athlete’s career. To avoid such errors, new “benchmarks” (i.e., reference concentrations of prohibited substances) need to be produced. However, reference substances are as prone to expiration as pharmaceutical products and are represented by several hundred different substances. Moreover, WADA updates its prohibited substance list annually, making it very difficult for analytical organizations to continuously keep a complete set of reference substances in stock.
- Quantitative magnetic resonance spectroscopy is a promising technique that can be used to quickly prepare reference substances as needed, allowing analytical organizations to continuously maintain a complete set of substances in stock. This technique was developed by optimizing MRI (magnetic resonance imaging)—used commonly in hospitals and other facilities—for chemical analysis. AIST is among the first to adopt this technique and has been using it to prepare reference substances for agricultural chemical residue testing by other organizations. The use of this technique has reduced the time needed to prepare these substances to less than a tenth of the time required by conventional methods.¹
- Using this technique, AIST has been working to produce new “benchmarks” for use in doping tests for the 2020 Tokyo Olympics and Paralympics and other international sporting events.²

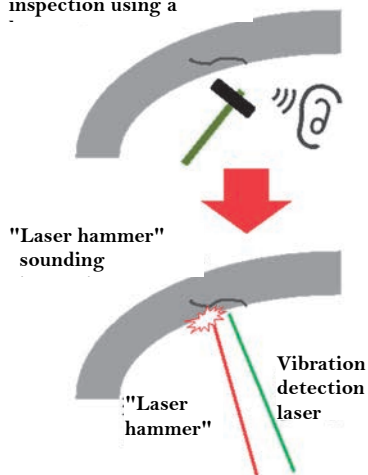
(Commentary)

1. “Versatile calibration technique research and development” funded for FY2009 by the Ministry of Economy, Trade and Industry: Under this R&D program, empirical research on quantitative magnetic resonance spectroscopy was carried out jointly by AIST (team leader), National Institute of Health Sciences, JEOL Ltd., Wako Pure Chemical Industries, Ltd. (currently FUJIFILM Wako Pure Chemical Corporation) and Kao Corporation. The technique developed in this project has been used to produce approximately 130 reference substances for agricultural chemical residue testing. FUJIFILM Wako Pure Chemical Corporation is the distributor of these substances.
2. New “benchmarks” for doping tests: AIST’s National Metrology Institute of Japan established a doping test reference research lab in July 2018 at which research is underway to increase the reliability of the quantitative analyses used in doping tests.

Automated Safety Inspection of Concrete Infrastructure Using a High-powered Laser

Contributors: National Institutes for Quantum and Radiological Science and Technology (QST), Institute for Laser Technology (ILT) and RIKEN

Conventional sounding inspection using a



Images provided by QST

Left: Application of a "laser hammer" causes concrete surfaces to vibrate. These vibrations are then measured and analyzed using a vibration detection laser. Internal cavity inspections can be performed about 20 times faster than conventional methods using this technology.

Right: Testing the performance of the vehicle loadable laser hammer sounding inspection system

(Outline)

- Much of Japan's concrete infrastructure, including its tunnels and bridges, was constructed during the post-war period of rapid economic growth. Its advancing age necessitates the development of efficient repair and maintenance technologies. Active efforts have been made to develop automated, fast, non-destructive, remotely controllable concrete inspection technologies. QST has developed a technology capable of repeatedly emitting powerful laser pulses. Using this technology, QST and ILT then jointly developed a vehicle loadable high-speed laser hammer sounding inspection system.¹
- QST and ILT have used the system experimentally in vehicular tunnels in Nara City, Osaka Prefecture and Shizuoka Prefecture. RIKEN has been simultaneously developing an imaging and measurement system that the joint team hopes will improve the efficiency of concrete tunnel lining inspections when integrated with the laser hammer sounding inspection system.²

(Commentary)

1. The vehicle loadable high-speed laser hammer sounding inspection system: QST and ILT have developed a system capable of emitting powerful 50 Hz laser pulses and a high-speed laser during an infrastructure maintenance and management research project supported by the Cross-ministerial Strategic Innovation Promotion Program (SIP). The joint team then succeeded in demonstrating the ability of this system to speedily inspect the concrete linings of vehicular tunnels.
2. Verification experiments in vehicular tunnels in Nara City, Osaka Prefecture and Shizuoka Prefecture: The laser hammer sounding inspection system was tested in vehicular tunnels. Experiments were carried out to verify its ability to speedily perform inspections. These R&D activities will continue in an effort to achieve practical use of this system.

Scientific and Technological Achievements that Contribute to Daily Life ⑪

Processing Record-breaking Bagworm Silk into Industrial Fiber Materials

Contributors: National Agriculture and Food Research Organization (NARO) and Kowa Company, Ltd.



Images provided by NARO

Research has found that bagworm silk is superior in quality to spider silk as an industrial fiber material.¹
A silk harvesting technique has been successfully developed, enabling industrial use of bagworm silk.²

(Outline)

- Spider silk has long been called the strongest natural fiber. It has been researched globally as a groundbreaking biological material potentially capable of serving as a sustainable fiber resource, reducing dependence on petroleum-based fibers.
- NARO has discovered that silk spun by bagworm moth caterpillars³ is superior in fiber quality to spider silk.
- Bagworm silk is more resistant to breakage than carbon fiber when used as a structural material and is thermally stable. These superb properties may enable bagworm silk to be used to produce fiber-reinforced plastics when combined with resin.
- Ongoing research efforts focus on the potential use of silk as a regenerative medical material. Due to its advantageous characteristics, bagworm silk may be employed to develop high-quality biomaterials useful in regenerative medicine.
- Threads of silk spun by bagworm moths usually form a zigzag pattern. In order to facilitate industrial use of these threads, a basic technique was developed to manipulate the behavior of bagworm moths, thereby enabling the harvesting of straight threads that extend to lengths of up to several hundred meters. Efforts are being made to optimize this technique for mass production.⁴

(Commentary)

1. Advantages of bagworm silk: Silk produced by bagworm moths has been found to be superior to spider silk in elasticity, strength against breakage and toughness. The relationship between the mechanical characteristics of bagworm silk and its structure was determined using high-intensity X-ray beams at SPring-8, the synchrotron radiation facility.
2. Silk harvesting technique: When bagworm moth caterpillars crawl, they produce silk threads from their mouths in a zigzag pattern to gain a secure foothold. NARO researchers discovered that when the caterpillars are forced to move along a certain path, they produce straight silk threads rather than zigzagging ones. Using this technique, straight threads as long as several hundred meters—a normal movement range for the caterpillars—can be produced.
3. Bagworm moth caterpillars: These caterpillars are the members of the moth family, Psychidae. They occur globally except in deserts and in the polar regions, with approximately 50 psychid species found in Japan. These caterpillars spin protein fibers as silkworms and spiders do.
4. Technical improvements for mass production: Kowa Company and NARO have been engaged in joint research to achieve commercialization of bagworm silk. This effort may lead to the creation of new industries that exploit bagworm silk.

Tree Rings Unveil the Past and the Future: Integration of Paleoclimatology, History and Archaeology

Contributor: Research Institute for
Humanity and Nature (RIHN)



Photos provided by RIHN (left) and the Otsu City Museum of History (right)

Left: Yakusugi (Japanese cedar grown on Yakushima Island) cross section being used in tree-ring research

Right: An ancient document describing the ways in which Japanese people responded to climate changes in the early modern period

(Outline)

- Tree-ring width¹ is the indicator most commonly used globally to retrieve past climate records. However, in warm and humid regions, tree-ring width is substantially less sensitive to climate changes. For this reason, it had been thought difficult to retrieve Japan's paleoclimatic records using this indicator.
- Around the year 2000, a technique capable of measuring cellulose oxygen isotope ratios in individual tree rings became available. Studies using this technique have revealed that these ratios can be correlated with summer rainfall amounts.^{2, 3}
- An RIHN-led research project (project leader: Professor Takeshi Nakatsuka) has been carried out in coordination with the National Institutes for the Humanities to understand the ways people in Japan responded to climate change over the course of Japan's history. In this project, the researchers analyzed cellulose oxygen isotope ratios and used the results to estimate yearly changes in precipitation in different Japanese regions over the past several thousand years.
- The data generated in this project is now available for advanced historical and archaeological research (e.g., analyzing the ways in which precipitation fluctuations might have impacted Japan's historical events and precisely dating materials excavated from archaeological sites to the year by matching the oxygen isotope ratios of tree rings and excavated materials). In addition, the data has begun to be used to validate climate models designed to predict precipitation distributions in the future.

(Commentary)

1. Tree rings: The trunks of living trees expand cross-sectionally and outwardly as they grow. Trees grow rapidly from spring to summer, forming a less dense, light-colored ring layer, and slowly from summer to fall, forming a denser, dark-colored ring layer, giving tree rings a striped pattern.
2. Records stored in tree rings: A pair of adjacent dark and light ring layers represent annual growth. By analyzing the cellulose oxygen isotope ratios in a given annual growth ring, scientists can determine atmospheric moisture content (i.e., humidity) and precipitation associated with the year during which the ring was formed.
3. Principle behind the use of oxygen isotope ratios to determine precipitation: Oxygen content in cellulose is derived from water in photosynthetic leaves. When leaves transpire water into the atmosphere, water containing lighter oxygen isotopes exits first. Accordingly, when trees are exposed to sunnier and dryer conditions favorable to transpiration, oxygen isotope ratios in leaf water increase (i.e., the ratios of heavier oxygen isotopes to lighter ones increase), resulting in increased oxygen isotope ratios in cellulose as well. Tree rings therefore can provide information on atmospheric moisture conditions in the years in which they formed.