IBS Research

2022 1st | 18th Issue

Frontline

–1000m the Final Frontier

Challenging the Impossible

People

The Scientist Who Chases After the First Rising Star at dawn

ALICE Experiments at LHC Run 3: A New Journey in Search of Matter in an Extreme State

Institute for Basic Science

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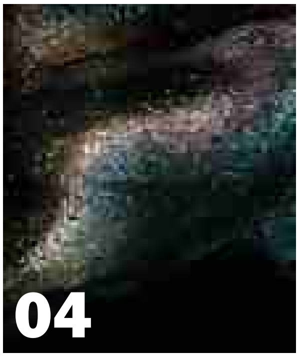

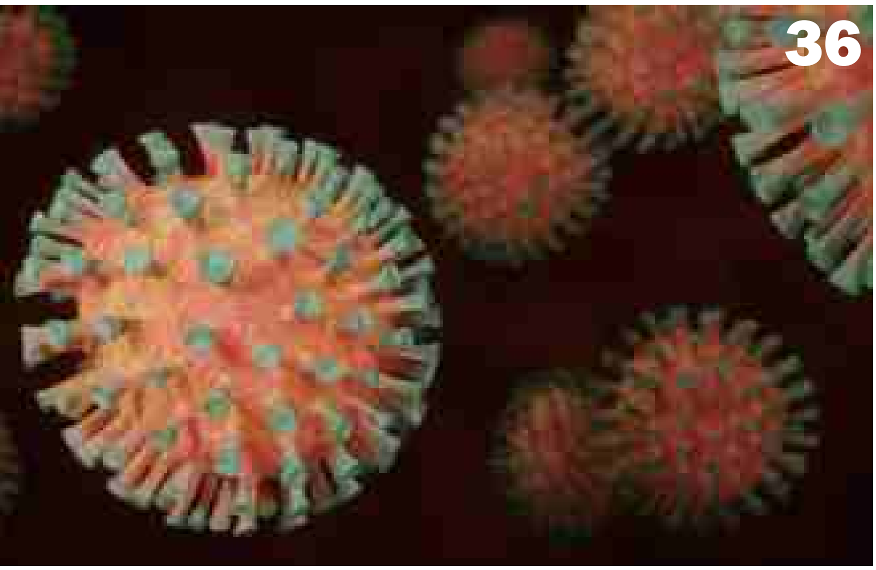

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On the Cover

At the foot of Mt. Yemi in Jeongseon–gun, Gangwon–do, the second underground laboratory of the IBS Center for Underground Physics, 'YemiLab' will be completed this year. Our tour of this laboratory starts with an elevator. It is a high–speed elevator with a speed of 4 m/s, which is 4 times faster than that of typical elevators installed in 15–story apartment buildings. In this elevator, we traveled down a 600–meter–deep vertical tunnel.

As a comparison, the Lotte Tower in South Korea is 555 meters high. This makes it equivalent to using an elevator to travel down deeper than the world's 5th tallest building. While the facility is vertically deep underground, the main laboratory consists of a linear straight tunnel, meaning there is no danger of getting lost. In contrast, the research at the center can be said to be as lost as it is in the middle of the open sea. The Center is preparing in earnest for a long journey to find Majorana fermions, which still show no trace of being discovered even after 80 years since it was first proposed theoretically. It also seeks to search for 'WIMPs', a strong candidate for dark matter whose property we know nothing about. The underground physics research constantly challenges the rare probability that is close to 0, comparable to finding a specific grain of sand in the desert. We personally visited this majestic site and took photographs for the cover of this issue.

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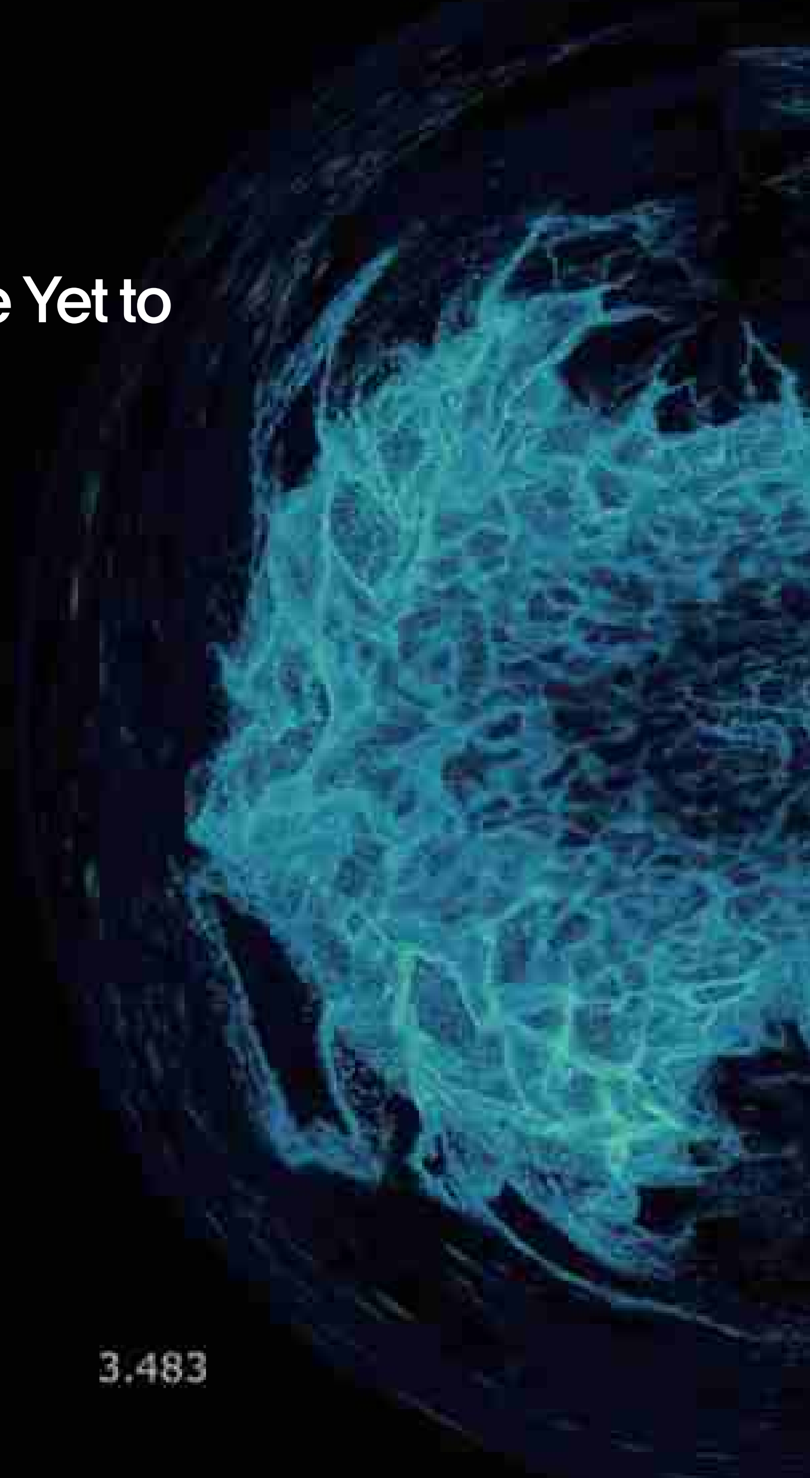
Art in Science

The Smallest Universe Yet to be Seen by Mankind

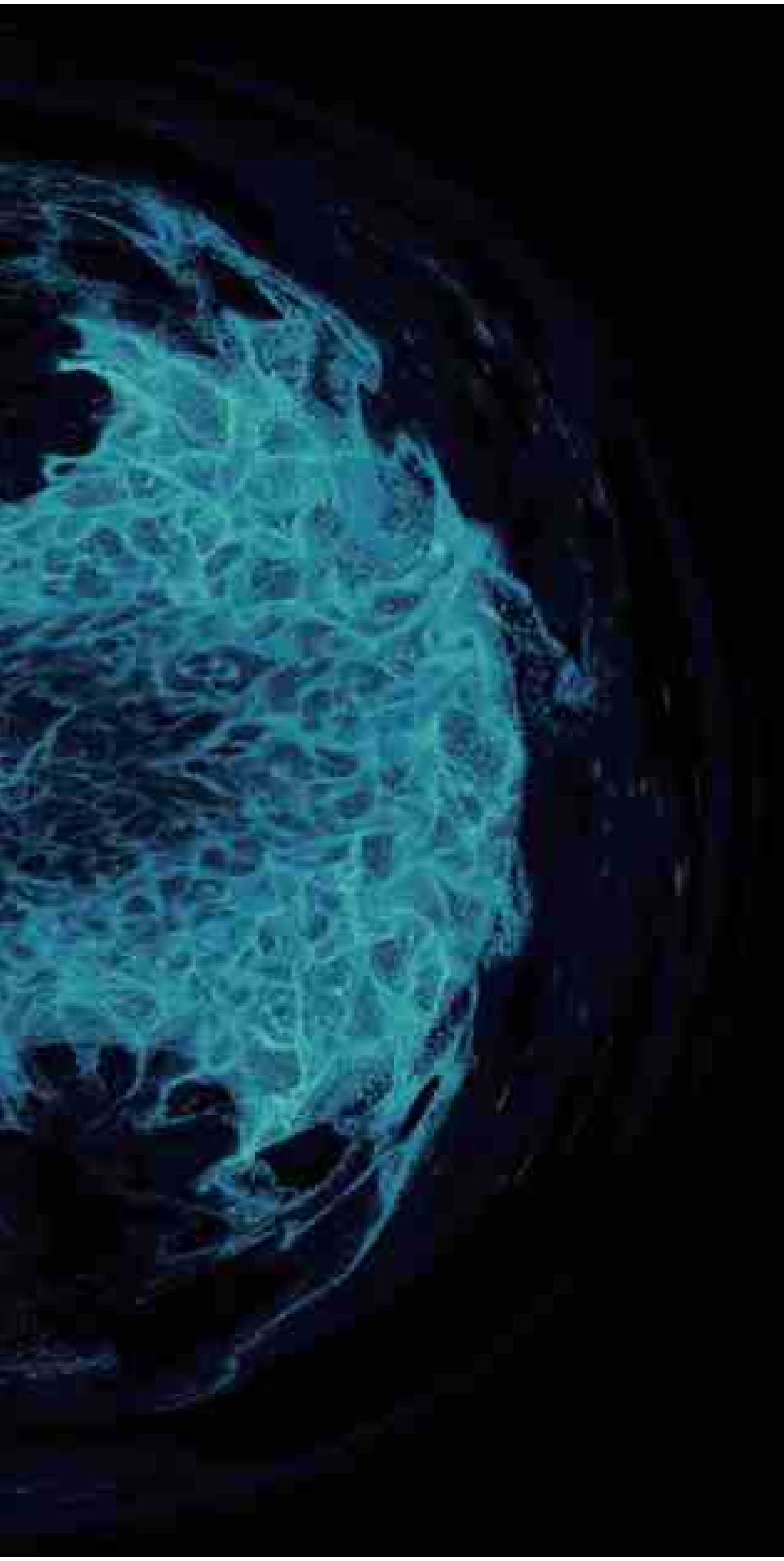
In July 2022, NASA released several images taken by the James Webb Space Telescope (JWST). Above all, it contains the most distant image of the universe that mankind has not seen so far. On the other hand, at an unexpected moment, researchers sometimes encounter a fairly small universe that mankind has not seen as well. Here we introduce the researchers' own universe, which appeared only to them at a special moment.



Art in Science

The Institute for Basic Science (IBS) holds the 'Art in Science' contest every year. The contest is held to showcase artistic images that scientists obtain during their work. In this issue, we introduce some of the award-winning works from the 2021 IBS Art in Science contest.

View video
on YouTube



Beautiful Lives of the Stars

by JUNG Jun Hyuk
(Students majoring in CT at Seoul National University of Arts)

The work started out as a curiosity about what would happen when we gather and visualize the luminance data that shows the birth and death of stars. A star is another name for self-illuminating objects that provides mystery to the night sky. The stars are formed from interstellar matter such as gas and dust when these matters coalesce in the denser regions of interstellar space. Stars born in this way express their existence and mystery by emitting light, as they live through the pre-main sequence, main sequence, and post-main sequence stages, ending in death. In the work, the luminosity* data of stars repeatedly appear and disappear as waves. If you observe the luminance data over several hours, you can see that they maintain a similar pattern and change regularly. As such it is possible to express the beauty of the stars' lifetime through data visualization.

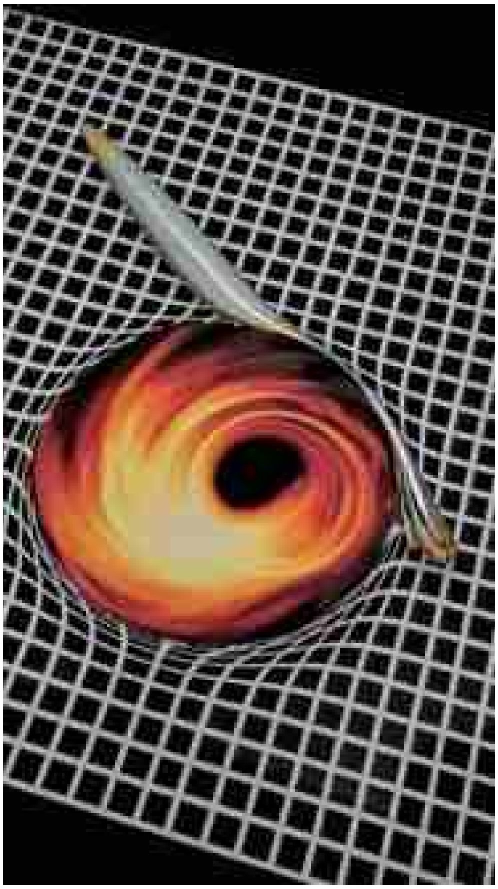
Luminosity*

The brightness of a star according to the intensity of light emitted over a certain period of time. This brightness can be obtained from the radius and the surface temperature.

Smell of the Sea

by LEE Jun Hyuk
(Department of Bioscience and Neurology at the Korea Institute of Science and Technology)

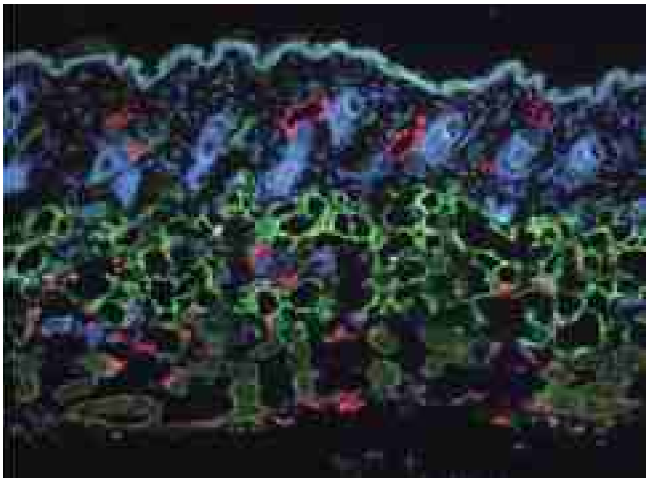
The brain works hard even when we perform simple tasks such as smelling an object. In particular, the role of the olfactory cortex is important for 'recognition' beyond 'sensing' odors. This image was obtained while expressing synaptophysin mCherry–eGFP in the olfactory cortex via fluorescence staining to perform an observational study of the astrocytes in the region. This image, taken at the beginning of summer, is reminiscent of the beach. I think this is an image that represents my desire to go on vacation to the beach while being tired of repeated labwork this year. Even at this moment, I can already imagine the smell of the sea, so I named this work the scent of the ocean. I hope I can go to the beach soon.



Distortion of Time and Space

by LEE Gun Hee(Busan Science High School)

This photograph shows a model of a black hole was floated on the water, which bends the background under the water due to surface tension. Normally, the pen should not be visible due to being hidden behind the black hole model, but the surface tension created by the black hole model causes the light to bend so that the pen underneath is refracted and revealed. This shows the same effect as gravitational lensing where light is bent under the influence of gravity due to a large object such as a black hole. Gravitational lensing is a phenomenon in which light from a very distant celestial body is bent by strong gravity from a large celestial body during its travels along the curved space–time. The gravitational lensing effect has been presented as strong evidence to support Einstein's general theory of relativity. In the photo above, the black hole model represents a celestial body with a large mass, a curved surface of the water is a curved space–time, and the pen is a distant celestial body.

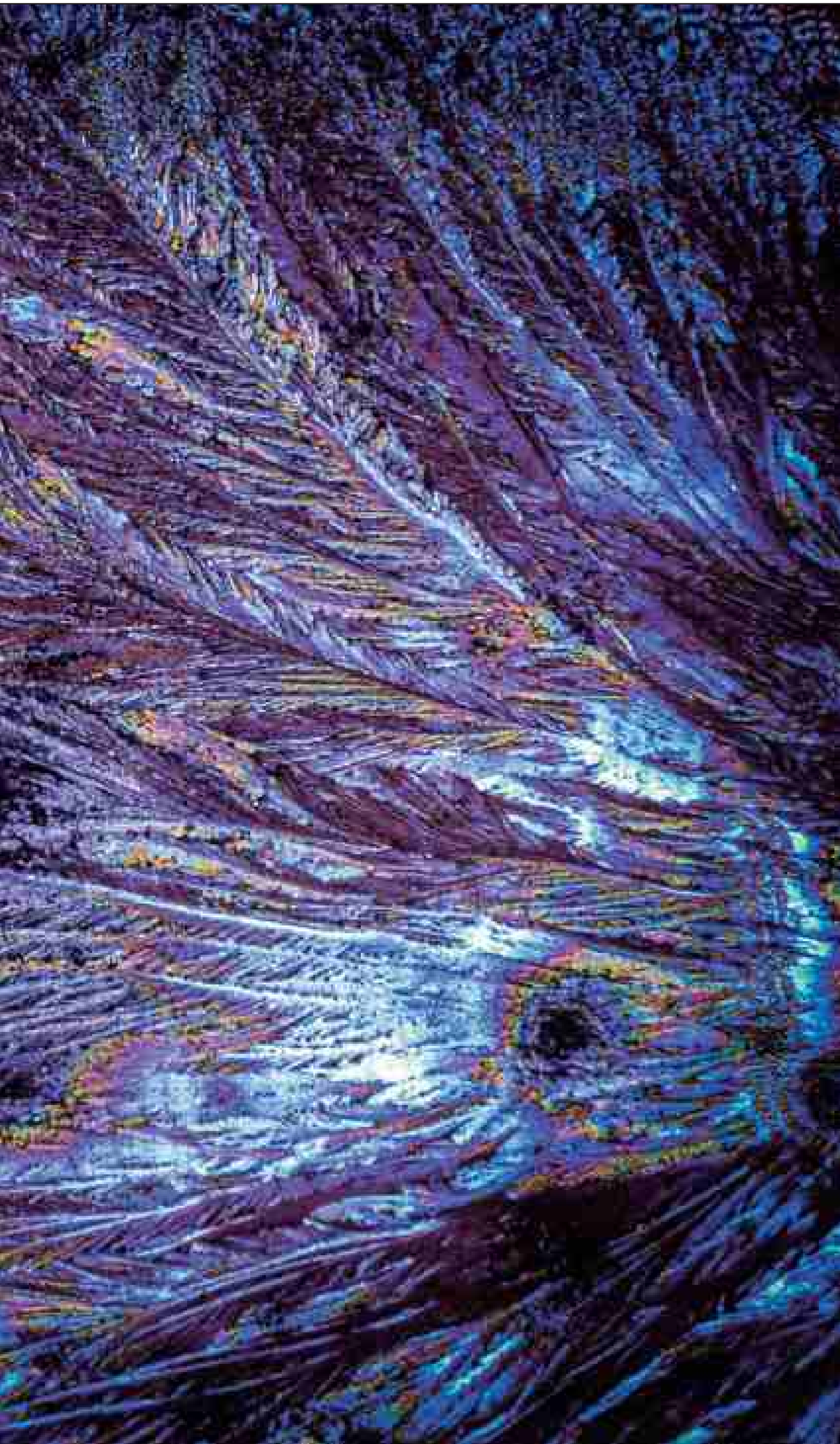


Microcosm

by YOON Sun-Young

(Faculty of Cosmetic Science at Chow Women's University)

This image was obtained while studying the relationship between lymphatic vessels and hair growth. In the skin tissues of mice, the nucleus (blue), lymphatic vessels (red), and adipocytes (green) were stained and images were obtained using a fluorescence microscope. There are various cells in the skin, which is like a huge universe. Individually, cells are arranged chaotically and appear disordered, but they end up discovering a unique order and form the skin tissue. The presented image shows the magnificent order established by diverse types of cells to the extent that it can be called a microcosm. All living things, not just the mouse used in the experiment, have their own microcosms that are like cosmos of chaos.



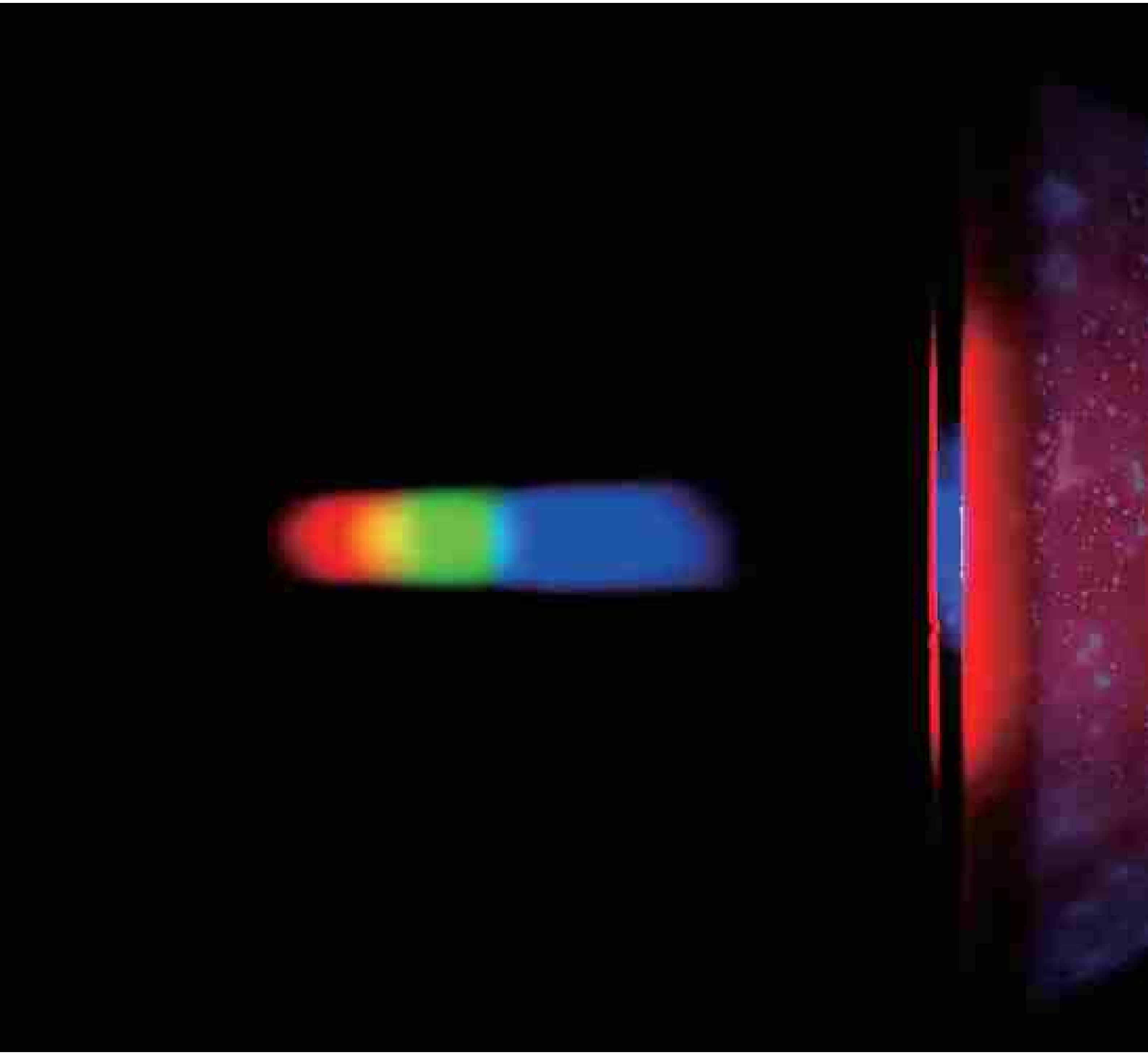
Shining Wings

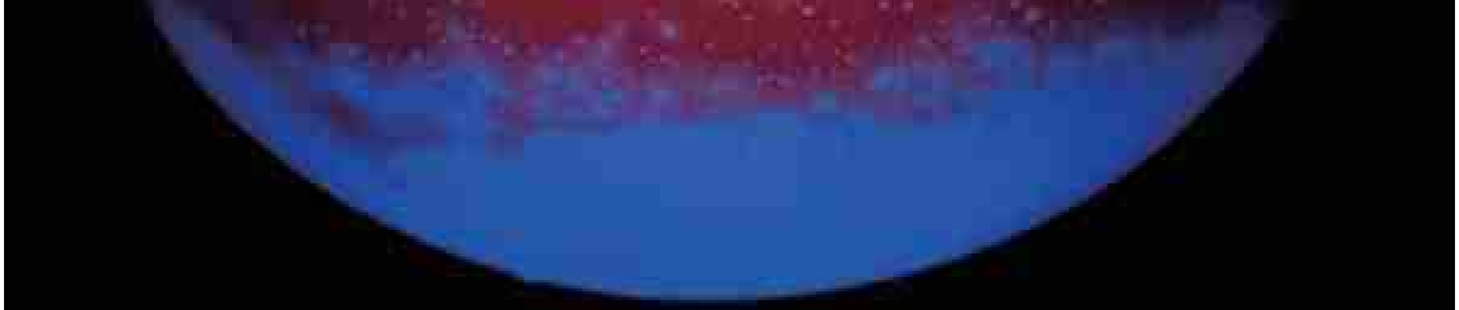
by KIM Jung-Soo
(Professor JOO Cheol-Min of
the Department of Mechanical
Engineering at Yonsei University)

This work is an image of the birefringence characteristics of vitamin C crystals which was taken using a polarizing microscope. Birefringence is a phenomenon that occurs when light is incident on an optically anisotropic medium, the light is split into two refracted lights due to the refractive index is different depending on the polarization direction of the light. The birefringence property provides a variety of information about the composition and structure of a material, such as the shapes and arrangement of molecular crystals inside the material. Since the technology for imaging the birefringence properties of materials have a wide range of applications, such as in bio, medical, and food industries as well as materials sciences, we were able to take this image while conducting related research. This birefringence image of vitamin C can make us all say "is this really vitamin C?" This shows how we can find beauty in the small parts of everyday life that we don't know about. "The real voyage of discovery consists not in seeking new landscapes, but in having new eyes."

– Marcel Proust

※ This work is a vertical image.
Try turning it 90˚ clockwise!





End of Extraterrestrial Planets

by KANG Ju Wan, SEO Seong Min, LEE Sang Eon, and KIM Seo Wi(Gyeongnam Science High School student)

The light that illuminates our daily lives is made up of many different wavelengths. Of these, visible light, which we can see and feel, is the most beautiful gift that nature has given us. The white contains light red, yellow, and green lights which have different characteristics such as different diffraction angles. The three primary colors of light pass through a narrow gap and deflect each other slightly, creating a variety of new colors. On the backside of the CD, which is a representative diffraction grating plate, the light is reflected by numerous thin gratings and causes interference, showing colorful patterns. Similar to CD, the grating film also consists of many thin gratings. The visible light with a wavelength of 400 nm to 700 nm spreads widely on the diffraction grating films with several thousand thin grooves per 1 cm on a transparent plate. To observe the pattern more easily, a hemisphere bowl of water was filled with water and oil bubbles so that vivid colors can be displayed on the surface. The red light passing through the white oil bubbles mixed in the water looks like a gas giant planet with active convection at its surface.

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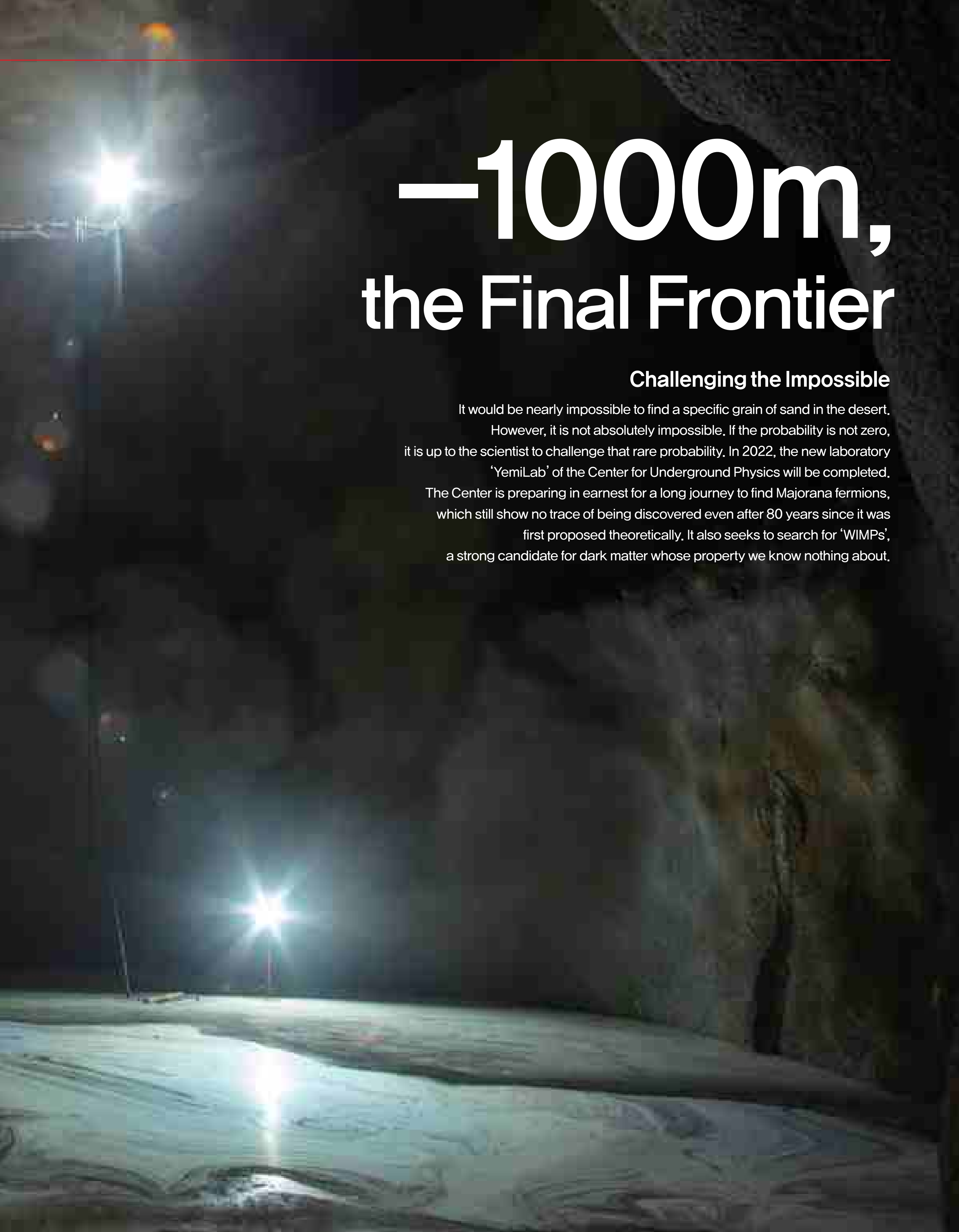
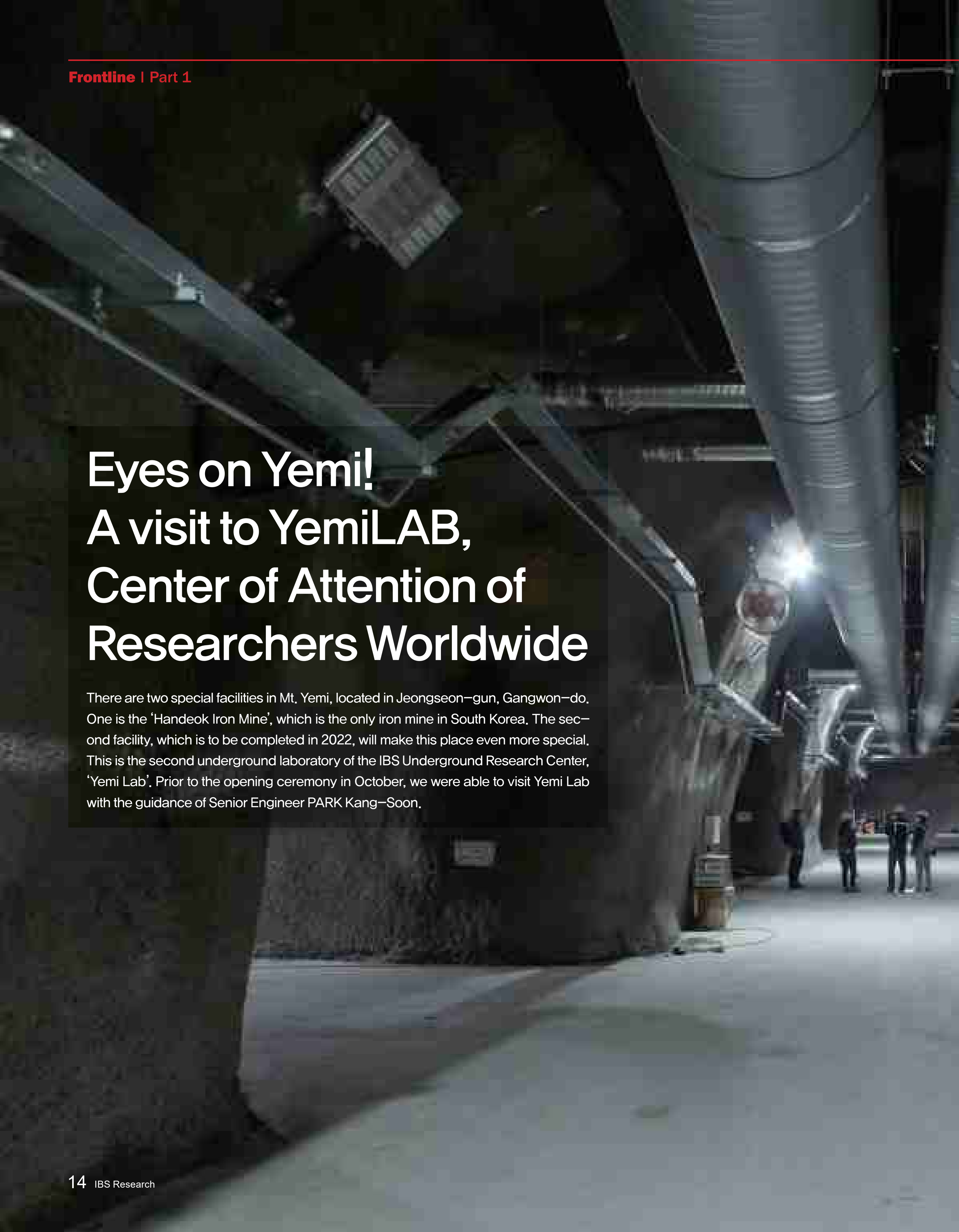


–1000m, the Final Frontier

Challenging the Impossible

It would be nearly impossible to find a specific grain of sand in the desert. However, it is not absolutely impossible. If the probability is not zero, it is up to the scientist to challenge that rare probability. In 2022, the new laboratory 'YemiLab' of the Center for Underground Physics will be completed. The Center is preparing in earnest for a long journey to find Majorana fermions, which still show no trace of being discovered even after 80 years since it was first proposed theoretically. It also seeks to search for 'WIMPs', a strong candidate for dark matter whose property we know nothing about.



Eyes on Yemi! A visit to YemiLAB, Center of Attention of Researchers Worldwide

There are two special facilities in Mt. Yemi, located in Jeongseon-gun, Gangwon-do. One is the 'Handeok Iron Mine', which is the only iron mine in South Korea. The second facility, which is to be completed in 2022, will make this place even more special. This is the second underground laboratory of the IBS Underground Research Center, 'Yemi Lab'. Prior to the opening ceremony in October, we were able to visit Yemi Lab with the guidance of Senior Engineer PARK Kang-Soon.

"The IBS facility has tunnels that run in straight lines, so there's no risk of getting lost. However, the tunnels on the mine's side are complex as it was made for mining iron ore. Make sure to follow the guide's instructions, and if, by any chance, you get lost on the mine's side, please turn back the way you came."

Before entering the laboratory construction site, I had to pick up a hard hat and safety boots, as well as long-sleeved clothes and a dust mask for safety. I also had to receive thorough safety training as the construction work was still in the finishing stages.

The laboratory started off with an elevator – a high-speed elevator with a speed of 4m/s, moving four times faster than a regular elevator in apartment buildings. The reason for installing such a high-speed elevator is simple: it must move through a 600-meter-long vertical tunnel. Since Lotte Tower in Jamsil, Seoul, the tallest building in Korea, is 555 meters tall, taking this elevator is akin to traveling down deeper than the world's fifth tallest building.

"The deep vertical depth allows even the facility itself to be used for experiments. An example would be a free fall experiment. We have already received a request for cooperation from the National Aeronautics and Space Administration (NASA), saying they want to study the reaction of living organisms in free fall."

Scientific research takes place in a variety of unexpected places. All facilities that have been built might as well be made available for research, except I'd never suspected that even an elevator could play such a role.

Senior Engineer Park is in charge of the construction process of the YemiLab. To this end, he transferred from a research position to an engineering position. After getting off the elevator, he shared with me a range of stories of what had transpired when building the laboratory as we walked through the 782-meter-long tunnel leading up to the laboratory area.

"The closer the lab is to completion, the more convinced I am that this is an area made for research. The natural conditions here are far superior to those at other underground laboratories around the world."

The process of building the underground laboratory is unique in itself. Going deeper underground helps to reduce the cosmic ray* effect to the greatest extent possible. But in order to go deep underground, you have to fight the "water" underground.

"Usually, when underground tunnels are constructed, over 200 tons of groundwater is produced per hour, so disposing of this much water during construction is quite challenging. However, when the tunnel was being dug for the YemiLab, only about 3 to 4 tons of water was emitted per hour, which made our job somewhat easier."

The level of radiation emitted from the tunnel itself is also significantly lower than that at other laboratories. For example, it is about 100 times lower compared to Japan's Kamioka Observatory. Park praised the site as "a good place for research facilities to be built in many aspects."

1. Elevator for going down to the underground laboratory. It is 4 times faster than typical apartment elevators. **2.** The place that indicates the beginning of YemiLab is marked with a yellow sign for visibility in the dark mine. **3.** A neutrino detector will be installed in the LSC cavity, which has a diameter of 20 m and a height of 28 m. **4.** The AMoRE experiment team was already installing dust shields and installing equipment while the construction was in the finishing phase. **5.** IBS also built a dormitory for researchers after consultation with Jeongseon-gun. **6.** The tunnel leading to the underground laboratory is equipped with complex systems for electricity and ventilation. **7.** Senior Engineer PARK Kang-Soon provided a guided tour of the YemiLab.

Listening to his chronicles about the development of finished concrete (shotcrete) formulated to emit as little radiation as possible, an electrical facility that can provide up to 2000kW, and a special ventilation system for an underground tunnel, the 782 meters journey felt a bit short.

The full-scale research facility begins with a huge cavity where the Liquid Scintillation Counter (LSC) will be installed. The LSC is a massive cavity with a diameter of 20 meters and a height of 20 meters (28 meters including the upper dome), where a neutrino detector will be installed. An adjacent space is available for the installation of an accelerator. The closer the accelerator and the detector are, the higher the probability of finding the target neutrino becomes.

After passing through the LSC cavity, we arrived at a space for underground experiments. The most important spaces are the AMoRE lab, which aims to verify the phenomenon of neutrinoless double beta decay, and the COSINE lab, which explores the dark matter candidate WIMP. The AMoRE lab team was already in the midst of setting up a test facility, building a device that can provide shielding from external radiation, and installing a part of a detector.

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After traveling 600 meters down vertically by elevator and walking further down along a inclined ramp, we reached a depth of 1000 meters deep underground. This means we delved even deeper than the height of Mt. Yemi itself, which is 998 meters above sea level. The facility was built under the leadership of the Center for Underground Physics, and various institutions such as Kyungpook National University, the Korea Meteorological Administration, the Korea Institute of Geoscience and Mineral Resources, and the National Institute for Mathematical Sciences are planning to conduct diverse studies on topics such as earthquakes, strata, and bedrock conditions, which cannot be done above ground.

"Being 1000m underground means being surrounded by an environment that can bring fresh inspiration to researchers. The sheer size of the YemiLab is the 6th largest in the world. We have no doubt diverse studies that will surprise the world will come out of it. The value of the YemiLab is already being recognized by researchers. Even before its completion, many have reached out to tell us that they're interested in conducting joint research with us here. Only the best researchers will be able to work with the YemiLab."

Senior Engineer Park displayed a look of undeniable pride on his face. I was also filled with expectations that in just a few years, the lab would indeed produce outcomes that would take the world by surprise. We wish the researchers working with the YemiLab the best of luck. ibs

Cosmic ray*

Earth is constantly being bombarded by particles from space. This noise obscures the microscopic signals of the particles that the researchers are looking for.

There and Not There: The Neutrino's Journey?

YemiLab is preparing for an opening ceremony in October. The day in July when we visited the YemiLab for live coverage, we did not expect much since we were told that the site was still under construction. Because we didn't expect there to be any experimental equipment in the dusty construction site environment, which would negatively impact the precision. However, it appears we have underestimated the enthusiasm of Korean scientists. This is the story of the AMoRE team.

AMoRE laboratory in YemiLab. The AMoRE team, led by Director KIM Yeongduk of the Center for Underground Physics, is trying to prove that the neutrino is a Majorana particle by observing the neutrinoless double beta decay phenomenon.

The Center for Underground Physics is conducting two experiments within a broad framework. The AMoRE team, led by Director KIM Yeongduk, to observe the neutrinoless double beta decay phenomenon using molybdenum (Mo) isotopes (stay with me here; I promise to explain more soon). The COSINE team (named after an observation that exhibited periodicity), led by Associate Director LEE Hyunsoo, uses sodium iodide (NaI) to explore a dark matter candidate, WIMP (Go to Part 3 for more information about the COSINE team).

Unlike the other spaces in the tunnel that remained empty, the AMoRE laboratory was being already being prepared for the AMoRE-II experiment, with temporary doors and radiation shields installed. It also had the air conditioner running in contrast to the space outside the hall, which was exceptionally warm due to geothermal heat. What's even more surprising was that mobile phones and the Internet were operational even at 1,000 meters underground. Inside a building that looked like it has been assembled from containers, researchers were doing something with a black box. When asked what they were doing, they replied they were using a "dark box" (which can completely block light from the outside) to test the main devices that go into the muon detector.

Inside the building lay the key to the AMoRE-II experiment, a detector and a radiation shielding structure surrounding the detector. The goal of the research team is to embark on the AMoRE-II experiment in earnest here by the end of the year.

To understand the AMoRE experiment, it is necessary to understand the basic particles that make up the universe. Most people may think of atoms, but I'm talking about an even smaller and more fundamental elementary particle.

When you break an object into infinitely small pieces, you arrive at the atoms comprising that object. Atoms consist of a nucleus and electrons. Atomic nuclei are made of protons and neutrons, which are composed of elementary particles commonly known as "quarks". Thanks to untiring research by scientists, we now know that there are many types of fundamental particles. Quarks come in six flavors: up, down, charm, strange, top, and bottom. Electrons, muons, taus, and (electron-, muon-, and tau-) neutrinos are also some of the fundamental particles that make up matter.

These particles are collectively called “fermions”. Different particles are created depending on how fermions are combined and what force they use. The particle that transmits the force required by fermions is a boson: there are gluons, photons, and W and Z bosons. The Higgs boson, the subject of the 2013 Nobel Prize in Physics, was the last boson to complete the Standard Model theory, which is that bosons carry an appropriate force to combine fermions, which then become atoms as we know them.

In addition to the already discovered particles, there are several particles that exist theoretically but have not yet been found. An example is the Majorana fermion proposed by Italian physicist Ettore Majorana (1906 – missing). Originally a student of mathematics, Majorana discovered a fermion that is both a particle and an antiparticle while researching the “Dirac equation”, which integrates the special theory of relativity and quantum mechanics.

“A particle and an antiparticle” sound oxymoronic as a hot iced Americano. The Dirac equation was originally created to describe the motion of electrons, and the existence of “positrons” was discovered thanks to the equation. A positron is a particle that is identical to an electron except with the opposite electrical charge. Hence, electrons are particles, and positrons are antiparticles. A Majorana fermion must be electrically neutral because it is both a particle and its own antiparticle at the same time.

Either fortunately or unfortunately, Majorana believed this fermion was not a completely new particle but an already known particle – a “neutrino”. Neutrinos are electrically neutral and met many of the requirements that Majorana had envisioned (i.e., light mass). Since Majorana’s proposal in 1937, scientists have searched for Majorana fermions, but in more than 80 years, no one has discovered them. By this point, you might be getting a sense of what the AMoRE team is up to.

Elementary particles in the standard model

fermion		boson	
quark	lepton	gauge boson	scalar boson
up(u)	electron(e)	gluon(g)	Higgs(H)
down(d)	muon(μ)		
charm(c)	tau(τ)	photon(γ)	
strange(s)	electron neutrino(νe)	W	
top(t)	muon neutrino(νμ)		
bottom(b)	tau neutrino(ντ)	Z	


1

Even designing an experiment for the Majorana fermion, which is already a conundrum in itself, is challenging. You must first observe the phenomenon of the disappearance of particles and then confirm whether the disappearance was actually caused by matter that is both a particle and an antiparticle. The AMoRE team is looking for clues within the framework of “neutrinoless double beta decay”.

Isotopes are elements that have the same number of protons (atomic number) but different masses because of a different number of neutrons in the nucleus. For example, oxygen, atomic number 8, has 8 protons but has 2 to 18 neutrons, which gives it as many as 15 isotopes. There are stable isotopes that comfortably maintain the number of neutrons they innately have and unstable isotopes that alter the atomic nucleus to balance the ratio of neutrons and protons. Oxygen is stable when the number of neutrons is 8, 9, or 10, but is unstable when there are fewer or more neutrons, which causes it to lose or gain protons or neutrons to change the shape of the nucleus and become a stable atom. The process by which unstable isotopes become stable isotopes is called “decay”.

Beta decay is one of the ways in which isotopes decay – when a proton becomes a neutron, or a neutron becomes a proton. For example, if a positively charged proton undergoes beta decay, it releases an electrically neutral neutron, a positively charged positron, and a neutrino. Then, what can we say about double beta decay? Here, a decay occurs twice, resulting in double the output: two neutrons, two positrons, and two neutrinos. Double beta decay

1. Researchers test key detector components using a dark box. **2.** The barrier behind which the detector will be installed. In order to block not only cosmic radiation but also radiation from the environment, a thick shielding material measuring several tens of centimeters thick was set up as a barrier. **3.** Research Fellow LEE Moo-Hyun explains the AMoRE experiment at the Daejeon Institute. The detector will be manufactured at the Daejeon headquarters and installed at the YemiLab as early as the end of this year. The first observation data will be collected in earnest starting next year. **4.** With the help of Senior Engineer PARK Kang-Soon, we were able to tour YemiLab. A dustproof facility was installed next to the detector to prevent contamination while preparing for the experiment.

in which two neutrinos are emitted has been found in several isotopes, but since beta decay must occur simultaneously, even the shortest half-life is more than 1018 years.

It's about time to bring up Majorana fermions again. If a neutrino is a Majorana fermion, it would be both a neutrino and an anti-neutrino. In this case, it becomes possible for a neutrino to be absorbed and emitted within an atomic nucleus, creating a neutrinoless double beta decay instead of one that would have originally produced two neutrinos.

In other words, if a neutrinoless double beta decay is observed, it will prove that neutrinos are Majorana fermions. After 85 years (as of 2022), Majorana's claim will be proven to be true, and like the LHC scientists who discovered the Higgs boson, such discovery will stand a strong chance of receiving the Nobel Prize in Physics.

The AMoRE team has been preparing step by step since 2015 to observe this phenomenon. They selected molybdenum-100 (^{100}Mo), which has the shortest half-life of any double beta decay, as the main experimental material. Molybdenum 98 (^{98}Mo) would be a stable isotope in its natural state, but the AMoRE study uses expensive molybdenum, which is ^{100}Mo concentrated to about 95%. They cultivated high-purity crystals themselves with lithium molybdenum to create detectors. After creating five detectors with a weight of 1.9 kg to conduct a pilot experiment, the team launched the full-scale AMoRE 1 experiment in 2020. The Y2L lab in Yangyang, Korea, is using 18 detectors for the study, which is expected to be completed at the end of this year or early next year.

The YemiLab is conducting the AMoRE-II study. The scale of the study has grown noticeably, so the lab has divided the study into Stages 1 and 2. In Stage 1, which will be conducted with the launch of the YemiLab, they will experiment with about 30 kg of crystals. For use in detectors, lithium molybdenum crystals are being cultivated in a lab in the Daejeon headquarters and another in Russia. 178 kg will be used in Stage 2.

The reason for continuing to scale up the size is to increase the probability of observing the desired response. A double beta decay normally produces two neutrinos. Between these reactions, the very rare neutrino-free reaction must be captured. Researcher Moo-Hyun LEE explained, "The probability of ^{100}Mo atoms undergoing a double beta decay without neutrinos is extremely low as it is typically expected to take more than 10^{26} years," adding "the more molybdenum crystals there are, the easier it would be to detect the desired response."

The AMoRE project is just getting started. Hopes are high among the research team as it has succeeded in securing 100 kg of ^{100}Mo isotopes as planned, and the YemiLab offers an excellent research environment. Once closed, the detector facility situated 1000 meters underground will not be reopened unless there is a specific issue to be addressed. We hope that the next time they open the door will be because of an outcome that will take the world by a surprise. ibs

WIMP
COSINE Project

We are
Investigating
Most important
Particles in the
Universe

'…on a mote of dust suspended in a sunbeam.'

Just before leaving the solar system, Voyager 1 took family portraits of the planets making up the solar system. After seeing the images, astrophysicist Carl Sagan called the Earth "a pale blue dot," describing humans on Earth as a species living "on a mote of dust suspended in a sunbeam".

From the perspective of the vast universe, humanity is infinitely minuscule. Humans have been continually exploring the universe since they began to ponder their existence beyond basic survival. Nevertheless, what we have discovered so far is only a nanoscopic fraction of what is out there, just like the human race seen from space. Humanity is perpetually knocking on the doors of unknown territory, and unraveling the identity of dark matter is one of its many challenges.

Dark matter is "something" that accounts for about 25% of the total mass of the universe, but its identity is still unknown. Although it is a type

ESA

The Bullet Cluster is a prime example of the cosmological feature that hints at the existence of dark matter. The pink area is an X-ray image of the material produced by the collision. The blue part indicates the gravitational lensing effect. If there was no dark matter, the pink and blue regions would have coincided. An unobserved 'something' caused a gravitational effect, resulting in a weak gravitational lensing effect.

of matter that is (presumed to be) prevalent in the universe, it cannot but be still expressed as "something" that we know nothing about, because it has not even been observed, as well as being completely intangible. However, evidence of the existence of this "something" has been steadily discovered since the 1930s, starting with the speed of galaxy clusters' motion.

There are hundreds of billions of galaxies in the universe. They may appear to be scattered randomly at first glance but are arranged according to their own rules. Just as the planets in the solar system revolve around a large center of mass called the Sun, so do galaxies around a common center of mass. Swiss astrophysicist Fritz Zwicky (1898–1974) discovered that these galaxies move much faster than mathematically calculated while observing their velocities, meaning the actual mass of the galaxy was greater than was known. In other words, he shared a glimpse into the possibility of a "something" with a certain mass, which has yet to be observed.

Zwicky's discovery led to research that a similar phenomenon is occurring in the stars belonging to galaxies. In galaxies, countless stars orbit around the center of the galaxy. According to the mass distribution of galaxies observed so far, the closer to the center of the galaxy, the faster the orbital speed, and the farther from the center, the slower the orbital speed should be. However (!), as you may have expected, the actual observations differed from the calculations: the velocity remained the same even as the stars moved away from the center. As American astronomer Vera Rubin (1928–2016) published her findings on this phenomenon, she started a full-on debate about dark matter. Now scientists had to make a choice: either acknowledge that there is an unobservable and unidentifiable "something" or make a completely new discovery that would defy the existing law of gravity.

This image of Stephan's Quintet was photographed by the James Webb Telescope, which was launched in December 2021 and has been operational since 2022. Zwicky was the first to suggest the possibility of dark matter by observing the speed at which galaxies move.

NASA/ESA/CSA/STScI

Evidence of that "something" has kept popping up with advances made in space observation technology. For example, the separation of visible and invisible masses in bullet-shaped galaxy clusters can be interpreted as the separation of dark matter from the visible matter due to cluster collisions.

In any case, the continuing evidence has led scientists to realize that it is necessary to uncover the identity of this "something" that has not yet been captured in humankind's exploration rather than change the well-established law of gravity. They coined the term "dark matter" by adding the word "dark" to mean unobserved to the "something" and began to study this matter in earnest.

The COSINE team, led by Associate Director LEE Hyunsoo of the Center for Underground Physics, is searching for one of these dark matter candidates, WIMPs. WIMPs are one of the main candidates for dark matter, along with axions and inactive neutrinos. The three substances have in common that they exist theoretically but have never been detected in practice. The inactive neutrino is the fourth neutrino candidate after the three known flavors of neutrinos (electron, muon, and tau) and is known to have a greater mass than the other three neutrinos (in theory). An axion is a particle proposed in the process of explaining the interaction of fundamental particles. A lot of axions are created during the creation of the universe according to their proposed creation process.

WIMPs, the subject of the COSINE team's primary focus, stands for "weakly interacting massive particles". They are speculated to exist to this day without increasing in numbers or decaying since their creation at the moment the universe came into existence. They are also well-known as particles proposed by the late Dr. Benjamin Whisoh LEE (1935-1977), together with Dr. Steven WEINBERG, an influential particle physicist and winner of the 1979 Nobel Prize in Physics.

The definition of WIMP is in line with the explanation of dark matter (26.8%), which accounts for most of the matter in the universe. For reference, only 4.9% of matter in the universe is known to us, and the remaining 68.3% is dark energy.

A view of the COSINE detector.

The history of WIMPs goes back to 1977 when LEE and Weinberg published research[1] on the minimum mass of an imaginary particle that is heavy and electrically neutral. The two scientists noted in their paper that the gravitational field of these heavy neutrinos would provide a plausible mechanism for the shrinking universe. In other words, if there is some particle in theory that has not yet been observed, and if the physical properties of this particle can be revealed, information related to the origin and obliteration of the universe could be obtained. It is in line with the explanation of dark matter (26.8%), which accounts for most of the cosmic matter. For reference, only 4.9% of the matter in the universe is known, and the remaining 68.3% is dark energy.

For this reason, WIMPs are considered a strong dark matter candidate. At first, no one had the courage to even attempt to observe them as they hardly interact with matter. However, Italy's Gran Sasso National Laboratory opened the door of possibility to the discovery of WIMPs by capturing their signal (hereafter referred to as the DAMA project) in the late 1990s. Since then, scientists around the world have continued the quest.

The test method is as follows: if WIMPs are real and they are indeed dark matter, then they would move at 220 km/s, in theory, the same speed at which the solar system orbits the galaxy. In addition, since the Earth revolves around the Sun at 30 km/s, a relative difference in speed of 60 km/s occurs depending on whether the direction of the Earth's orbit is the same as that of the Sun. The DAMA project claims that this seasonal change made it possible to observe WIMPs.

The only problem is that even decades later, no other research group has achieved the same

1. Y2L located in Yangyang, Gangwon-do. 2. LEE Hyun Su, Associate Director of the Center for Underground Physics. He is in charge of the COSINE Project.

results. For this reason, the DAMA study is also a key research subject for scientists exploring the potential candidacy of WIMPs as dark matter. The COSINE team uses sodium iodide (NaI), the same material that DAMA tested in the past. Based on the observation results that exhibit periodicity according to season, the team was named COSINE.

The detection of WIMPs starts with the manufacture of detectors, which are made with pure NaI crystals. According to a recently published study, WIMPs are so rarely detected as one or fewer responses per ton detector a year, meaning as many high-purity detectors with extremely reduced background radiation are necessary to be able to detect any response at all. The COSINE-100 experiment, which has been conducted at the Y2L lab in Yangyang, Korea. Since 2016, the team has grown crystals up to about 10 kg and mobilized as much as 100 kg of these crystals. The results of their study mobilizing both observation and statistical methods have been published in major journals such as Nature and Physical Review Letters.

In sum, WIMPs as traditional dark matter have not been observed in contrast to the claims made by DAMA, but another possibility remains. A researcher from the COSINE team has said, "The way we look at the results of DAMA now has significantly shifted from the way we looked at them 20 years ago. Among the scientists studying dark matter, it is accepted that what DAMA observed was not WIMPs as standard dark matter. But it is clear that the signals change with the seasons."

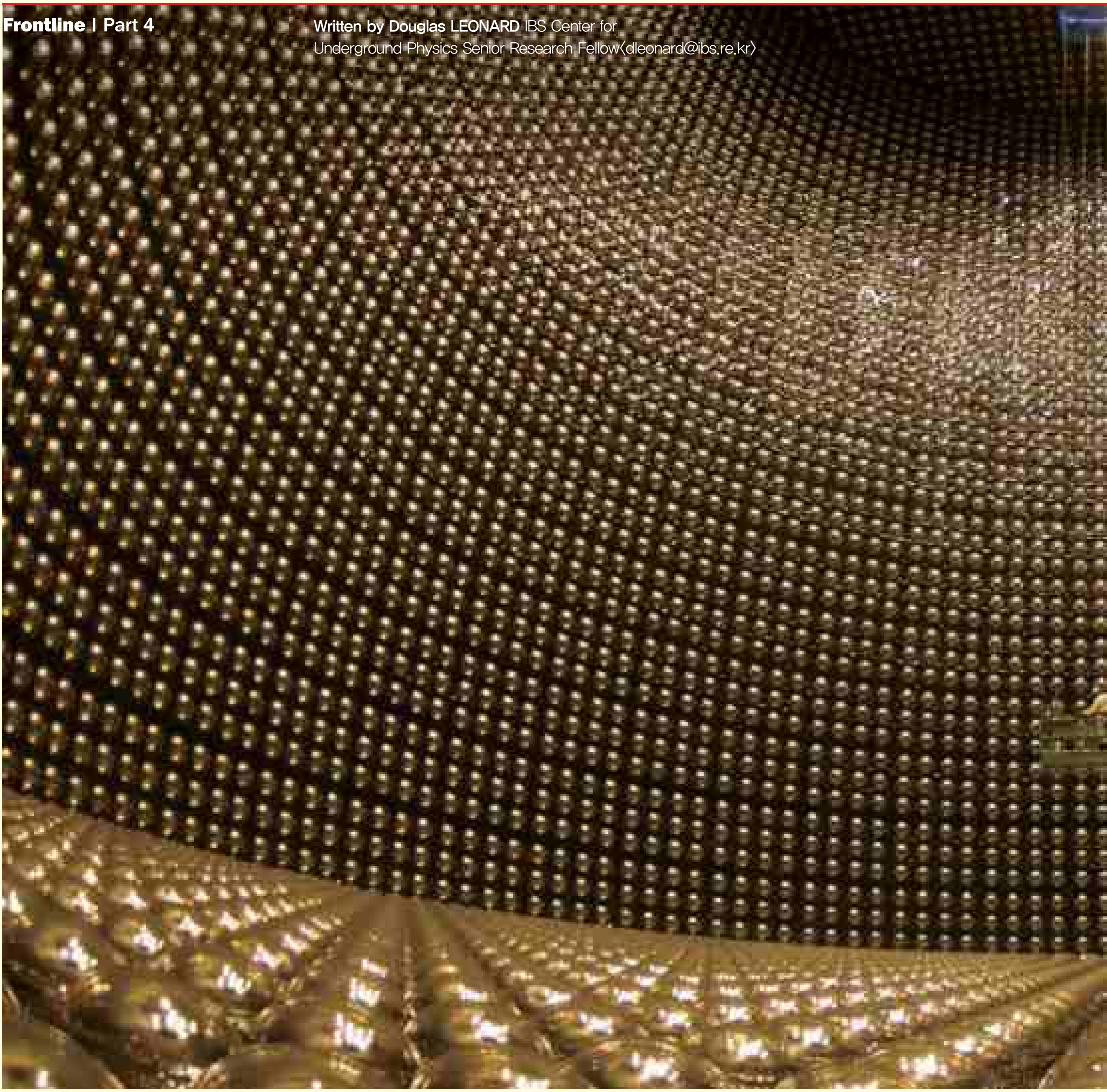
The YemiLab marks the beginning of the search for new WIMP candidates. The COSINE-200 project, which will take place at the YemiLab, increased the amount of NaI crystals going into the detector to double the previous amount at 200 kg. The key to this project is to reduce the background radiation of the detector by three times or more. Researchers at the Institute for Basic Science are accumulating know-how as they are directly engaged in developing core technologies ranging from powder purification to detector manufacturing using crystal growth. The technology development is set to be completed within this year, and full-scale observation experiments will begin with the launch of the YemiLab.

The ultimate goal of the COSINE-200 experiment is to explore the possibility of the next-generation COSINE-1t study as well as the complete verification of the DAMA experiment. The YemiLab was designed to be able to perform 1t-class experiments, which are essential to boost the accuracy of the extremely low-probability experiment. Through COSINE-200, the lab aims to secure the world's best NaI detector technology and validate its capacity to lead the world by competing with the world's leading high-performance dark matter detectors, surpassing DAMA.

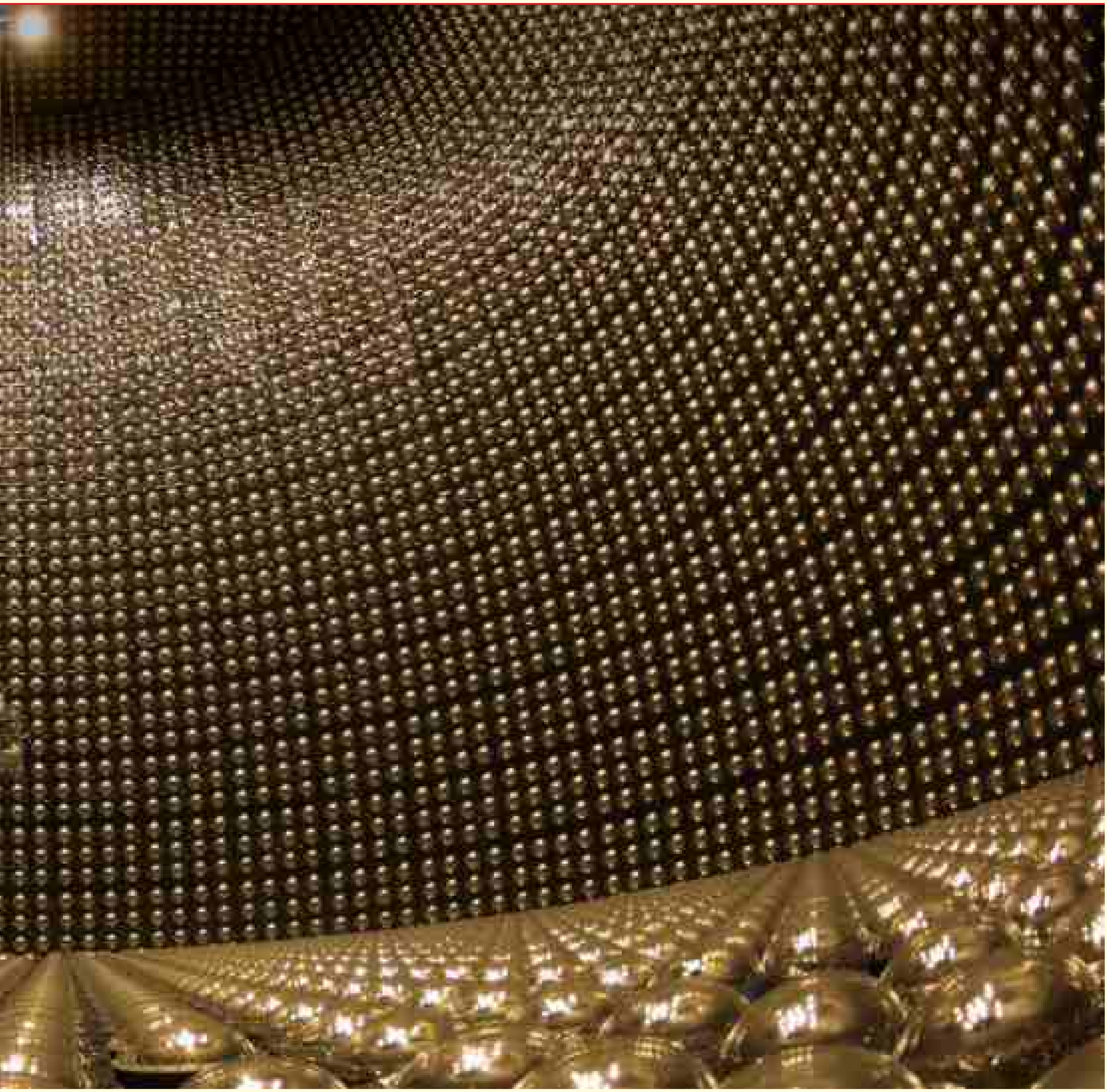
Associate Director LEE noted the following regarding future possibilities: "So far, domestic dark matter research has focused on the verification of DAMA signals. With COSINE-200, however, we aim to investigate the potential of developing the world's best-performing dark matter search detector, transcending DAMA. This experiment, and the subsequent COSINE-1t, will help the Korean researchers develop detectors using home-grown technology to explore a new realm that humans have yet to observe. Just like Columbus, who discovered the new world by taking the road untraveled, we expect to be able to eventually observe dark matter signals by exploring areas that humanity has not yet been able to observe." ibs

1) Cosmological Lower Bound on Heavy-Neutrino Masses(Physical Review Letters, 1977).

Written by Douglas LEONARD IBS Center for Underground Physics Senior Research Fellow〈dleonard@ibs.re.kr〉



Bigger and Deeper: Underground Labs Around the World



Interior of Kamiokande neutrino detector in Kamioka, Japan.

Physics and other scientific research by nature advance human knowledge by pushing the extremes of our abilities to observe, and thus understand, the physical world. These extremes come in many forms. Observations are pushed to larger distances across the cosmos and to smaller subatomic scales. Experimental apparatuses are advanced to larger sizes and to higher energies. Recently many experiments have also been pushed in another direction, downward, to greater depths underground. This is largely driven by searches for rare-event physics interactions, interactions which that can create very rare and sometimes very subtle signals, generally by depositing very small amounts of energy in high-sensitivity detectors. These interactions come in several forms, relating to a range of physics topics, but the common point is that they are very rare, requiring one to look for interactions in large amounts of material for long times in order to see enough events to conclusively observe something new.

The difficulty with such experiments is that their sensitivity is limited by much more-common "noise" or "background" events generated by a barrage of mundane interactions. It's like trying to listen for a fly in a rock concert. You might be able to hear a loud human-sized fly, but there will be a the quietest fly that you can possibly hear. If you're trying to prove if a particularly unusual sound (or signal) is present in a loud environment, you will only be able to set a limit, to say that a sound of that type that is louder than, for example, 80 dB doesn't exist there. While limits do improve our knowledge of what is, or rather isn't, in the world, to set better limits, or improve the chance of a discovery, we need a quieter environment. This brings us to underground laboratories.

Several sources of backgrounds exist for rare-event experiments, but most of this is in the form of radiation arising from either inside the detector itself, including any of its parts, or from the external environment. The reason to go underground relates to the latter. Near the surface of the Earth, there are many high-energy muons raining down through the air and into all matter. These charged particles, related to electrons, are created when cosmogenic radiation strikes the atmosphere. They can deposit energy in rare-event detectors, creating spurious signals. While they do pass through matter, their flux is attenuated, like light through sunglasses. The only practical way to truly reduce the muon interactions in the detectors is to place the experiments deep underground where they are shielded from the muon background.

One of the first significant underground physics experiments was the Davis experiment. In 1965 Ray Davis used a tank containing chlorine atoms in a cavern at the 4850 level (4,850 ft deep, or about 1,500 meters) of the Homestake Gold Mine, in

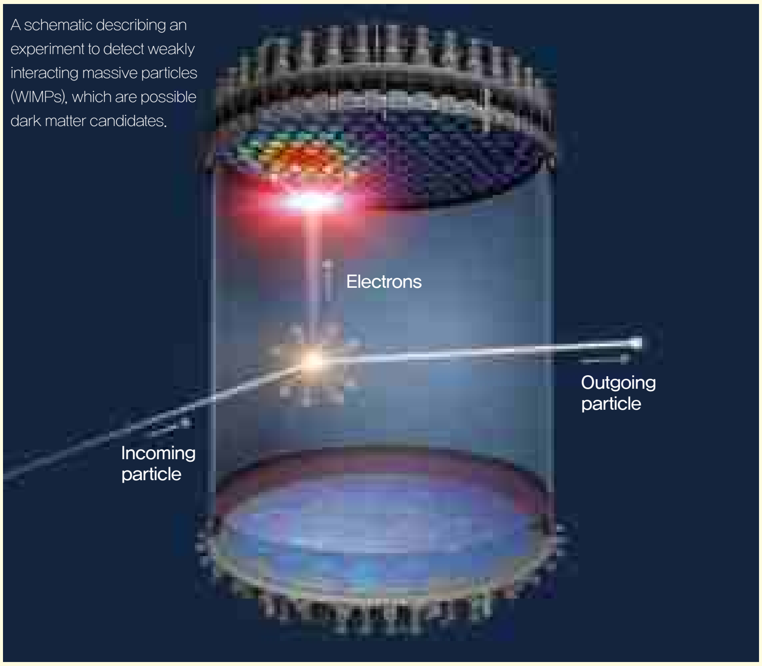
The DAMA/LIBRA experiment at the Gran Sasso National Laboratory (LNGS) in Italy produced a claimed observation of dark matter using a NaI detector. The results of this study have inspired many scientists, including those at the Center for Underground Physics, who are now conducting experiments for cross-validation. This picture depicts LNGS as seen from the outside.

TQB1(위키미디어 커먼스)

South Dakota, USA, to search for interactions of neutrinos, a type of subatomic particle, produced in the sun. The neutrinos converted the chlorine atoms into 37Ar (argon-37, an isotope of argon) atoms, which were detected by ambitious chemical separation techniques. This experiment observed about a third fewer neutrinos than expected, leading to a campaign of new underground neutrino experiments and to our new understanding that neutrinos "oscillate," ie that the three known "flavors" (types) of neutrinos essentially change from one flavor to another as they move (in a quantum sense, they exist as all three flavors at once). The experiment site has since been revived and incorporated into the Sandford Underground Research Facility (SURF) housing multiple underground experiments.

The SAGE and GALLEX experiments in the Baksan Neutrino Observatory in Russia and in the Gran Sasso National Laboratory (LNGS) in Italy, respectively, confirmed the neutrino deficit in the early 1990's. Further umderground experiments resulted in new understanding that neutrinos "oscillate," i.e. that the three known "flavors" (types) of neutrinos essentially change from one flavor to another as they move (in a quantum sense, they exist as all three flavors at once). The Super-Kamiokande water-Cherenkov detector in the Kamioka mine in Japan and the Sudbury Neutrino Observatory (heavy-water-Cherenkov detector) in Canada are credited, via a Nobel Prize, with the first direct verification of neutrino oscillations, detecting neutrinos of both solar and atmospheric origin. In parallel, properties of neutrinos and neutrino oscillations from various sources were observed in detail in a number of underground experiments such as LSND in Los Alamos, New Mexico, KamLAND, and T2K in Kamioka, and Borexino at LNGS, among many others. These provided precision measurements of oscillation properties from a variety of sources, including from well-controlled man-made accelerators and reactor sources, and even provided still-unresolved hints of the existence of a fourth neutrino flavor known as sterile neutrinos.

Meanwhile, underground labs were proving useful for other rare-decay searches. In particular searches for neutrinoless double-beta decay and dark matter have evolved in scale over a similar timeframe, turning many of the mentioned sites (particularly Kamioka, LNGS, SNOLab, and SURF, along with the CJPL/CJPL-II labs in China) into large underground hubs for a broad range of physics research.



A schematic describing an experiment to detect weakly interacting massive particles (WIMPs), which are possible dark matter candidates.

LUX-ZEPLIN Collaboration, SLAC National Accelerator Laboratory

Human knowledge advances through observation and fundamental understanding of the world. Scientists have been building bigger and more powerful equipment to advance our knowledge. And now we are going "deeper" underground in a search for better knowledge.

Dark matter describes a number of types of unobserved particles that are theorized to make up some of the mass of the universe and are motivated by a number of observations, including cosmological evidence of missing mass. Almost by definition, dark matter is difficult to observe, involving rare and subtle interactions. One type of dark matter particle, WIMPs, can be observed by detecting energy imparted by rare collisions with atomic nuclei. Several experiments have been built and operated in many underground labs across the world to look for these interactions with ever-increasing sensitivity. The SURF lab has a central place in this history as well, hosting the first such experiment using a germanium spectrometer as well as the LUX and LZ liquid-xenon-based experiments (both at the Davis cavern) progressively boasting among the highest sensitivities in the world for certain theoretical model assumptions. But they were certainly not alone, with strong competition from the Xenon collaboration/experiments at LNGS and the CDEX (germanium detectors) and PandaX (using liquid xenon) experiments at the CJPL/CJPL-II labs in China, as well as a number of distinctive experiments in Kamioka, Boulby, and elsewhere. The DAMA/Libra experiment, also at LNGS, even has claimed an observation of dark matter in a different material, sodium-iodide, a claim which is now under scrutiny by other experiments including the COSINE experiment at the Center for Underground Physics and the ANAIS experiment at the LSC lab in Spain.

Next-generation underground projects continue to grow in size and capability. Underground physics experiments produce a range of opportunities for new discoveries, and of course, for new questions.

The Italian scientist Ettore Majorana proposed a type of fermion that can be both a particle and an antiparticle at the same time. Scientists around the world are constantly making new detectors to look for signals to prove that neutrinos are Majorana fermions.

Neutrinoless double-beta decay is a theorized type of radioactive decay that would have stark implications for our understanding of matter and neutrinos in particular. Specifically, its existence would impact understanding of neutrino oscillations and imply that neutrinos are "Majorana" particles, meaning they are their own antiparticles. Beta decay itself is a very common form of radioactive decay of atoms that occurs in everything around us, emitting an electron and a neutrino. In fact, aside from muons, this and similar decays form the majority of the background signals to rare event experiments. In neutrinoless double beta decay, the Majorana neutrino nature effectively allows the two neutrinos that would be emitted to annihilate as virtual particles, transferring all energy to the emitted electrons. Because of the background concern, this can only be easily observed in specific nuclei which cannot undergo two separate beta decays in sequence. Of course, underground environments are required to reach high sensitivity. Many experiments have been performed using several isotopes. EXO-200 at WIPP in New Mexico, and KamLAND-Zen at Kamioka set limits using xenon-based detectors based on very different technologies. The GERDA experiment at LNGS has used high-purity germanium detectors, and the CUORE (LNGS) and SNO+ (SNOLAB) experiments to search for the decay of ^{130}Te (tellurium -130), also with very different techniques. Meanwhile, at the Modane Underground Lab (LSM) in France, the CUPID-Mo experiment searches for decays in ^{100}Mo (molybdenum-100), and the SuperNEMO detector can observe decays from multiple materials. The full list is too long to list, but the diversity of both isotopes and technology are is important for pushing the limits and interpreting and confirming future observations.

While being underground reduces muon backgrounds, common to all of these projects is the need to also remove potential backgrounds from radioactive decays mentioned above. Since these decays occur in matter all around us, this is done primarily by finding or creating ultra-high-purity materials to construct the detectors from. This effort has almost become a research field in and of itself, as, by design, it requires detection technologies of similar sensitivity to those of the physics

Detectors at the Sudbury Neutrino Observatory, located at what is now SNOLAB in Ontario, Canada.

experiments themselves, creating a bit of a chicken-and-egg problem. Thus, most of the mentioned labs have underground detectors and other facilities devoted to this purpose. Particularly, high-purity germanium counters are found at facilities such as DURF in CJPL, BHUC at SURF, BUGS in Boulby, and a number of high sensitivity detectors are located at other labs, all used together with other detection and purification technologies to push radio-purity to new levels.

What started as a few scientists working on obscure projects in dark solitary places, has evolved into a field of research centered around common environmental and technological requirements, with a large focus on neutrino oscillations, neutrinoless double beta decay, and dark-matter searches. Other science endeavors involving nuclear astrophysics, gravitational wave physics, and even biology and quantum computing are finding common needs for these resources and environments. With new lab constructions and expansions, including CJPL-II, the new Stawell Underground Physics Laboratory in Australia, and Yemilab in Korea, next-generation underground projects continue to grow in size and capability. Notable examples include the massive DUNE project which will detect neutrinos at SURF from a beam created at Fermilab, the 260,000-tonne Hyper-K water-Cherenkov detector being constructed at Kamioka, tonne-scale neutrinoless double beta decay projects such as nEXO and LEGEND, next-generation dark matter experiments such as XLZD, and new exotic underground physics searches, all producing a range of opportunities for new discoveries, and of course, for new questions.

CI LEE Yeon Joo of the Planetary Atmospheres Group within the Center for Climate and Earth Science

The Scientist Who Chases After the First Rising Star at Dawn

In June 2022, the Institute for Basic Science (IBS) launched a new Pioneer Research Center (PRC) in the earth science field – 'The Pioneer Research Center for Climate and Earth Science'. The new PRC was established alongside its first research group, the 'Planetary Atmospheres Group'. Dr. LEE Yeon Joo (age 39), a researcher from the German Aerospace Center (DLR), was appointed as the CI (Chief Investigator) of this new Group.

When the Sun rises over the horizon and heralds a new day, there appears a morning star brighter than any other celestial body in the eastern sky. The star symbolizes a fresh new start and has long piqued scientists' curiosity. Dr. LEE Yeon Joo, Chief Investigator of the Planetary Atmospheres Group under the Pioneer Research Center for Climate and Earth Science, is one of them. Dr. LEE has long had a deep curiosity about the star and closely monitors her morning star.

A scientist who fell in love with the goddess of beauty

IBS Research met CI LEE at the IBS Headquarters in Daejeon in June. The Planetary Atmospheres Group, led by CI LEE, is the first research group of the new Pioneer Research Center for Climate and Earth Science. The IBS plans to gradually establish more research groups going forward.

CI LEE's group chose Venus as its first research subject. She has been interested in the planet since she received her degree. Why Venus? After all, there are many other planets in the solar system.

"My master's degree was in the Earth's atmosphere. When I was looking for schools to pursue my doctoral degree, I came across the Venus exploration missions. The fact that we know so little about this planet despite its close proximity to Earth intrigued me."

CI LEE has been pursuing Venus ever since. When she conducted her doctoral research at the Max Planck Institute for Solar System Research (MPS), she joined the team for the Venus Express, an exploration spacecraft for Venus launched by the European Space Agency (ESA) in 2005. She received a doctorate for her research while on the team. Then, she joined the team for Akatsuki, also known as Planet-C, a Venus exploration spacecraft launched by the Japan Aerospace Exploration Agency (JAXA) in 2010 to investigate the atmosphere of Venus. At that time, her research on the relationship between UV reflectivity and the latitudinal speed of Venus' atmosphere was recognized as an excellent research achievement by the American Astronomy Association (AAS).

CI LEE jumped at every opportunity to observe Venus and joined other planetary exploration teams. Spacecraft exploring space away from Earth fly closely by other planets on their way to their destinations. This helps them to gain speed in that they are attracted to each planet's gravitational pull and then leave that planet at a faster speed, using that planet as a sort of slingshot. This has the added benefit of allowing scientists to observe those planets as well as the destination object. The Voyager space probes transmitted massive amounts of data when they flew by

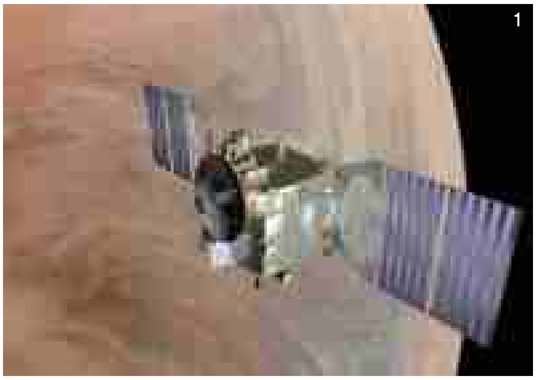
Jupiter and Saturn, and they both eventually left the solar system. CI LEE did not miss the chance of getting another glimpse of Venus by joining the BepiColombo project in 2015, which was jointly led by ESA and JAXA to explore Mercury. It is no exaggeration to say that she joined most of the well-known Venus exploration projects.

The goal is to build a CubeSat that can observe the planets of our solar system and put it into orbit.

Listening to her story, one might be curious about the projects CI LEE will launch at the IBS. Korea launched its first lunar orbiter on August 4, 2022, but does not have any plans to send one to Venus. Then, how will she continue to research Venus?

"You don't need to send an exploration spacecraft to study Venus. There are many ways of observing it."

Out of all the planets that can be observed from Earth, Venus is the third brightest object after the Sun and the Moon. At its brightest, Venus' magnitude is about -4.5, about 16 times brighter than Sirius, which is more luminous than any other visible star. You do not need to be good at finding stars to spot Venus. If you spot something bright in the sky in the West right after sunset or in the east right before sunrise, it is probably Venus. It is easy to spot but finding it during the day is impossible. As Venus' orbit is inside that of the Earth, it rises and sets along with the Sun, meaning that it is in the sky during the day. The Sun is so bright during the day that no heavenly body can be seen from Earth, and Venus is not an exception.



1. 1ESA's Venus Probe 'Venus Express', which was launched in 2005 and completed its mission in 2014. 2. Venus is similar in size to Earth, and as such it is said to be Earth's twin planet. (From left) Mercury, Venus, Earth, and Mars size comparison.

"My plan is to develop a CubeSat designed to explore Venus and put it into the Earth's orbit."

A CubeSat is a miniaturized satellite of only ten centimeters cubed. It was first devised for graduate students at Stanford University for educational purposes in 1999 and launched into space in 2003. This small satellite has many applications. It can be used to observe the ground, monitor illegal logging, or track wild animals, and so on. As for space exploration, it can be used as a communications relay during a spacecraft's journey. CubeSats provided relay communications from InSight, a Mars lander launched in 2018, to Earth during its landing on Mars. In September this year, a spacecraft will be intentionally made to collide with an asteroid, and the process will be relayed by a CubeSat.

CI LEE plans to observe Venus with a CubeSat fixed to face the planet.

"An exploration spacecraft, as it gets nearer to Venus, can observe a narrow range with high resolution. To better understand Venus, it is important to see how the planet as a whole is changing."

A CubeSat will be a good means to realize her plan. As it observes the planet from the outside of the Earth's atmosphere, the time of day is not a significant issue. If the miniature satellite can be put into a polar orbit that passes over the poles, Venus can be observed every 90 minutes.

If you observe Venus regularly, you will be able to understand how it changes in more detail. You can get more information from a video than a photo, anyway. A CubeSat is expected to help obtain meaningful data about immediate changes in Venus.

Astronomers focus on Venus

Venus has not had much appeal in Korea. Unlike the Moon, to which astronauts were sent, or Mars where manned explorations are likely in the near future, a manned exploration on Venus would be daunting. Data from Venus exploration spacecraft sent

Tracking changes in unidentified absorbers using data that only CubeSat can gather

by the U.S. and the Soviet Union in the 1960s revealed that its surface temperature is above 400℃. Its atmosphere is heavy with carbon dioxide, which is thought to create an extreme greenhouse effect. In the 1970s and 1980s, the Soviet spacecraft called Venera successfully touched down on Venus' surface. Venera 13 transmitted data for about 2 hours. Through the series of such explorations, we know that Venus' surface is completely dry.

The planet is now receiving more attention as new aspects of Venus have been released. The clouds of Venus are mostly made up of sulfuric acid, and there is an unknown absorber at the top level of the clouds. The absorber absorbs energy at near-ultraviolet and visible blue wavelengths. It was first observed about a century ago, and some particles have been proposed to make up the absorber.

"Changes in solar energy (UV) absorption would affect Venus' atmospheric circulation. There is a possibility that Venus' climate is changing as solar energy and atmospheric circulation have something to do with climate."

Climate change on the Earth is driven by solar energy. Where there is much solar energy, an updraft is created. Less solar energy creates a downdraft. Updrafts and downdrafts drive atmospheric circulation. Therefore, how much solar energy is absorbed or reflected depends on the atmospheric conditions on Earth. If there are thick clouds, for example, much of the solar energy will be reflected.

Then, what about Venus? It is always covered with thick clouds. Scientists are interested in the unknown absorber at the top of Venus.

"Solar reflectance changes according to the volume of the absorber. When observing Venus, you can find dark and light areas. The dark patches are where the absorber absorbs much UV, while the bright patches reflect much UV. What is the unknown object and why such a phenomenon occurs is the riddle we need to solve."

As there is much to be explored, countries around the world are announcing plans to send a space probe to Venus. Last year, ESA and NASA confirmed that they would do so. ESA is launching the EnVision spacecraft, and NASA decided to send DAVINCI+ and VERITAS. Russia unveiled its Venera-D mission in follow up to the Venera program completed in 1984. India is preparing for its Shukrayaan-1 mission to Venus. CI LEE at the IBS is preparing to consistently observe Venus with a CubeSat in line with those missions.

"When those space probes are observing Venus in its vicinity, we will observe the planet from Earth to investigate changes in Venus in more detail."

As the Center was just recently established, there are many things to do. First and foremost, she must hire a team of talented researchers to work with.

"We are looking for those who have a passion for space science research as well as a startup that will develop a CubeSat together with us. There is a lot of work to do."

CI LEE said that she is willing to visit not just research institutes at home and abroad but also universities to find the needed talents. ibs

Viewpoint 1

Written by JUNG Min-Kyung
Research Fellow at the Center for Viral Immunology, Korea Virus Research Institute〈mkjung@ibs.re.kr〉

The 1st anniversary of IBS Korea Virus Research Institute,

Why We Need to Conduct Basic Research on Viruses

"Coronavirus Infectious Disease-19 (COVID-19)," declared a pandemic in March 2020, has rapidly changed the world around us over the last two years. In this situation, the two key topics that were most important to the researchers in the field were: first, rapid vaccine development and dissemination, and second, the emergence of various mutants and breakthrough infection.

The Korea Virus Research Institute is led by CHOI Young Ki, the Director of the Center for Study of Emerging and Re-emerging Virus V (left) and SHIN Eui-Cheol, the Director of the Center for Viral Immunology (right).

LEE Su Hyoun

South Korea has efficiently responded to COVID-19 over the past two years by employing an effective quarantine system and having a high percentage of the population vaccinated. However, breakthrough infections have been rampant following the emergence of the Omicron variant at the end of last year. The pandemic situation changed rapidly, and we were blindsided by the successive emergence of new variants such as Alpha, Beta, Gamma, Delta, and Lambda. Omicron, which was first reported in November 2021, has far more mutations than its predecessor and an unprecedented level of transmission. The number of daily confirmed cases exceeded 600,000 in Korea in March 2022, and the number of confirmed cases in the vaccinated (breakthrough infections) also increased, raising skepticism over the effectiveness of vaccines.

Amid such a difficult situation, we realized that measures such as social distancing themselves are not enough to weather the storm. This is why research into the virus and viral immunity is vital to fundamentally address the COVID-19 breakthrough infection.

Rapid response to the pandemic would not have been possible without the preceding basic research. The experience and research of the SARS in 2003 and MERS in 2015 were helpful in understanding COVID-19. Indeed, it was possible to extensively use mRNA vaccines because their research had already been underway not just for antivirals but for cancer treatment.

Thanks to the basic research and development of mRNA vaccine technology, we were able to understand and respond to the virus faster and more efficiently. Still, it is regrettable that we have not been able to see greater contributions by Korean researchers to such development. Realizing the need for basic research in responding to new virus variants, the Korean government pushed ahead with the opening of the Korea Virus Research Institute (KVRI) in July 2021, led by Managing Director CHOI Young Ki.

The KVRI research teams quickly delved into the related study and produced meaningful outcomes in less than a year after opening. They found out that COVID-19 vaccine-induced memory T cells have strong immunity against not only early COVID-19 virus variants but also the Omicron variants. The result explains why vaccinated individuals do not develop severe symptoms after breakthrough infection. The KVRI has produced various research outcomes in basic viral research, showing that it will play a pivotal role in research in Korea and make valuable contributions against the next potential pandemic.

It doesn't end here, the mindset necessary to prepare for the next pandemic

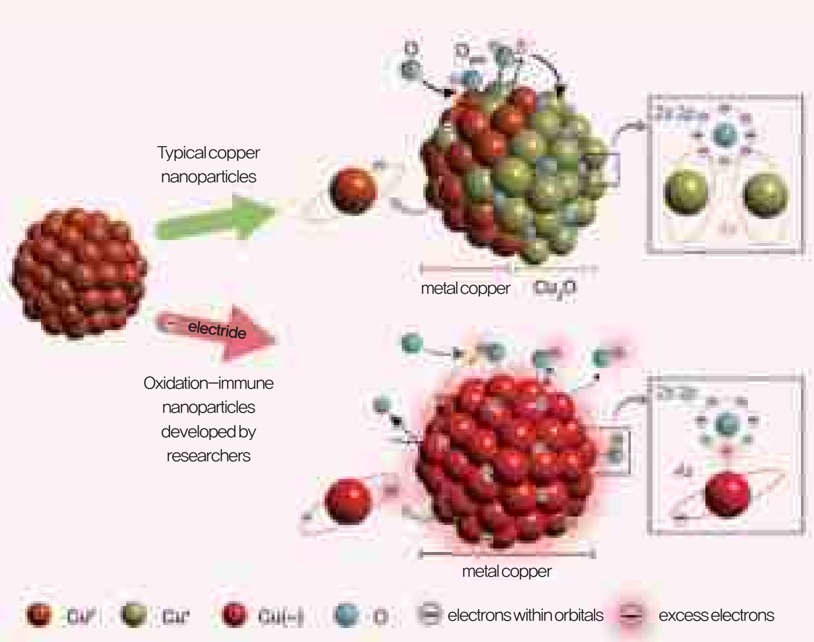
It is too early to announce the end of the COVID-19 pandemic. A mutant with greater transmissibility than the Omicron variant might emerge in the near future. Humanity may have to live with the virus, but if that is the case, we should be capable of putting it under control. No one can rule out the possibility that a totally novel virus could appear any time soon. That is why we should be ready for a new virus mutant.

On the occasion of the KVRI's first anniversary, we hope that the institute will be able to build sufficient research capabilities to become an essential hub for viral research, making significant contributions not only to health and national security for Korea but also to global health. ibs

Center for Integrated Nanostructure Physics

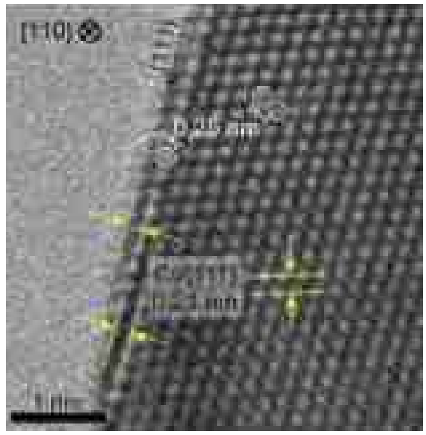
Development of Copper Nanoparticles that Never Rust in the Air

Comparison of Copper Nanoparticles



The oxidation process of typical copper nanoparticles (top) and oxidation–immune copper nanoparticles with electrons accumulated on the surface (bottom).

Metals usually oxidize and rust when exposed to air. This is a natural phenomenon that occurs when metal atoms and oxygen atoms in the air combine on the surface. When the metal is oxidized, its properties as metal are lost, and in severe cases, it cannot be used as a material. Therefore, great efforts have been made to prevent metal oxidation, such as by plating the metal surface or using the cathodic protection* method. Until recently, metal nanoparticles have been widely used in various fields such as materials, catalysts, and sensors, but there has been no technology that completely prevents their oxidation. Research Fellow KIM Seong–Woong from the IBS Center for Nanostructure Physics has developed copper nanoparticles that do not oxidize in the air even without any surface treatment. Copper nanoparticles have the highest utility among metal nanoparticles, but have the disadvantage of being easily oxidized. The research team focused on the new material called 'electride', which has been studied



Transmission electron microscopy image of the surface of copper nanoparticles exposed to air.

for many years to overcome the shortcomings of and improve the utilization of copper nanoparticles.

When copper nanoparticles are formed on an electride that contains a high concentration of electrons, a large number of electrons are transferred from the electride to the copper nanoparticles. These excess electrons are accumulated on the surface of the copper nanoparticles. It was observed that only these excess electrons on the surface react with oxygen in the air so that the underlying copper nanoparticles do not oxidize. Above all, it was confirmed that copper nanoparticles did not undergo any oxidation even when exposed to air for more than several months, and the metallicity of copper remained intact. By applying this phenomenon, the research group succeeded in synthesizing oxidation-immune silver nanoparticles as well.

Furthermore, the group developed a process for mass-producing these oxidation-immune copper nanoparticles. A large number of these nanoparticles can be easily produced by placing electride in a liquid containing dissolved copper metal ions and facilitating a reaction. The process using these electrides can be applied to the synthesis of other metal nanoparticles and is expected to be frequently used for the production and application of metal nanoparticles that do not require surface modification.

Research Fellow Kim who led the study explained, "Copper nanoparticles that are not oxidized even when exposed to air for a long time without surface treatment such as coating with a foreign material, is a phenomenon that goes against the conventional wisdom." The results of this study are expected to open a new chapter in the synthesis and application of metal nanomaterials including copper nanoparticles. In particular, copper has antibacterial and antiviral functions and is used in antibacterial films and masks, but there was a problem that the function deteriorates when exposed to air for a long time. However, the copper nanoparticles developed using this process are expected to contribute greatly to the sanitation industry, as they can retain their excellent sterilization ability for an extended period.

This research rewrites the existing concept of metal oxidation reaction, and it is expected to lead to the development of new applied technology in all fields beyond those where nanoparticles are used. In particular, if this technology is used to produce copper foil and aluminum foil, which are important components of secondary batteries, it can allow for the construction of thinner materials that retain their metallic properties. This research was published on February 11 in the journal Nature Nanotechnology.

Cathodic protection*

A method to prevent corrosion in the metal by making it a cathode. This is done by connecting the metal to be protected (such as steel) to a more easily corroded "sacrificial metal" (such as aluminum), which acts as an anode. This causes sacrificial metal to corrode instead.

Center for Climate Physics

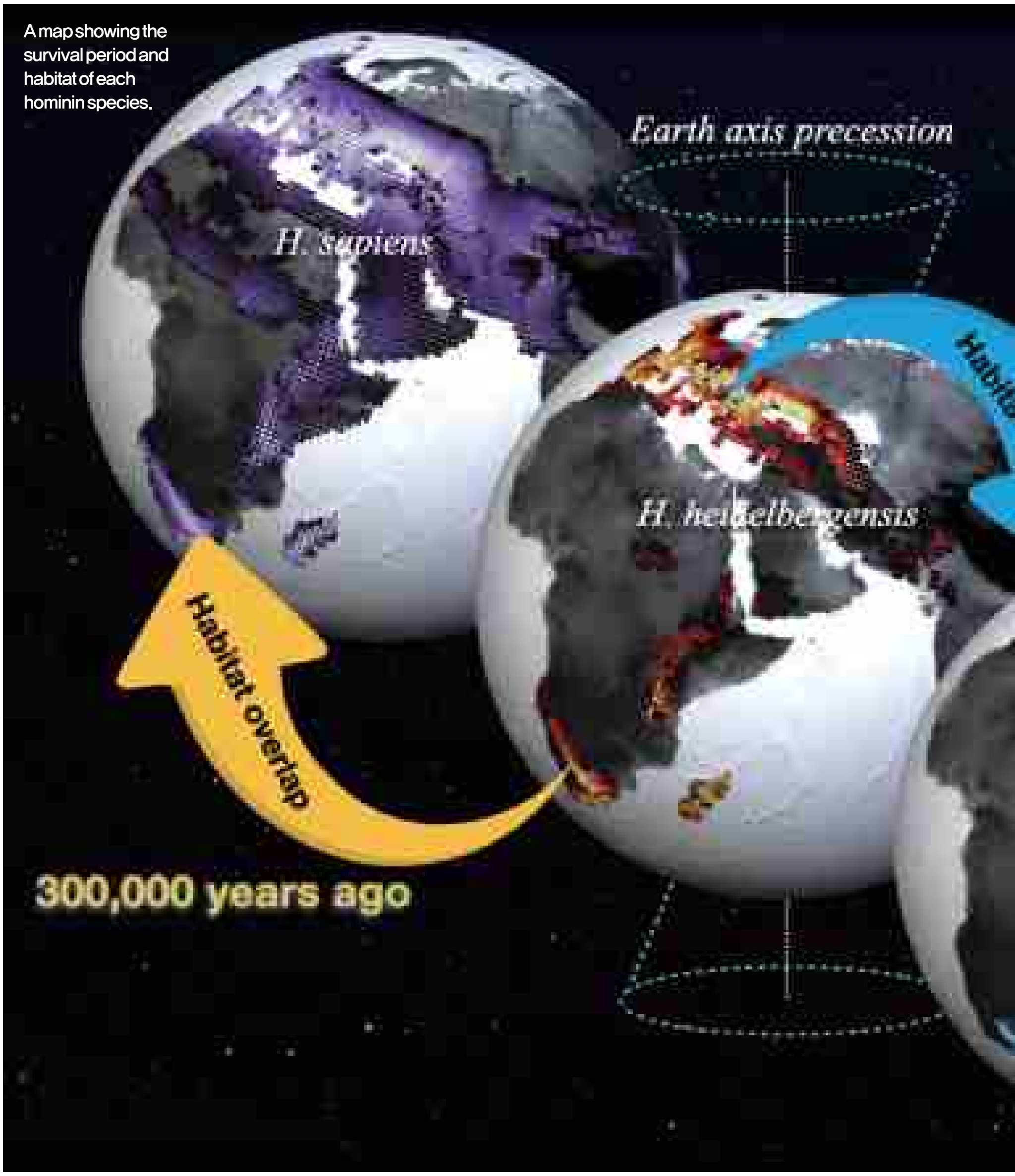
Early Human Habitats Linked to Past Climate Shifts

A study published in Nature by an international team of scientists provides clear evidence for a link between astronomically-driven climate change and human evolution.

By combining the most extensive database of well-dated fossil remains and archeological artefacts with an unprecedented new supercomputer model simulating earth's climate history of the past 2 million years, the team of experts in climate modeling, anthropology and ecology was able to determine under which environmental conditions archaic humans likely lived (Fig. 1).

The impact of climate change on human evolution has long been suspected, but has been difficult to demonstrate due to the paucity of climate records near human fossil-bearing sites. To bypass this problem, the team instead investigated what the climate in their computer simulation was like at the times and places humans lived, according to the archeological record.

This revealed the preferred environmental conditions of different groups of hominins*. From there, the



Preferred habitats of Homo sapiens (purple shading, left), Homo heidelbergensis (red shading, middle), Homo neanderthalensis (blue shading, right) calculated from a new paleoclimate model simulation conducted at the IBS Center for Climate Physics and a compilation of fossil and archeological data. Lighter values indicate higher habitat suitability. The dates (1 ka = 1000 years before present) refer to the estimated ages of the youngest and oldest fossils used in the study.

team looked for all the places and times those conditions occurred in the model, creating time-evolving maps of potential hominin habitats.

"Even though different groups of archaic humans preferred different climatic environments, their habitats all responded to climate shifts caused by astronomical changes in earth's axis wobble, tilt, and orbital eccentricity with timescales ranging from 21 to 400 thousand years," said Axel TIMMERMANN, lead author of the study and Director of the IBS Center for Climate Physics (ICCP) at Pusan National University in South Korea.

To test the robustness of the link between climate and human habitats, the scientists repeated their analysis, but with ages of the fossils shuffled like a deck of cards. If the past evolution of climatic variables did not impact where and when humans lived, then both methods would result in the same habitats. However, the researchers found significant differences in the habitat patterns for the three most recent hominin groups (Homo sapiens, Homo neanderthalensis, and Homo heidelbergensis) when using the shuffled and the realistic fossil ages. "This result implies that at least during the past 500 thousand years the real sequence of past climate change, including glacial cycles, played a central role in determining where different hominin groups lived and where their remains have been found", said Prof. Timmermann.

From the contact zone analysis, the researchers then derived a hominin family tree, according to which Neanderthals and likely Denisovans derived from the Eurasian clade of Homo heidelbergensis around 500-400 thousand years ago, whereas Homo sapiens' roots can be traced back to Southern African populations of late Homo heidelbergensis around 300 thousand years ago.

"Our climate-based reconstruction of hominin lineages is quite similar to recent estimates obtained from either genetic data or the analysis of morphological differences in human fossils, which increases our confidence in the results," remarks Dr. Jiaoyang RUAN, co-author of the study and postdoctoral research fellow at the IBS Center for Climate Physics.

The new study was made possible by using one of South Korea's fastest supercomputers named Aleph. Located at the headquarters of the Institute for Basic Science in Daejeon, Aleph ran non-stop for over 6 months to complete the longest comprehensive climate model* simulation to date. "The model generated 500 Terabytes of data, enough to fill up several hundred hard disks," said Dr. YUN Kyung-Sook, a researcher at the IBS Center for Climate Physics who conducted the experiments. "It is the first continuous simulation with a state-of-the-art climate model that covers earth's environmental history of the last 2 million years, representing climate responses to the waxing and waning of ice-sheets, changes in past greenhouse gas concentrations, as well as the marked transition in the frequency of glacial cycles around 1 million years ago," adds Dr. Yun.

Going beyond the question of early human habitats, and times and places of human species' origins, the research team further addressed how humans may have adapted to varying food resources over the past 2 million years. "When we looked at the data for the five major hominin groups, we discovered an interesting pattern. Early African hominins around 2-1 million years ago preferred stable climatic conditions. This constrained them to relatively narrow habitable corridors. Following a major climatic transition* about 800 thousand year ago, a group known under the umbrella term Homo heidelbergensis adapted to a much wider range of available food resources, which enabled them to become global wanderers, reaching remote regions in Europe and eastern Asia," said Elke Zeller, PhD student at Pusan National University and co-author of the study.

"Our study documents that climate played a fundamental role in the evolution of our genus Homo. We are who we are because we have managed to adapt over millennia to slow shifts in the past climate," says Prof. Axel Timmermann.

Hominin*

Species classified as the ancestors of humans. This study detailed five different groups. (1) Homo sapiens, (2) Homo neanderthalensis, (3) Homo heidelbergensis, (4) Homo erectus, (5) Homo ergaster and Homo habilis

The longest comprehensive climate model*

Using this model, it is possible to comprehensively simulate the characteristics of various Earth systems with a global climate system model that combines atmospheric-ocean-sea ice-land processes.

Major climatic transition*

Refers to the large-scale climate change that occurred from 1,000,000 to 800,000 years ago. It caused colder and longer-lasting ice ages and changed the cycle of the glacial period from 41,000 to 100,000 years.

Center for Genome Engineering

A New Era of Mitochondrial Genome Editing has Begun

Mitochondria*

It is an organelle within a cell that produces energy.

While gene editing was largely successful in the nuclear genome of the cells, however, scientists have been unsuccessful in editing the mitochondria*, which also have their own genome. Many existing genome editing tools could not be used due to limitations in the method of delivery to mitochondria. For example, the CRISPR-Cas platform is not applicable for editing these mutations in mitochondria, because the guide RNA is unable to enter the organelle itself.

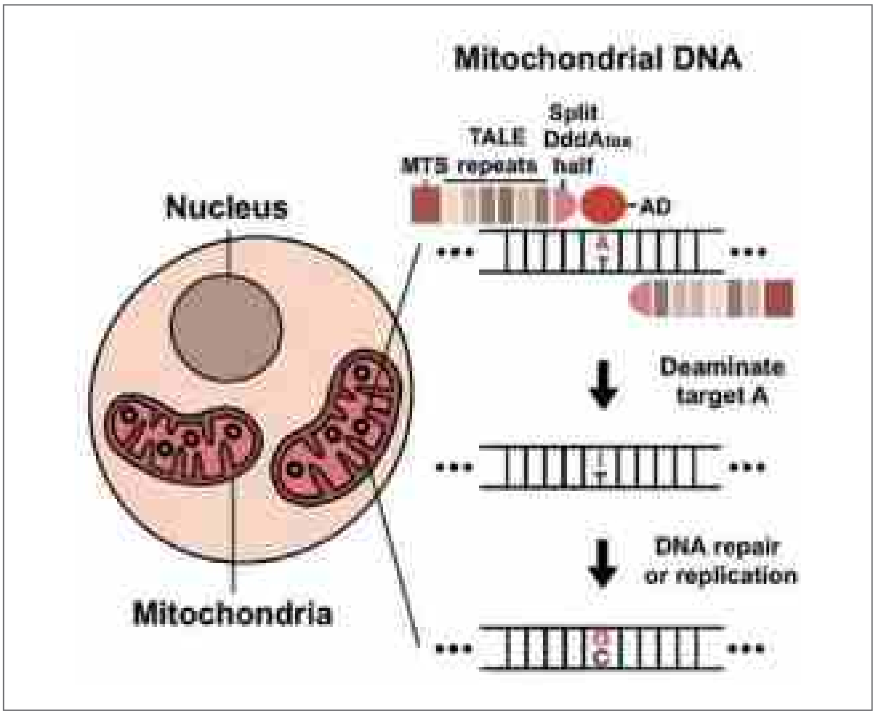
Researchers from the Center for Genome Engineering within the Institute for Basic Science developed a new gene-editing platform called transcription activator-like effector-linked deaminases, or TALED. TALEDs are base editors capable of performing A-to-G base conversion in mitochondria. This discovery was a culmination of a decades-long journey to cure human genetic diseases, and TALED can be considered to be the final missing piece of the puzzle in gene-editing technology.

The researchers created TALED by fusing three different components. The first component is a transcription activator-like effector (TALE), which is capable of targeting a DNA sequence. The second component is TadA8e, an adenine deaminase for facilitating A-to-G conversion. The third component, DddAtox, is a cytosine deaminase that makes the DNA more accessible to TadA8e.

One interesting aspect of TALED is TadA8e's ability to perform A-to-G editing in mitochondria, which possess double-stranded DNA (dsDNA). This is a mysterious phenomenon, as TadA8e is a protein that is known to be specific to only single-stranded DNA. Director KIM Jin-Soo said, "No one has thought of using TadA8e to perform base editing in mitochondria before, since it is supposed to be specific to only single-stranded DNA. It was this thinking outside of the box approach that has really helped us to invent TALED."

The researchers theorized that DddAtox allows dsDNA to be accessible by transiently unwinding the double-strand. This fleeting but temporary time window allows TadA8e, a super fast-acting enzyme, to quickly make the necessary edits. In addition to tweaking the components of TALED, the researchers also developed a technology that is capable of both A-to-G and C-to-T base editing simultaneously, as well as A-to-G base editing only.

The group demonstrated this new technology by creating a single cell-derived clone containing desired mtDNA edits. In addition, TALEDs were found to be neither cytotoxic nor cause instability in mtDNA. Also, there was no undesirable off-target editing in nuclear DNA and very few off-target effects in mtDNA. The researchers now aim to further improve the TALEDs by increasing the editing efficiency and specificity, eventually paving the way to correct disease-causing mtDNA mutations in embryos, fetuses, newborns, or adult patients. The group is also focusing on developing TALEDs suitable for A-to-G base editing in chloroplast DNA, which encodes essential genes in photosynthesis in plants.



Graphical abstract showing how TALEDs work in mitochondria. First, adenine is deaminated to inosine. Next, inosine is converted to guanine by DNA repair or replication.

Center for Nanoparticle Research

Development of Stretchable Nanodevices with Excellent Light Sensing Capabilities

Researcher at the IBS Center for Nanoparticle Research developed a stretchable nano device that can detect light in the visible light region with high precision even when it is deformed into various shapes. This research is expected to be applied to the realization of artificial retina* and the development of stretchable optoelectronic devices.

Despite its curvature, the human eye can precisely detect light of various wavelengths without any deterioration in visual acuity. However, the same cannot be said for electronic devices, where light detection ability deteriorates when it is bent. To simulate the functionality of the human eye, the research team synthesized quantum dots (semiconducting nanoparticles that emit light), organic semiconducting polymers*, and rubber–like elastic polymers in an optimal ratio to create highly elastic composite material. The active matrix* multi–layered phototransistor* array was fabricated based on this materials, and machine–learning was used to allow for accurate detection of various wavelengths of light even when the shape changes.

The research team focused on the separation between the quantum dots and the organic semiconducting material within in the nanocomposite material. When the material is stretched, the gap between the quantum dots widens and the electrical performance decreases. However the organic semiconductor can fill this gap, which enables stable conversion of light into electricity even when the material is stretched. The physical limiations of stretchable electronic devices were supplemented by further application of machine learning*, which improved the stability of photoelectric performance. The electrical performance of a stretchable electronic device must remain constant despite constant external deformation. However, since the rubber material cannot be completely restored when it is stretched, there is a problem of gradual deterioration of the electrical performance. To overcome this, the research team stacked phototransistor arrays with different light sensitivities in a multi–layered structure to detect light in various wavelengths while applying physical deformation. The electrical performance degradation that occurred due to deformation was compensated with machine learning calculation.

All materials used in this phototransistor array are compatible with the traditional semiconductor fabrication processes. It is also possible to greatly increase the transistor density. As the device can detect light with high resolution even when bent or stretched, it is expected to be applicable as a key component for wide–angle cameras or artificial retina technologies that require particularly high resolution. The integration of highly stretchable photoelectric materials and device manufacturing technology with machine learning techniques was an important key to realizing this technology.

Director HYUN Taeghwan said, "This new manufacturing method can be applied to many types of nanomaterials, polymers, and elastomers as well as optical materials to produce various nanomaterials with high functionality and flexibility."

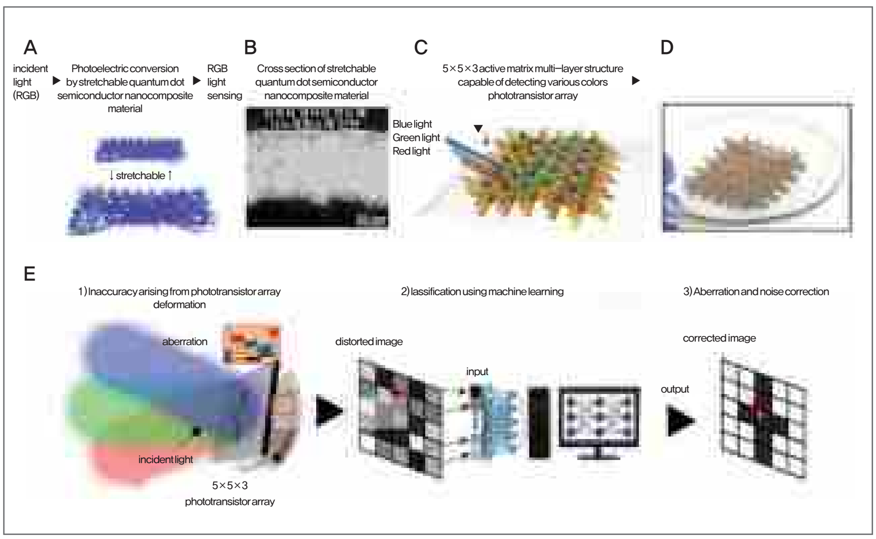
Artificial retina*
Device that mimics human retina. It converts external light input into electrical signal and transmits them to the brain.

Organic semiconducting polymer*
A polymer that consists of atoms alternately forming single/double bonds, which allows the electrons to move and gives the material semi–conductor properties.

Active matrix*
It refers to an array structure in which each pixel acts as a phototransistor.

Phototransistor*
An optical sensor that converts light energy into electrical energy.

Machine learning*
It refers to technology that aims to realize learning ability in computers.



The research team produced a highly stretchable semiconducting quantum dot nanocomposite material. In particular, it was demonstrated that stable light sensing capability can be maintained even when the material's shape is deformed.

Center for Soft and Living Matter

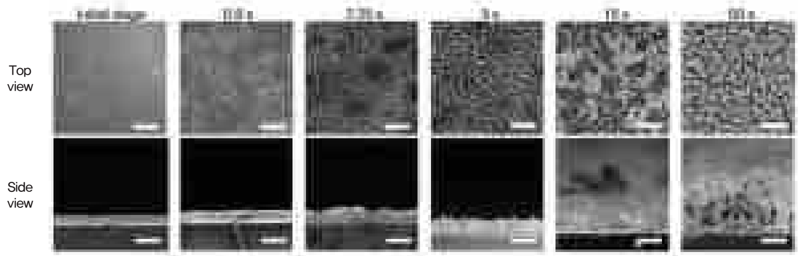
Reliable Diagnostics at the Tip of Your Finger

Biomarkers are components that may be present in biological samples and are related to specific diseases. Therefore, doctors can analyze biological samples from a patient to check their health condition or to monitor the progress of a specific therapy. Typically, these samples need to be purified and diluted before the analysis, and current medical diagnostic techniques rely on healthcare facilities and laboratories for these routine analyses. This is a lengthy process that requires trained personnel and expensive instrumentation to extract, transport, store, process, and analyze the samples in centralized locations. Moreover, during a period of global crisis like the ongoing pandemic, the pressure of thousands of analysis requests can saturate and collapse the healthcare system.

On the other hand, point-of-care devices, which are small automated instruments, are capable of performing diagnostics in decentralized locations and can provide quick answers. One example of such a device is the glucose meter that people with diabetes use to monitor their sugar levels in the blood. These devices can overcome the inherent limitations of having to process a sample through a centralized system, empowering anyone to be able to monitor their health from home, simply using a tiny blood sample extracted with a fingerprick.

However, the development of these devices has been burdened by the technical challenges related to measuring biological samples. Biomarkers for some diseases and infections are only present in the samples in very small amounts, which in turn imposes the challenge to develop extremely sensitive detection techniques. While increasing the surface area of the

Figure illustrating the mechanism for generating nanostructures and nanoporous gold surfaces.



Mechanism to generate nanostructured and nanoporous gold surfaces based on the preferential etch and deposition of the sub–strate using a surfactant that forms micelles in solution, sodium chloride, and a gold salt. Applying electric pulses, first, chloride is adsorbed on the surface, then gold is etched away but captured by the surfactant micelles. Finally, it is redeposited on the substrate growing the nanostructures in the process. At the bottom, scan–ning electron micrographs show the formation of nanostructures and nanopores on the surface throughout the process.

The actual biosensor built using the porous gold nanoelectrode produced using this new process.

biosensor can increase the sensitivity of the instru–ment, these surfaces tend to be quickly clogged and contaminated, rendering them unusable.

To this end, the team led by Professor CHO, Yoon–Kyoung at the Center for Soft and Living Matter with–in the Institute for Basic Science (IBS) in Ulsan, South Korea recently developed a biosensor using a meth–od to generate nanostructured and nanoporous sur–faces. This combined strategy not only provides the sensor with an unprecedented sensitivity but also makes it resistant to fouling by proteins.

While previously there has been no known meth–od to reliably create electrodes using such nanostruc–tured and nanoporous substrates, the team reported a simple method to generate such materials. The mech–anism is based on the application of electric pulses to a flat gold surface in the presence of sodium chlo–ride and a surfactant that can form micelles in solution. These electric pulses drive a preferent reaction to etch and redeposit gold from the surface and, in turn, grow nanostructures and form the nanopores (Figure 1). The use of surfactant in the form of micelles is essential to the success of this strategy since it prevents the mate–rial that is being etched from diffusing away during the process, so it can be redeposited.

The formation of these nanostructures yielded a large surface area which was beneficial for increas–ing the sensitivity of the assays, whereas the for–mation of nanopore substrates was ideal to prevent contamination from the biological samples. Both the nanostructures and the nanopores' combined ben–efits were key to the success of this strategy, which could be applied for the direct analysis of clinical plasma samples.

The researchers further demonstrated this new technology by building a biosensor for the detec–tion of prostate cancer. The electrode was sensitive enough to discriminate between a group of prostate cancer and healthy donors using only a tiny amount of blood plasma or urine samples. No dilution or pre–processing steps were used, which means that the technology could easily be used for the point–of–care diagnosis of cancer.

Professor Cho stated, "We believe that this tech–nology is essential for the future development of point–of–care devices and diagnostic tests that work with biological samples. The capability to detect low concentrations of relevant biomarkers with robust performance opens a door to possibilities in the field of diagnostics for cancer, pathogens, and other dis–eases."

Written by CHO Seung Woo Research Fellow at the IBS Center for Genomic Integrity(UNIST Professor)〈swcho@unist.ac.kr〉,
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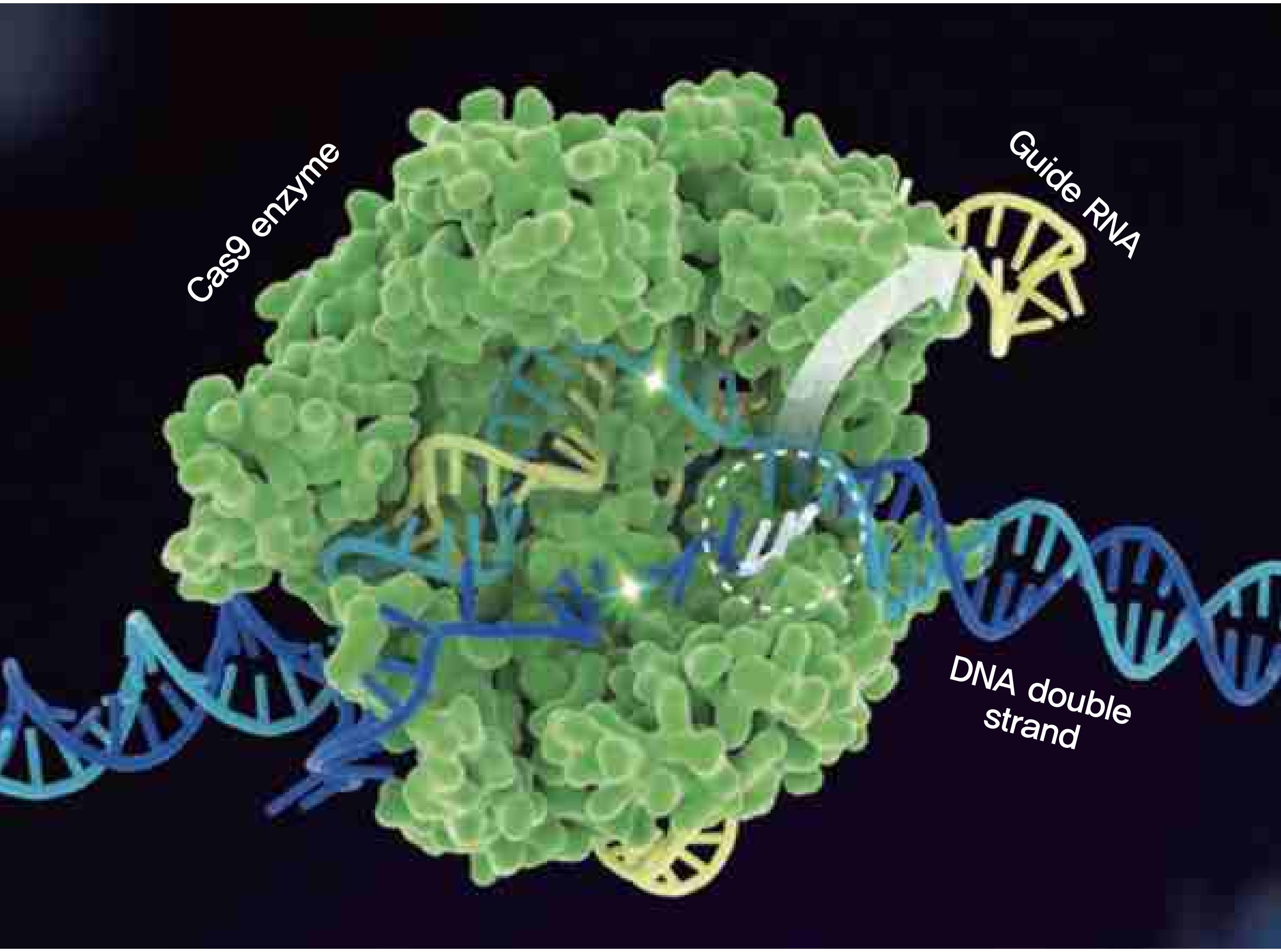
10 Years After CRISPR,

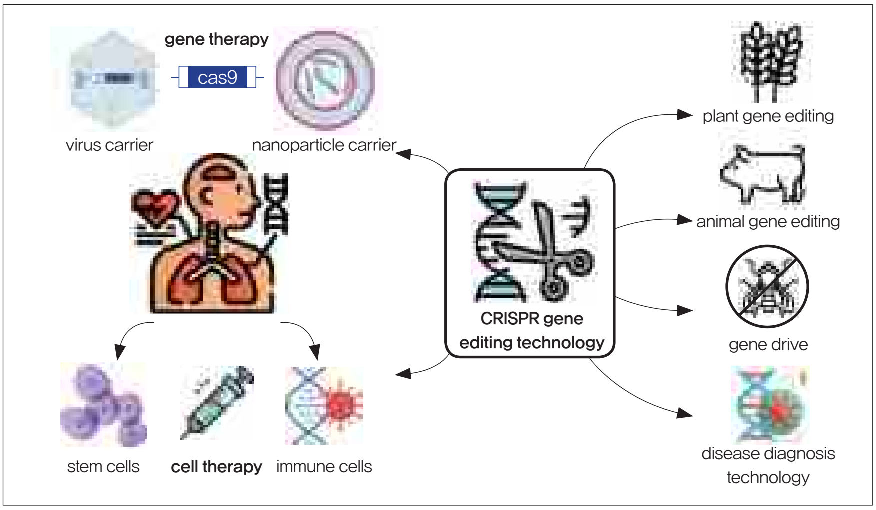
Taking a 'Big Step' to Conquer Incurable Diseases

In CRISPR gene editing technology, the Cas9 enzyme (light green) cuts the DNA double helix (blue) to which the guide RNA (yellow) is bound. The cut DNA is replaced with a normal gene.
The history of this technology began when Professor Jennifer DOUDNA of UC Berkeley, USA, published the results of a study applying CRISPR to bacteria in the journal Science on June 29, 2012. It is a technology that can freely edit a specific gene in the genome. For the past 10 years or so, various studies have been conducted to treat diseases and improve crops through gene editing.



Success in the treatment of diseases

CRISPR technology is composed of a guide RNA that can find a specific DNA sequence and bind to it like a zipper, and Cas9, an enzyme that cuts the binding site. The region cut by CRISPR can be replaced with a normal gene, and as such, it was touted as a method to treat the root cause of genetic diseases. CRISPR technology was inspired by bacteria. Bacteria keep a fragment of the virus DNA as a marker, and when the same virus invades later, their genes are immediately cut into pieces by enzymes. CRISPR refers to a repetitive sequence of DNA that is a marker for a virus.



Jennifer DOUDNA, a professor in the Department of Molecular and Cellular Biosciences and Chemistry at UC Berkeley, was awarded the Nobel Prize in Chemistry in 2020 for the development of the CRISPR together with Emmanuel CHARPENTIER, a professor at the Max Planck Institute in Germany. CRISPR Therapeutics, founded by Professor Charpentier in Switzerland together with Vertex Pharmaceuticals of the U.S., announced in May that most of the 75 patients with incurable anemia had improved after a clinical trial in which CRISPR was applied. The two companies plan to request approval for the gene editing treatment within this year (2022).

Intellia Therapeutics, co-founded by Professor Doudna, worked with Regeneron and used CRISPR to successfully treat transthyretin amyloidosis, a disease caused by the accumulation of damaged liver proteins in the blood. Since CRISPR is an approach to treating the basis of the genetic disease in question, there is an expectation that a single injection will provide a lifelong therapeutic effect. In addition, Beam Therapeutics of the US is preparing clinical trials for lowering cholesterol, and Korean company Toolgen is preparing clinical trials to treat Charcot-Marie-Tooth disease, a genetic disease that causes nerve damage. Toolgen is also pursuing a clinical trial to apply CRISPR technology to next-generation cancer immunotherapy drugs that give immune cells the ability to detect cancer cells.

Application in COVID-19 diagnosis, as well as agriculture

CRISPR has also been applied to diagnose diseases. In April 2017, MIT Professor Feng Zhang announced a nucleic acid-based diagnostic technology using CRISPR. It was also developed as a COVID-19 diagnostic kit. When the guide RNA binds to the RNA of the coronavirus, the enzyme protein cuts off the other RNA strand to which the fluorescent particle is attached. This will give off a light signal so that the status of infection can be determined.

The technology can also be used in vaccines for COVID-19. Gene therapy is possible by replacing mRNA in vaccines using CRISPR.

Agriculture is also preparing for a gene-editing revolution. The same technology has been applied to a variety of crops since 2016 when CRISPR was applied to a mushroom to prevent it from browning, which was approved for marketing in the United States. Recently, in the UK, a tomato that can solve vitamin D deficiency has been developed.

In May 2022, the British government introduced a bill to Parliament that would exclude crops modified using CRISPR technology from being designated as GMO. The logic was that the CRISPR technology does not introduce genes from other organisms like GMOs, but modifies the organism's own genes. A study was also conducted to eradicate mosquitoes that spread the Zika virus and malaria using CRISPR technology.

Patent disputes, bioethics controversy

While the CRISPR revolution has just begun, CRISPR can also be a weapon if used incorrectly. For example, concerns that CRISPR could be used to alter an individual's innate traits have become a reality. Patent disputes are also noteworthy. UC Berkeley and the Broad Institute at MIT and Harvard University competed for priority over who applied CRISPR technology to humans first. Recently, the U.S. Patent and Trial Court ruled in favor of the Broad Institute. Attention is focused on how the patent battle will be concluded in the appeal trial in the first half of 2023.

Special

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ALICE Experiments at LHC Run 3:

A New Journey in Search of Matter in an Extreme State

After finishing Run 2[1] at the end of 2018, CERN[2] has been working for about 3 years and 6 months to plan out various improvements to be applied in future experiment at the Large Hadron Collider (LHC). Although it was delayed by about a year from the plan due to the impact of COVID-19, the LHC successfully resumed its tests on July 5th. This marks the beginning of the LHC Run 3, which will be run for about three years. CERN also broadcast live online the meaningful start of LHC Run 3, and I personally went to the site to witness this moment.

LHC over the past decade

The world's largest piece of experimental equipment in a 27km tunnel about 175m underground

The CERN straddles Switzerland and France and is home to the Large Hadron Collider (LHC), the world's largest particle accelerator. Experiments involving the collision of subatomic particles - a proton against a proton, a proton against an atomic nucleus, and a nucleus against a nucleus - are conducted in the vacuum tubes installed in the gigantic tunnel. The findings of these experiments help scientists to understand the origin and evolution of the universe as well as the composition and working principles of matter, or to study a variety of physical phenomena. Collision tests are performed with four detectors, each of which has a different purpose, and the outcomes are recorded and analyzed.

The LHC has two very important objectives for the physics community. One is investigating what happened within a millionth of a second right after the big bang. This effort is spearheaded by A Large Ion Collider Experiment (ALICE) collaboration. The other is the search for the Higgs boson, one of the greatest achievements of the LHC Run 1, which is led by the ATLAS and CMS Experiments. Scientists discovered traces of the Higgs boson, which is called the "God particle that bestows mass on all matter," in the LHC. The particle was predicted in the Standard Model but has not been observed yet. The scientists who established the model won the Nobel prize in physics in 2013. The year 2022 marks the 10th anniversary of the discovery of the Higgs boson, so it is all the more meaningful to the LHC.

An upgrade in the LHC RUN 3 enables more

1) LHC is divided into Run 1, Run 2, and Run 3 according to the operating period. The operating period from 2009 to February 2013 is called Run 1, and the operating period from 2015 to 2018 is called Run 2. Run 3 started again on July 5, 2022. **2)** CERN is a research center where scientists from all over the world cooperate to conduct research on particle physics. It is also called the European Organization for Nuclear Research.


CERN

hadrons to collide per unit time by enhancing the densities of hadron beams, allowing scientists to collect more collision data. The ATLAS and CMS experiments are also expected to collect more data during the LHC Run 3 than has been collected so far. These experiments will help researchers study the Higgs particle in detail, beyond its discovery. It is expected that the large amount of data collected during the run will help efforts to increase the precision of experiments and look into the difference between the theories based on the Standard Model and the data.

Run 3 brings new changes to ALICE experiments

With the restart of the LHC, performance improvements were made in the key experiments conducted at CERN, notably ATLAS, CMS, ALICE, and LHCb. Two major upgrades were made in the ALICE experiments designed to study the collision of heavy ions.

First, the data collection speed at the Time Projection Chamber (TPC), a device for tracking charged particles, was significantly increased, allowing scientists to collect about 50 times more data during the same period of time than during the previous lead-lead collisions. In the previous runs, it took the scientists almost a month per year to collect the data from collision experiments. Thanks to the upgrade, far more data can be collected in just days during Run 3.

Second, a new detector called the Inner Tracking System 2 (ITS2) was installed to precisely detect the hadrons' collision points and particles' trajectories. Its location is very close to the collision point. The ITS2 detector is based on high-density silicon semiconductor sensors. The detector has a seven-layered structure and about $10m^2$ of its surface area consists of 12.5 billion pixels. The $15\times30mm^2$ sensor chip is made up of 500,000 pixels, and each pixel is $29\times27um^2$. The high-pixel density detector with 5 um of spatial resolution will be able to track the trajectories of charged particles. Expectations for Run 3 are high as Korean researchers participating in the ALICE experiment have made contributions to the development and construction of the silicon-sensor-based detector for a long time.

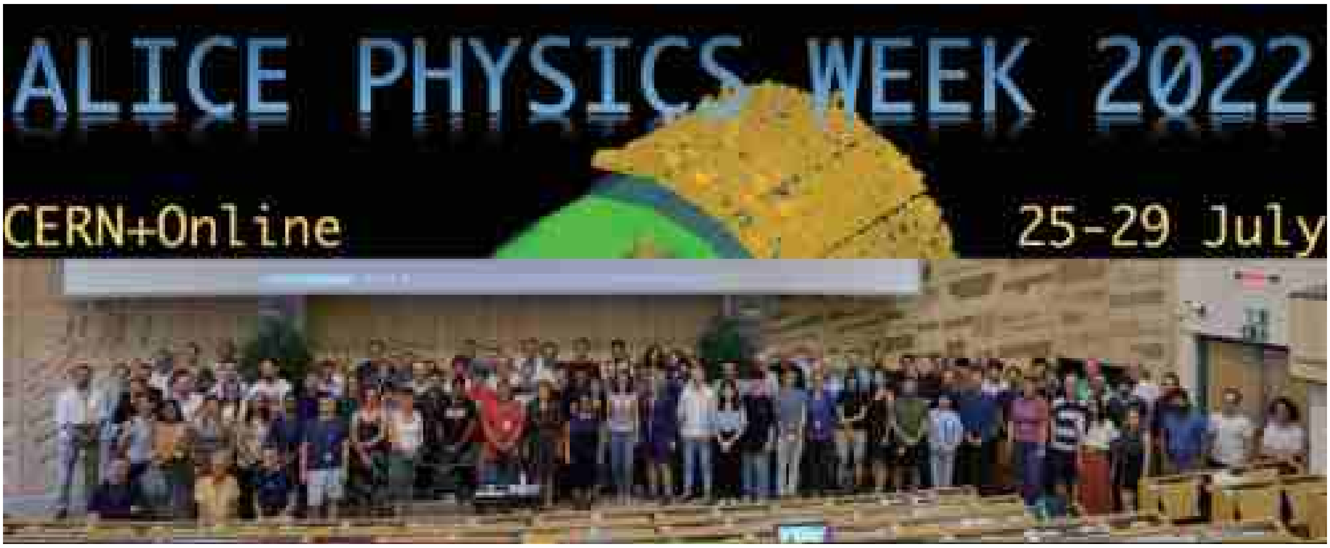
A new focus of the ALICE experiment

The ALICE experiment mainly studies the properties of a new state of matter known as quark-gluon plasma (QGP). Just as an H_2O molecule assumes a solid (ice), liquid (water), or gaseous (vapor) state depending on the temperature and pressure, the elementary particles – quarks and gluons – that make up the hadrons such as protons and neutrons change as well. Nuclear physics studies the properties and the changes in the state made up of the particles. Quark-gluon plasma is a state of matter in which quarks and gluons are deconfined. Scientists think that the state is similar to the beginning of the universe where only the elementary particles existed under extremely high temperatures and energy densities.

One way of generating QGP is the collision of high-energy heavy ions. The nucleus of a lead atom has 208 nucleons. If we accelerate 416 neutrons in two lead nuclei with the energy of about 2.5 TeV and make them collide at one point, an enormous amount of energy can be concentrated in about 100 fm^2 of the nucleus size. Quarks and gluons are not confined in hadrons in moments in this state of matter characterized by extremely high temperature and energy density. Then, the expansion of the collision system lowers the density and temperature, generating hadrons. That is why the collision of heavy ions is also called a mini-big bang.

Measuring the hadrons created right after the collision is a way of studying the properties of the quark-gluon plasma. The total energy of the collision system can be calculated with the momentum and quantity of hadrons, allowing scientists to delve into energy density and temperature that contribute to the creation of matter. This gives information about the properties of the plasma on a macro-level but not of the properties of the constituents of matter on a micro-level. To obtain such information, the detailed structure of matter should be investigated by a probe, similar to how an electron microscope is used to observe the details of material. However, it is difficult, if not impossible, to apply an external micro-probe to fleeting quark-gluon plasma that is created and disappears in an instant. That is why heavy quarks such as charm quarks and bottom quarks that are generated during the collision are used to probe the plasma. Charm and bottom quarks with different masses of 1.3 GeV/c^2 and 4.2 GeV/c^2 respectively have higher energy than the temperature of the plasma. Unlike lightweight particles, they are produced via initial hard scattering in the early collision of heavy ions. The heavy quarks do not disappear quickly but are hadronized, meaning that they persist long enough from the start of QGP to its end. The detailed measurement of hadrons containing heavy quarks enables tracing of what happens inside the plasma.

As there are far fewer created hadrons con-



CERN

Last July, during my visit to CERN, 'ALICE PHYSICS WEEK 2022' was held from the 25th to the 29th. This conference was a place for scientists from all over the world to gather and discuss the latest results and plans for the ALICE experiment. Several Korean researchers also attended the event.

2022 CERN

1. Figure showing the data that was continuously collected by the TPC (Time Projection Chamber) detector, which is used to detect charged particles in the ALICE experiment.
2. ALICE ITS2 detector, which was newly upgraded this year.

taining heavy quarks than such relatively light hadrons as phi-meson and K-meson, data analysis with a high level of precision is necessary. The detector that tracks the trajectories of the particles, which sit near the collision point, plays a very important role. Heavy hadrons decay into several lightweight particles after a certain time period. At that time, hadrons containing charm quarks and those containing bottom quarks decay about 300 um and 500 um away from the creation point, respectively. If we can precisely measure the trajectories of the particles created in decay, it is possible to find the decay location relative to the collision point of hadrons. A precise measurement of the distance to the decay point will allow scientists to distinguish hadrons containing charm quarks from those containing bottom quarks. It is expected that the two types of quarks with different masses react differently inside QGP. This will give researchers an opportunity to investigate the plasma with two different probes. The silicon trajectory detector and enhanced data collection capability of ALICE Run 3 are expected to enable more precise measurements. This run will contribute to the expansion of research into hadrons that contain bottom quarks, which has not been fully conducted due to insufficient data.

New experiments to challenge Run 3: Finding the Super Mini Big Bang

Another interesting experiment planned during the LHC Run 3 is the collision using light nuclei such as oxygen nuclei. One of the surprising experiment outcomes during the previous LHC runs was that phenomena considered conditions for the creation of QGP were observed even in smaller collision systems between protons or between protons and lead nuclei, which are far smaller than hadrons. Comparing the collision systems of different sizes enables observation of how little quark-gluon plasma can be created and what changes occur with decreasing QGP sizes.

As a part of such experiments, the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory collided protons against gold nuclei, deuterons against gold nuclei, and helium-3 against gold nuclei. During the LHC Run3, collisions involving oxygen nuclei such as protons against oxygen nuclei and oxygen nuclei against oxygen nuclei are planned. This will help compare collision systems of different sizes on top of the previous collision experiments of protons against protons, protons against lead nuclei, and lead nuclei against lead nuclei. Such experiments will further research into not just mini big bangs but also ultra-mini big bangs.

About 50 Korean researchers from nine research institutions including myself are participating in the ALICE experiments. They were involved in developing and building the ITS2 detector and have carried out research about heavy quarks and small collision systems. I look forward to seeing Korean researchers making more contributions during Run3.

KANG Seok
Graduate student at the Center for Vascular Research

HONG Seon Pyo
Research fellow at the Center for Vascular Research

Reflecting on the Meaning of Research Beyond Beautiful Images

Those Who are Serious About Art In Science

Sometimes in life, we see sights that are too good to behold alone. It may be a stunning natural landscape, or it may be heartwarming human interactions. When you see a good sight, you will want to leave it as a record and share it with others. This moment also appears during scientific research. How does it feel to share the artistic moments captured during your research with others? We met and heard the stories of the two winners of the 'Art in Science' contest held by the Institute for Basic Science.

Art in Science was initiated to share with the public the beauty and awe discovered in the process of scientific experiments or research. It started as a small-scale contest in 2015 only for IBS researchers but has grown into a large one open to all researchers.

The Center for Vascular Research has participated in the contest since the very beginning, and it has multiple awardees to its name. In 2020, student researcher KANG Seok and research fellow HONG Seon Pyo of the IBS Vascular Research Center won the grand prize and bronze prize, respectively. Dr. KANG won the silver prize in 2021. IBS Research met Dr. KANG and Dr. HONG to find out about their secret to winning.

Congratulations on winning the award. How do you feel?

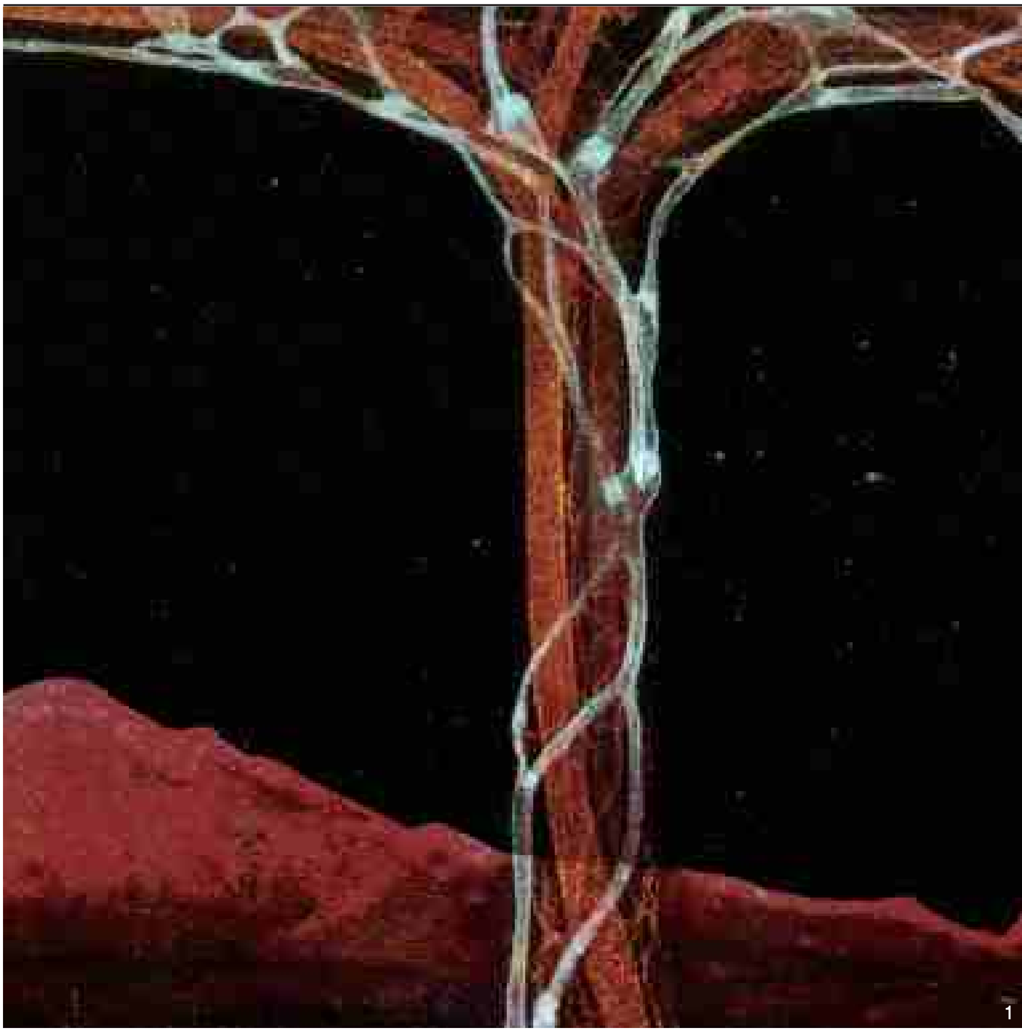
HONG Seon Pyo(HONG) I am delighted that I won the prize at a time when the quality of the works submitted to Art in Science was very high. It was good to have such an opportunity to share images obtained from research.

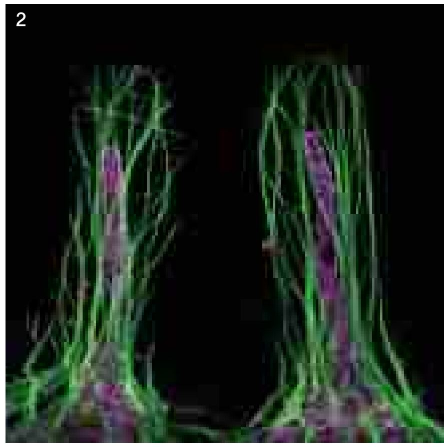
KANG Seok(KANG) In 2020, I was surprised and delighted to win a higher prize than I had expected. In the beginning, I simply submitted pretty images that I came across in the course of my experiments. Over time, however, I realized that I wanted to share with others the images from my research.

In what research did you get the award-winning images?

HONG The image used for Flowers Covered with Grass, which won the bronze prize in 2020, was obtained when writing a research paper that I published as a post-doctoral researcher. The image was not actually included in the paper, though. Villi are small projections from the wall of the small intestine that play an important role in absorbing nutrients and fats. Inside the villi, there are lymphatic capillaries called lacteals. My research at that time was focused on the essential role that intestinal stromal cells surrounding a lymphatic capillary play in helping the capillary absorb nutrients. In the image, the areas in purple are the capillary and what surrounds it in green are smooth muscle cells.

KANG My research area is the embryonic development of lymphatic capillaries and related key factors. Ancient Future, which won the grand prize in 2020, was the image of mouse embryo blood vessels taken to see the process of vessel development. There are lymphatic valves in the capillaries that make sure the fluid moves in one direction. This is not a tree of 2021 is the image of marker protein of the lymphatic capillaries at the





1. This is not a tree (KANG Seok, 2021). 2. Flowers covered with grass (HONG Seon Pyo, 2020). 3. Ancient Future (KANG Seok, 2020).

mesentery that connects the intestines and the abdominal wall. It was taken when observing the process of the valves being made.

They look like artworks, not just images from actual research. It seems that the combination of colors really matters.

HONG The initial images are taken by using different wavelengths, meaning that everything cannot be seen by the human eye. We can only see some wavelengths in the visible light spectrum. I color the image later as I see fit. For Flowers covered with grass, for example, I made the color of the smooth muscle cells green to bring up the image of grass.

Images for research are unlike artworks. To make objects of the images stand out, contrast colors such as red or green are usually used. Academic journal publishers recommend researchers choose colors more carefully so that those with a color deficiency can clearly see the images.

KANG I tend to use primary colors to make images easy to see. For the works submitted to Art in Science, I intentionally colored the images in line with the theme. In This is not a tree, for example, I chose orange and sky blue, which I do not usually use, to create an image of a tree and the cosmos.

The title of your work of art seems to interestingly allude to your research subject. Please explain how you work on them.

HONG When I come across images that are well structured or have a feeling of space, I collect them as candidates for my artworks. Then, I go over them carefully to check whether an object captured in the image is meaningful from the perspective of my research. Even though the contest is intended to create cool images, as a researcher, I want to submit images that can show others what I research. In that sense, Flowers covered with grass left something to be desired because it directed attention mainly to the structure of the image and not so much to the meaning of research.

KANG At the Center for Vascular Research, we observe living organisms through highly magnified images. There are many images that make me associate them with something familiar in other fields. I usually choose and refine one of them for the contest, connecting the image to the research that I do. In the case of This is not a tree, I thought that the lymphatic capillaries of the mesentery looked just like a tree. I thought deeply about how to associate a lymphatic capillary with a tree. I worked on the image and came up with the title based on the idea that a lymphatic capillary serves as a medium connecting the inside and outside of the intestines just like a tree connecting the sky and the earth.

You must put a lot of emphasis on the research implications.

HONG Because I am a researcher, I think research intent should manifest itself in the image. An academic paper that presents images with clear research intent is likely to attract others' interest. I think a good image is one that clearly shows the research outcome.

Are there any research images that you consider especially impressive?

KANG At the Center for Vascular Research, we deal with a lot of images and produce many good ones. Many of them were featured on the front covers of different journals. I like the one featured on the cover of the Journal[1] of Clinical Investigation in 2018. The paper was about the high expression of a specific protein in myocardial infarction. The cover image is simple but powerful enough to inspire researchers to study a new treatment based on the observations of the research.

2018 JCI cover image.

Art in Science is growing year by year. As an awardee, is there anything you would like to say to those who will participate in the contest?

HONG Finding pretty images is not difficult. In fact, many of my colleagues at the Center for Vascular Research submit images to the contest. I guess the audience, in the end, will be most moved when they realize what exactly the image is and what the research is about. Every year, great works are exhibited in Art in Science. I can't wait to see more fantastic works.

KANG Researchers can see a world that is far larger or smaller than the actual one that we see in our daily lives. In those worlds, you can find something extraordinary and amazing. I hope it can be shared with many people. ibs

1) Angiopoietin-2 exacerbates cardiac hypoxia and inflammation after myocardial infarction(ournal of Clinical Investigation, 2018)

Written LEE BoYoung Research Fellow at the IBS Center for Cognition and Sociality⟨blee@ibs.re.kr⟩

Treatment for Depression Started by an Accident!

The paper I will introduce today is not a "classic" with a long history, but it is quite widely known among research-ers in the field of depression. In 2010, a research team led by Ronald Duman (1954-2020), a professor of molecular psychiatry and a psychiatrist at Yale University School of Medicine in the United States, published in Science how ketamine (a type of anesthetic) has a rapid antidepressant effect. The molecular principle (mechanism) was also revealed for the first time.

It is no exaggeration to say that Professor Duman opened a new horizon in the treatment of depression with this paper. It is undoubtedly a masterpiece that has been read and helped countless researchers, as the number of citations grew to reach 2518 times (as of August 1, 2022) in just 12 years. Sadly, he passed away in February 2020. I begin this article with a respectful tribute to Professor Duman, who has made a significant mark in the academic world by devoting himself to the field of depression for over 30 years.

The first antidepressant was discovered by accident!

The history of antidepressants is much short-er than you might think. The first antidepres-sant was discovered during a 1950s clinical trial for iproniazid, a drug originally designed to treat tuberculosis, at Seaview Hospital in Staten Island, New York.

Iproniazid is a monoamine oxidase inhibitor (MAOI), known for inhibiting the deamination of monoamine neurotransmitters such as serotonin, dopamine, adrenaline, and norepinephrine, which activate neurotransmission between nerve cells. It was during a clinical trial that iproniazide was found to alleviate patients' sense of helplessness and sadness and improve their appetite and sleep, displaying the qualities of an antidepressant.

Around the same time, reserpine, a drug used for the treatment of vascular diseases such as high blood pressure, was found to cause depres-sion in some patients by inhibiting vesicular monoamine transporters that results in depletion of monoamines (serotonin and catecholamines) in the brain. Researchers confirmed that symptoms of depression were mitigated with the suspension of reserpine intake.

The two drugs provided a pivotal foundation for establishing the monoamine theory in the early research on the treatment of depression. Many of the popular antidepressants widely used to this day were developed based on the said theory.

Researchers started targeting drugs that inhibit monoamine depletion as antidepres-sant candidates and developed monoamine oxi-dase inhibitors as well as tricyclic antidepressants (TCAs), which evolved into the selective serotonin reuptake inhibitors (SSRIs) or serotonin and nor-epinephrine reuptake inhibitors (SNRIs) that are commonly prescribed to this day.

Why we need a new treatment for depression

What drugs that help to treat depression have in common is that they increase monoamine neu-rotransmitters such as serotonin, dopamine, adrenaline, and norepinephrine in the synap-tic cleft of nerve cells and activate postsynaptic receptors to relieve symptoms of depression.

Antidepressants prescribed today are most-ly second- or third-generation drugs, for the use of the aforementioned first-generation antide-pressants - monoamine oxidase inhibitor types (developed based on the monoamine theory) - was discontinued in the United States following reports on their side effects related to cardiovas-cular disorders (abnormal heart rates, high blood pressure, fever, etc.). Tricyclic antidepressants (TCAs) that were released subsequently did not cause side effects as severe as the first-genera-tion treatments but were gradually phased out due to side effects such as vertigo, memory impairment, and drowsiness.

Second-generation antidepressants, on the other hand, are selective serotonin reuptake inhibitors (SSRIs) that mitigate depression by blocking the reabsorption of serotonin into cells and inhibiting the depletion of extracellular serotonin. While they have significantly fewer side effects than their predecessors, some patients have experienced symptoms like nausea, insomnia, and sexual dysfunction. Third-generation antidepressants, namely serotonin and norepinephrine reuptake inhibitors (SNRIs), do not differ greatly from second-generation drugs in terms of their efficacy and side effects. The unfortunate reality is that the antidepressants prescribed today only have a clinical effect on about 50% of the patients, which means there still are patients that remain nonresponsive to the currently available medications. In addition, side effects of various magnitudes cannot go unnoticed.

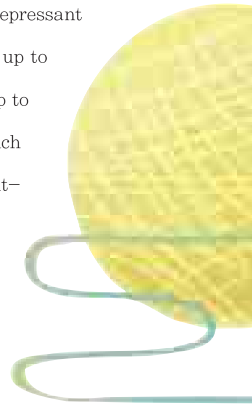
One of the biggest challenges to monoaminergic agent treatment is that they produce a delayed effect, taking from at least two weeks to sometimes months to generate a therapeutic response. The time lag has been problematic in that it can worsen depression and even heighten the risk of suicide.

On a quest to overcome the challenge, researchers embarked on a journey to discover antidepressants that could provide faster-acting treatment

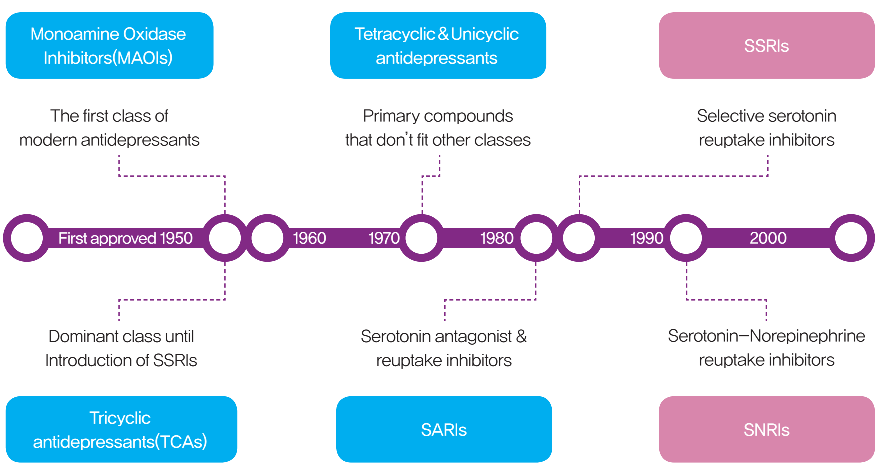
From anesthetics to novel antidepressants

Ketamine emerged as a critical keyword in depression research during the mid-1990s. Ketamine is an antagonist of the NMDA (N-methyl-D-aspartate) receptor, a type of receptor that binds to the excitatory neurotransmitter glutamate. An antagonist is a substance that binds to a receptor and inhibits the function (effect) of agonists such as neurotransmitters by taking away the site where they bind to the receptor. Ketamine is also an anesthetic that was approved by the FDA in 1956.

A research team led by Professor John Krystal at Yale University began a full-scale study based on the results of an animal model study that showed subanesthetic doses of ketamine produce antidepressant effects. The research team conducted a clinical trial in which seven patients with depression were administered subanesthetic doses of ketamine and found that it produced an antidepressant response within three days of administration. This result not only drew the attention of the scientific community but also led the research team to zero in on the potential of ketamine as a new antidepressant treatment to overcome the biggest drawback of existing antidepressants - delayed clinical effect. A follow-up clinical trial in 2006 (in 18 patients) yielded even more surprising results. Most of the patients showed a significant decrease in depression symptoms within 110 minutes of drug administration. For some patients, the antidepressant effect from just one injection lasted up to a week. However, it was unknown up to this point how ketamine produced such a rapid antidepressant effect in as little as two hours. In 2010, Professor Ronald Duman's team conducted a study focused on the "rapid antidepressant actions" of ketamine. The paper containing the research results introduced below is the main subject of this article.



History of antidepressants



Uncovering how ketamine works (mechanism)

The research team first put forward a hypothesis that the proteins produced in response to ketamine in the process of local protein synthesis via mammalian Target of Rapamycin (mTOR) signaling pathways that are involved in rapid synaptic protein synthesis would help stimulate nerve cells and therefore relieve depression. To test the hypothesis, they observed the prefrontal lobes of mice injected with ketamine. Surprisingly, mTOR proteins in the rodents were activated in just 30 minutes of ketamine administration, and activation of 4E-BP1 and p70S6K proteins involved in local protein synthesis increased rapidly. In addition, the team found that ketamine affects

the signaling mechanisms of Akt and ERK, the upstream activators of mTOR proteins, and local protein synthesis because ketamine-induced local protein synthesis was not activated with inhibition of Akt and ERK activation. In this way, the research team demonstrated that ketamine activates the Akt and ERK signaling pathways and promotes the local protein synthesis process. Another notable result of the study documented in the paper is the claim that high synaptic protein expression is maintained up to three days after a single injection of ketamine. The team has demonstrated that the effect of ketamine is not only rapid but also long-lasting. To confirm this, they conducted an experiment to see if the number of synapses actually increased due to ketamine and found that the administration of ketamine did not increase the number of synapses in neurons whose synthesis process was inhibited, leading to a claim that stimulated local protein synthesis has a major influence on synapse formation.

Moreover, the team also showed in a mouse behavioral experiment that inhibition of local protein synthesis suppressed ketamine-induced antidepressant effects. This suggests that local protein synthesis is directly involved in the antidepressant actions of ketamine. Furthermore, the team tested whether the local protein synthesis process also responds to Ro 25-6981, another antagonist of glutamate receptors, and found that Ro 25-6981 also promoted local protein synthesis within an hour and produced an antidepressant response.

Thus, for the first time in academia, the team published results that show modulation of glutamate receptors in addition to ketamine could play a key role in mitigating depression. This has given rise to a new wave of depression research, which, until then, had only focused on monoamine control. The study was especially meaningful in that it foreshadowed a shift in the direction of depression research to glutamate control. The paper became the cornerstone of establishing the glutamate theory.

Thanks to this, research is ongoing today to thoroughly elucidate how the neurotransmitter glutamate relates to depression, which has led to great progress in research on antidepressants. Successive researchers are now striving to continue to discover multiple factors that regulate the neurotransmitter glutamate and to develop new treatments with reduced side effect profiles. ibs

Center for Epitaxial van der Waals Quantum Solids have been launched

Director CHO Mun-Ho of the Center for Epitaxial van der Waals Quantum Solids.

IBS has launched a new research center in the field of physics, the Center for Epitaxial van der Waals Quantum Solids, on February 11th (Friday) at the POSTECH Campus. Professor CHO Mun-ho from the POSTECH Department of Materials Science and Engineering was appointed as its director. This means that IBS is now operating a total of 32 research centers in the fields of physic, chemistry, life science, earth science, interdisciplinary, and mathematics.

Newly appointed Director CHO obtained B.Sc from Yonsei University, and obtained his Ph.D. at Cambridge University, studying materials science. After pursuing a research career at Harvard University, he returned to South Korea and has been a professor at POSTECH since 2004. He has led the IBS Center for Artificial Low Dimensional Electronic Systems as its Group Leader since 2013 and as Associate Director since 2015.

Director CHO is a leading scientist in the field of the epitaxial growth of low-dimensional heterojunction materials and the realization of new quantum device platforms through the study of light-material interactions at these junctions.

In 2017, he developed a new two-dimensional semiconductor by freely controlling the semiconductor-metal properties of the atomically layered material. In 2018, he successfully controlled the electrical properties of a two-dimensional semiconductor using different wavelengths of light. In addition, in 2021 Director CHO announced the control of two-dimensional superlattice materials by stacking different atomic layer semiconductors by epitaxial growth. Many of Director CHO's past research in the field of low-dimensional semiconductor materials so far have been successfully translated into industrial applications, which illustrates the importance of integrating basic and applied research in achieving technological progress.

Since 2013, Director CHO has exerted academic leadership in the field as an Associate Director of the Center for Artificial Low Dimensional Electronic Systems. His leadership and efforts to provide an autonomous and creative research environment to junior researchers were instrumental in his group's success and their excellent research records over the past years. Based on these achievements, Director CHO received the LS Academic Award (2017) from the Korean Society of Metals and Materials and was also appointed as SeAh Chair Professor (2011-2018) and Mu Eun-Jae Chair Professor (2018-present) at POSTECH.

Director CHO stated, "By using epitaxial growth to manipulate the lattice symmetry of the materials bound by relatively weak van der Waals forces, it may be possible to create completely new semiconductors, semi-metals, superconductors, topological materials, etc. Based on this, we want to explore their potential as new platform materials in the quantum technology fields.

IBS President NOH Do Young said, "The new quantum material system that Director CHO wants to implement may serve as a platform material in new quantum technology. It is expected to provide us with a decisive advantage in the competitive field of quantum science." He added "An influx of completely new material science knowledge that the foundation of this new Center brings will have a beneficial effect on the development of physics in Korea as well as the IBS."

Launching of Extremal Combinatorics and Probability Group

Extremal Combinatorics and Probability Group CI, Hong LIU

In the Pioneer Research Center for Mathematical and Computational Sciences, the 'Extremal Combinatorics and Probability Group' will be newly launched on Friday, April 1. Professor Hong LIU from the University of Warwick, UK has been appointed as Chief Investigator (CI) to lead the research group, which is to be the 4th within the Pioneer Research Center.

Hong LIU graduated from Shanghai University of Science and Technology's Department of Applied Mathematics in China, where he received his Ph.D. He later worked as a postdoctoral researcher at the University of Warwick in the UK and then as an assistant professor.

Chief Investigator Liu is a world-renowned mathematician in the fields of extreme graph theory and additive combinatorics. In particular, his recent research on odd cycles is widely acclaimed across the world.

Liu's research fields are extreme combinatorics, probabilistic combinatorics, and discrete geometry fields. These are closely related to various areas of mathematics, computer science, and statistical physics, and in particular, additive number theory and information theory. Therefore extensive interdisciplinary studies are to be expected. Liu continues to be active in academia, where he has published over 40 papers in renowned domestic and foreign journals. His group is expected to become a core research group in his field.

Liu and his new Extremal Combinatorics and Probability Group will do their best to attract excellent researchers from around the world so that Korea can take the lead in this rapidly growing field.

Asian Science Camp 2022 is to be held at the IBS Science and Culture Center

Participants of the Asian Science camp 2022, where students from across Asia gather to meet with Nobel Laureates and leading researchers across various fields.

Asian Science Camp 2022 (ASC 2022) will be held in Daejeon, South Korea at the IBS Science and Culture Center from July 24th to 30th. Asia Science Camp is an international science camp that brings together world-class scientists and aspiring STEM field students across Asia all in one place. Nobel Laureates Stefan HELL (2014 in Chemistry), Randy SCHEKMAN (2013 in Physiology and Medicine), and Tim HUNT (2001 in Physiology and Medicine), in addition to more than 20 world-renowned scientists such as IBS Directors HYUN Taeghwan and KIM V. Narry will be present. They will be a great inspiration for the future generation of aspiring scientists who will be attending the ASC 2022.

The ASC was conceptualized in 2022 after the Lindau Science Meeting by two Nobel Laureates, Yuan-Tseh LEE (1986 in Chemistry) from Taiwan and Masatoshi KOSHIBA (2002 in Physics) from Japan. Since then, ASC has been held as an annual event that aims to enlighten science-talented youths through discussions and dialogues with top scholars and technologists in the world and to promote international friendship and cooperation among the best young students of the next generation in Asia.

Due to the COVID-19 crisis in 2019, the past two camps have been canceled in 2020 and 2021. The ASC was reopened in 2022, and it is the 14th camp to be held. This year's event will be held both onsite and online, due to the risk of a resurgence of COVID-19.

The ASC 2022 is the second camp that was hosted in South Korea, the other one being ASC 2011 which was held at the Korea Advanced Institute of Science and Technology (KAIST). This year 250 students from 25 different Asian countries, ages 16-21, were selected to attend the camp after a stringent evaluation process.

The students will attend lectures that will be held by renowned basic scientists from around the world. In addition to lectures, the students will participate in various events such as panel discussions, lab tours, and poster competitions. More information can be found on the official ASC website.

IBS Launches Pioneer Research Center for Climate and Earth Science and Planetary Atmospheres Group

LEE Yeon-Joo from German Aerospace Center is appointed as the Chief Investigator.

The Institute for Basic Science (IBS) launched a new Pioneer Research Center (PRC) in the earth science field – The Pioneer Research Center for Climate and Earth Science' – at its headquarters. The new PRC was established alongside its first research group, the 'Planetary Atmospheres Group'. Dr. LEE Yeon-Joo (age 39), a researcher from the German Aerospace Center (DLR), was appointed as the CI (Chief Investigator) of this new Group. The new PRC will begin its research on Wednesday, June 1st. As a result, IBS is now operating 35 research centers and two research centers in mathematics, physics, chemistry, life science, earth science, and interdisciplinary fields.

The new CI LEE conducted her doctoral research at the Max Planck Institute for Solar System Research (MPS) in Germany and received a doctorate in natural sciences from the TU Braunschweig, Germany. After that, she continued research activities at world-renowned research institutes such as the Japan Aerospace Exploration Agency (JAXA) and the Institute of Space and Astronautical Science (ISAS). Since 2019, she has worked as a researcher at the German Aerospace Center (DLR) and TU Berlin.

In 2019, CI LEE's research on the relationship between UV reflectivity and the east-west wind speed of Venus' atmosphere1) was selected as an excellent research achievement by the American Astronomy Association (AAS). In 2020, her research on the analysis of the extraterrestrial planet's atmosphere through observation of Venus2) was selected as the Top 50 Papers in Physics by Nature Communications. As such, CI LEE has been recognized for her outstanding research achievements in the field of planetary science.

In addition, CI LEE participated in many prestigious planetary exploration projects, such as the European Space Agency's (ESA) EnVision project, and the BepiColombo project which was jointly led by European Space Agency (ESA) and the Japan Aerospace Research and Development Agency (JAXA).

The Planetary Atmospheres Group led by CI Director LEE is expected to contribute to improving the understanding of the planetary atmosphere by tracking the long-term variability of Venus, changes in the planet's atmosphere over time, and the mechanisms that lead to atmospheric changes.

ISKKU Professor Hong Seung-Woo appointed as the Managing Director of the IBS Heavy-Ion Accelerator Research Institute

Professor HONG Seung-Woo of the Department of Physics at Sungkyunkwan University, who was appointed as the first managing director of the IBS Heavy-Ion Accelerator Research Institute.

IBS launched the Heavy-Ion Accelerator Research Institute on July 1. Sungkyunkwan University Physics Professor Hong Seung-Woo was appointed as the first Managing Director of the new research institute. After graduating from the Department of Physics at Sungkyunkwan University, Hong received a Ph.D. in Physics from the University of Texas at Austin and worked as a postdoctoral researcher. After that, he returned to Korea after working as a researcher at the Julich Institute in Germany. From 1990, he served as a professor at the Department of Physics at Sungkyunkwan University, where he served as the head of the Department of Physics, the managing director of the Basic Atomic Energy Research Institute, and the chairperson of the Nuclear Physics Division of the Korean Physical Society.

New Managing Director Hong participated in the project since the planning stage of the International Science Business Belt, where he established a plan for the construction of a heavy ion accelerator, and envisioned the conceptual design of a heavy ion accelerator as the general manager of the operation. As such he was evaluated as possessing a high level of understanding and expertise in heavy ion accelerator and rare isotope science.

In addition, he possesses a wide network of domestic and foreign experts and researchers in the field of accelerator facility construction, operation, and utilization. He also has extensive leadership experience as the former director of the RAON Cooperation Center at the Institute of Basic Science and as a director and president of the RAON Users Association. These strengths make him a suitable person to lead this project to achieve successful accelerator operation, performance improvement, and future research.

New Director Hong said, "We will set high goals and facilitate extensive sharing of ideas and communication to successfully lead the Heavy-Ion Accelerator Research Institute."

IBS conducted an open call for the managing director position of the research institute from May 11th to the 25th. The new director was selected according to the recommendation of the research institute managing director recommendation committee.

IBS discussed collaboration with two renowned institutes in the U.S.

On August 23rd, the IBS KVRI signed an MOU agreement with St. Jude Children's Research Hospital in the U.S. for joint research on viral infectious diseases.

The Institute for Basic Science (IBS) recently visited the National Institutes of Health (NIH) and announced its collaboration with St. Jude Children's Research Hospital in the U.S., with the aims of increasing virus research capacity and ability to respond to infectious disease outbreaks.

IBS President NOH Do Young, IBS Korea Virus Research Institute (KVRI) Managing Director CHOI Young Ki and others, visited the National Institute of Allergy and Infectious Diseases (NIAID), one of the 27 research institutes and centers at NIH, on August 18th. They convened meetings with NIAID Director Anthony S. FAUCI, Principal Deputy Director Hugh AUCHINCLOSS, Acting Director Richard KOUP of the Vaccine Research Center, and other representatives from NIAID's scientific divisions. Meeting participants discussed the latest research status of their respective institutes and possible research cooperation opportunities between the two institutions.

Dr. Fauci suggested that IBS and KVRI explore opportunities for potential collaboration with the different NIAID divisions and other NIH institutes and centers. He briefly summarized the history of the Vaccine Research Center, which was established in 1996 as part of an intiaitive by President William "Bill" Clinton to develop an AIDS vaccine. The Vaccine Research Center has since expanded its scope to discover and develop novel vaccines and biologics targeting other infectious diseases of global health importance.

Dr. Fauci noted a very successful example of the system set up at NIAID of having a diverse interdisciplinary research environment with scientists from different research fields constantly interacting with each other, even if their interests are somewhat different.

He also stressed the importance of consistent support for biomedical research from the government regardless of the political situation.

After meeting with the representatives from the NIH, IBS has embarked on another cooperative venture with St. Jude's Children's Research Hospital for cooperative research. On August 23rd, the IBS KVRI signed an MOU agreement with the hospital for joint research on viral infectious diseases. St. Jude's Children's Research Hospital is a world-renowned institute that leads research on treating pediatric diseases.

This agreement was promoted to strengthen the cooperative system between the two organizations, thereby expanding joint research in the field of infectious diseases and viruses. The IBS KVRI plans to utilize various research resources and infrastructure owned by St. Jude Children's Research Hospital, such as the genome information of new and variant viruses around the world, and conduct cooperative research including exchange of research personnel.

IBS launches the Life Science Institute

Director Justin C. LEE of the Center for Cognition and Sociality was appointed as the Managing Director of the Life Science Institute.

On July 1 (Fri), IBS launched the 'Life Science Institute' at the headquarters to improve synergy between research centers in the life sciences field and create a more stable research environment for researchers. C. Justin LEE, the Director of the Center for Cognition and Sociality, was appointed as the managing director of the new institute.

Starting with the introduction of the 'Particle and Nuclear Physics Institute' in December 2021, IBS is promoting research cooperation between research Centers in similar fields by introducing the Institute system.

The research institute gathers together about four research centers based on similarities in research themes while still allowing the research centers to operate with independence and autonomy as much as possible. However, existing research centers that do not fit into the field of any research institute or do not want to be incorporated into an institute will continue to operate under the current research center system.

This Life Science Institute is composed of three IBS Research Centers: Center for Cognition and Sociality (led by Director C. Justin LEE), Center for Genome Engineering (led by Acting Director KOO Bon-Kyung), and Center for Biomolecular and Cellular Structure (led by Chief Investigator KIM Ho-Min). In addition, an operation support team was set up to provide smooth administrative support within the research institute.

President NOH Do Young said, "The new IBS campus in KAIST and POSTECH will be completed this year. We also plan to expand research institutes specializing in various fields into these campuses." ibs

IBS Directors OH Yong-Geun and CHANG Sukbok receive HoAm Prize

Director OH Yong-Geun of the Center for Geometry and Physics (Professor of Mathematics, POSTECH) and CHANG Seok-Bok of the Center for Catalytic Hydrocarbon Functionalizations (Distinguished Professor, Department of Chemistry, KAIST) were selected as recipients of the 2022 HoAm Prize in Science.

Director OH, who received the Award in the field of Physics and Mathematics, is a world-class mathematician who has solved many unresolved problems in mathematics. In particular, he is known to advance symplectic geometry* by discovering the important theoretical foundation of 'Floer homology*' and its application. Director OH's research in modern symplectic geometry and symplectic topology is evaluated as an achievement worthy of being included in textbooks. He is credited with raising the status of the Korean mathematics community internationally, by becoming the first Korean keynote lecturer at the World Mathematical Conference.

Director Chang is an internationally recognized chemist in the field of organic chemistry. He is known for developing transition metal-based catalysts that can convert inert and low-reactive hydrocarbon molecules into high-value-added substances. This highly efficient catalyst developed by Director Chang is being used by many researchers around the world and has contributed greatly to the development of organic chemistry synthesis, in addition to suggesting possible application in various fields such as the development of new drugs.

The 32nd HoAm Prize Award Ceremony (2022) was held on May 31 (Tuesday), and awards, medals, and prize money of 300 million won were awarded to winners in each category. The HoAm Award was established by the late Samsung Chairman LEE Kun-Hee in 1990 to commemorate the outstanding achievements in academic, artistic, social development, and human welfare promotion, in honor of his father LEE Byung-Cheol's talent-first philosophy and spirit of public interest. So far this year, a total of 164 winners have been awarded 30.7 billion won in prize money.

There are a total of 9 IBS researchers who have received the HoAm Prize in the past (table on the right).

IBS Award history

	HoAm Prize Winners from the IBS
2018	Director KOH Gou Young, Center for Vascular Research
2015	Director CHEON Jin Woo, Center for Nanomedicine
2014	(Former) Director NAM Hong Gil, (Former) Center for Plant Aging Research
2012	Director HYEON Taeg Hwan, Center for Nanoparticle Research
2010	(Former) Director RYU Ryong, Center for Nanomaterials and Chemical Reactions
2009	Director HWANG Jun Muk, Center for Complex Geometry, Director KIM V. Narry, Center for RNA Research
2006	Director KIM Ki Moon, Center for Self-Assembly and Complexity
2004	(Former) Director SHIN Hee-Sup, Center for Cognition and Sociality

Symplectic geometry*
A field that studies the mathematical properties of complex spaces.

Floer homology*
Expansion of important topological information of space to energy level.


Director OH Yong-Geun of the Center for Geometry and Mathematics, who won the HoAm Prize in Physics and Mathematics (left), and Director CHANG Seok-Bok of the Center for Catalytic Hydrocarbon Functionalizations, who won this year's HoAm Prize in Chemistry and Life Sciences (right).

(from left) Research Fellow KOH Young Joo, Center for Underground Physics (Youngwoon Award), Senior Researcher PARK Joo-Cheon, Center for Exotic Nuclear Studies (Bosan Nuclear Physics Award), Senior Researcher BAE Young-Bok, Center for Theoretical Physics of the Universe (Astrophysics Award).

IBS scientists receive Awards at the Korean Physical Society

Three scientists from the Institute of Basic Science (IBS) received Awards at the 2022 Korean Physical Society. The awards ceremony was held online at the 2022 subcommittee of the Korean Physical Society on April 20.

In particular, IBS produced three award winners in three of the categories in each field of physics, confirming that it is successfully fostering young researchers in the Korean physics community.

KOH Young Joo, a research fellow at the IBS Center for Underground Physics, was selected as the recipient of the Youngwoon Award, which is given to experts in the field of experimental particle physics. The Bosan Nuclear Physics Award, which is awarded to researchers who made a significant contribution to the development of nuclear physics, was awarded to senior researcher PARK Joo-Cheon from the IBS Center for Exotic Nuclear Studies. The Astrophysical Prize, given to those who have made outstanding research achievements in the field of astrophysics, went to Bae Young-Bok, a senior researcher at the Center for Theoretical Physics of the Universe. IBS President NOH Do Young said, "I would like to congratulate the young IBS researchers for winning the Awards at the Korean Physical Society," adding "IBS will continue to strive to nurture young researchers who will lead the future of basic science." ibs

Talk to IBS

We look forward to suggestions from all researchers regarding research news content that require IBS's attention.
After confirmation and conducting additional coverage, the reported information will be introduced as an article within 〈IBS Research〉.
Anonymous reports are also accepted to protect the personal information of the informant. Thank you for your suggestions and warm interest.
For suggestions and subscription requests, contact us at ibs_official@naver.com.

About IBS Research

The first issue of 〈IBS Research〉 was published in December 2013, with the current issue being the No. 18. IBS publishes 〈IBS Research〉 semiannually to publicize its outstanding research achievements discuss the policy and key issues that are occurring in academia. Both research groups and project groups affiliated with the IBS are involved in the promotion of the IBS's excellence in academia to the research circles, as well as informing the importance and role of basic science to the policymakers and the public. 〈IBS Research〉 is published not only in Korean but also in English. It is hoped that this publication will help improve the public awareness of IBS at home and abroad and foster joint research collaboration with other institutions.

Communication Channels

Ch.135는 블로그와 포스트, 페이스북 등 IBS의 SNS 채널을 통합한 브랜드입니다.

✚ Science content at a glance!

▲ blog ▲ posts

IBS blog posts can be found here. If you are curious about the latest research activities of the IBS and related news, come visit the blog. All your questions will be answered at once. Various events and the latest scientific columns can also be found. The posts will explain things like why the scientists did this research, and how they overcame the difficulties faced.

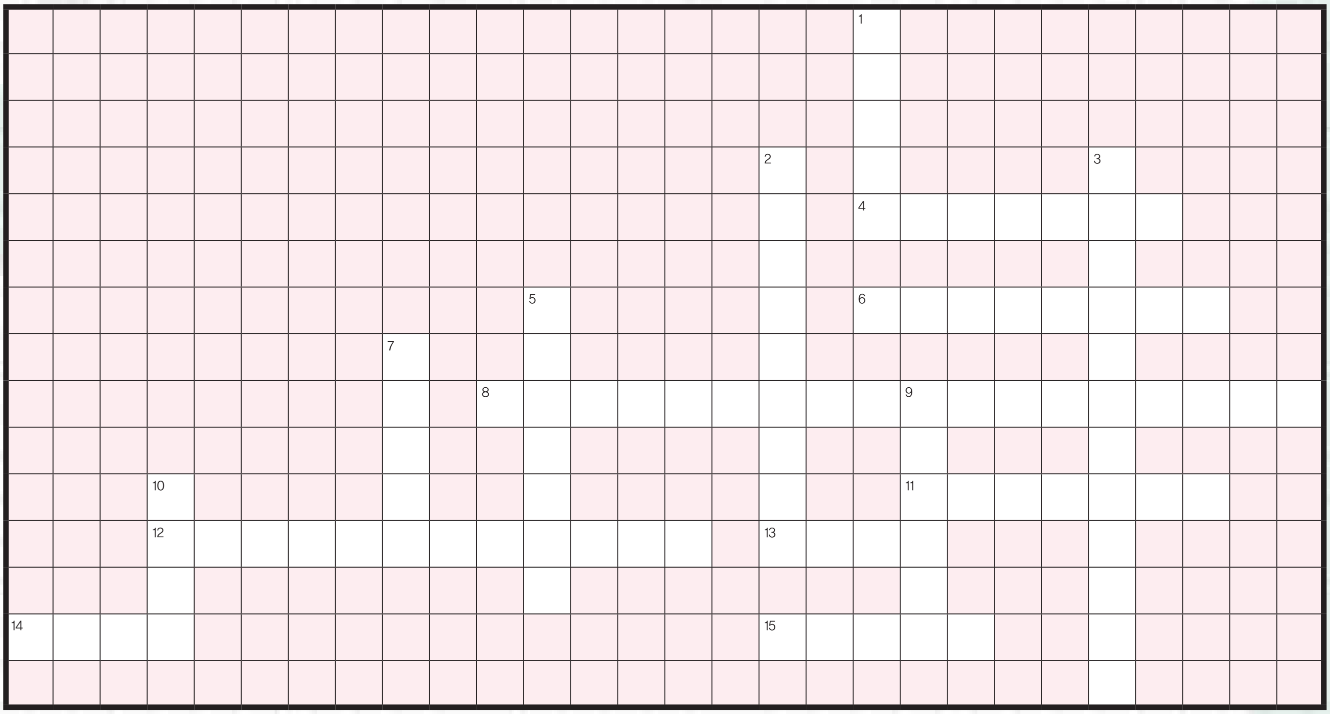
✚ Communityevent participation!

Check out our Facebook to communicate with IBS and participate in various events. IBS's Facebook page is an excellent place to obtain scientific knowledge! Follow us on Facebook to get notified about various lectures, quizzes, IBS events, and news from the scientific community.

✚ IBS in video

If you missed the IBS lecture, please visit our YouTube channel. The channel also includes vlogs of our researchers working at the IBS Research Centers. Other videos include easy to understand explanations of the IBS's research discoveries. There are also many artistic photos and videos researchers encountered during their research. You can also meet the IBS YouTube character 'Genome'. Come visit the IBS YouTube channel and click 'Like' and 'Subscribe'!

Complete the crossword puzzle below



Across

4 Box that blocks out all external light, which is used for testing detector equipments.

6 A type of a lepton, its name means 'little neutrons'.

8 A field of geometry that studies the mathematical characteristics of complex spaces.

11 Same element that contains same number of protons but different number of neutrons.

12 IBS holds this contest every year to share with public awe inspiring images encountered by scientists during their research.

13 Fourth planet in the solar system, which is a red planet.

14 Lepton that is heavier than electron, also called muparticle.

15 Elementary particle that constitutes protons and neutrons.

Down

1 Starting in 2019, this disease caused by coronavirus became a pan–demic.

2 Opposite of macrocosm. Means a smaller place or thing that is repre–sentative as a miniature version of something larger.

3 Full name of NaI. IBS Center for Underground Physics COSINE team use it to search for WIMPs.

5 This NASA space probe is now the farthest manmade object from Earth.

7 Bordering something living and nonliving, it can only replicate itself inside of another cell.

9 New gene editing technology which was awarded the Nobel Prize in 2020.

10 Name of heavy ion accelerator that is being constructed by the IBS.

Across 1 sodium iodide 2 dark box 7 Voyager 9 CRISPR 10 RAON 13 microcosm
Down 3 virus 4 Mars 5 COVID 6 art in science 8 quark 10 neutrino 11 muon
12 isotope 14 symplectic geometry

The 8th IBS Art in Science

IBS annually holds an Art in Science contest to share with the public the artistic beauty and awe encountered by the scientists during their experiments and research.

Artistic moments captured in the research process have been exhibited since 2015, and from 2020, the contest has been opened so that anyone can enter.

We await a variety of works containing artistic moments captured by the scientists

Contest Overview

- ✚ **Title** The 8th IBS Art in Science Contest
- ✚ **Eligibility** Anyone residing in South Korea
- ✚ **Entry** Image or video clip captured in the course of scientific experimentation or research
- ✚ **No. of Entries** No more than 3 entries per team (consisting of up to 5 members) or individual contestants
- ✚ **How to Submit** Submit the application form and entry via the contest website

2022 3rd IBS Basic Science Promotion Contents Contest

In celebration of the UN's "International Year of Basic Science for Sustainable Development", IBS is holding the '3rd IBS · Basic Science Promotion Contents Contest', where anyone can participate to publicize the importance of basic science. We are waiting for videos and images (infographics, webtoons) that can promote the importance of basic science or IBS-related topics (role of the IBS, research outcomes, etc.). We are looking for a PR King who will creatively promote the IBS. Entries will be published on the IBS website and official YouTube channel. Enter right now! Anyone residing in Korea can apply. You can submit 1 work per team (of 5 people or less) or per individual.

As for the video, please send it as a short clip of 3 minutes or less. There are no special restrictions on the image format. The deadline is until 24:00 on October 20th, please visit the website 'www.ibs공모전.com', fill out the application form, and submit your work! For more information, please contact the contest secretariat at lcm@intoinmedia.com.

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