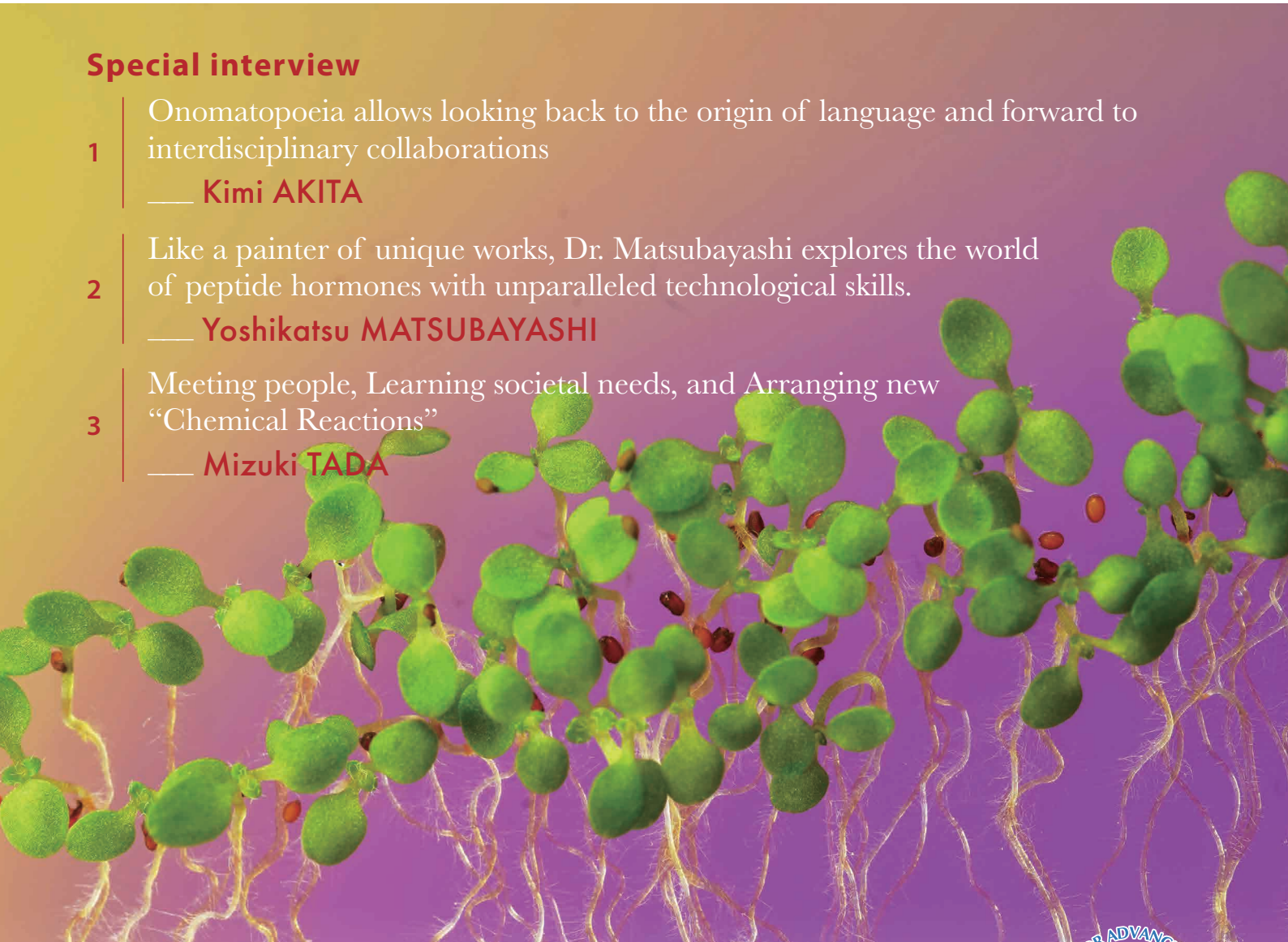
INSTITUTE FOR ADVANCED RESEARCH

LETTER

March 2024 Vol. 22

Special interview



Research Highlights

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The Showcase for Advanced Research and Development of Research Person of Talent

— Voyage for New Standards of Academia —

The Institute for Advanced Research (IAR), Nagoya University, was established in 2002 to promote the world's top-level research, and to contribute widely to society through the outstanding research outcomes. The IAR is among the first such organizations established in Japanese universities with the first director Prof. Ryoji Noyori. The IAR has since maintained promoting especially in Nagoya University's pure research from a broad perspective that transcends the conventional disciplinary boundaries. Today, the mission has expanded to include the promotion of academics at the Nagoya University, support for excellence in research, developing the next generation of central research and researchers, and conducting international research exchanges. The IAR aim to promote exploring the new research field as worthy of one of the world's leading research universities. We have been hosting IAR lectures and seminars, including the Nagoya University Lectures, delivered by eminent researchers, to whom the president of Nagoya University awarded special lectureship. The IAR has been also serving as a steering committee member of the University-Based Institutes for Advanced Study (UBIAS) which is the international network of the other institutions of this sort around the world. Furthermore, the IAR has been encouraging early-career researchers to be the next generation's leaders through the Young Leaders Cultivation (YLC) program and Young Researcher Unit. As Nagoya University aims to become one of the world's leading research universities in the framework of Tokai National Higher Education and Research System, the IAR aims to further expand the functions as a hub for research information and human resources, and as the showcase of research, research activities, and the development of research personnel. I keenly look forward to your continued support with your guidance and encouragement for the IAR.

Kunio AWAGA

Director of Institute for Advanced Research

Director
Kunio AWAGA

22
March 2024

INSTITUTE FOR ADVANCED RESEARCH

LETTER

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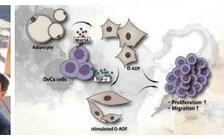


Cover Picture :
MATSUBAYASHI LAB's Representative
Research on Nature Plants 7, 310 (2021)

Special Interview 1

Kimi Akita

Associate Professor, Graduate School of Humanities, Nagoya University
Dr. Akita is the author of *Onomatope no Ninchi Kagaku* ("Cognitive Science of Onomatopoeia") and co-author of *Gengo no Honshitsu: Kotoba wa Doo Umare Shinka Shita ka* ("The Nature of Language: How Language Was Born and Evolved"). The latter is a bestseller with a circulation of over 200,000 copies. While focusing on onomatopoeia, Dr. Akita also conducts cross-disciplinary research.

Onomatopoeia allows looking back to the origin of language and forward to interdisciplinary collaborations

Encounter with the study of onomatopoeia and the development of the field

Dr. Akita used to study English linguistics, with special attention to expressions of emotions. "Worried," "excited," and "surprised" may be expressed in Japanese with the onomatopoeia "*kuyo-kuyo*," "*waku-waku*," and "*bikkuri*," respectively. Through a close examination of the two languages, he noticed that Japanese has many more types of onomatopoeia than English. Onomatopoeia (termed "ideophones" in linguistics) attracted his interest, but the field is often viewed as peripheral in the realm of linguistics. At first, he thought he would work on onomatopoeia only for his master's thesis. Before he knew it, however, he came to devote himself to the field for 20 years.

"What motivates me to keep working on onomatopoeia," Dr. Akita remarks, "is their seemingly chaotic behavior. They are impressionistic and are not apparently linguistic, but on a closer look, they follow certain patterns."

We use onomatopoeia every day but know very little about them. Examining them from a linguistic perspective allows finding numerous hidden regularities and commonalities with other languages, which fascinates Dr. Akita.

Onomatopoeia, a category of words that express sounds, states, and actions, is particularly familiar to Japanese speakers. For example, "*sara-sara*," "*gotsu-gotsu*," and "*sorori-sorori*" describe a rustling sound, a hard, rough surface, and slow, quiet steps, respectively. It is not easy to define onomatopoeia, but experts consider them to be "iconic" words, which here mean symbols that directly reflect sensory information. "(^_^)" is a Japanese icon that visually depicts the characteristics of a smiley face. Similarly, onomatopoeic words such as "meow" and "bow-wow" can be considered as iconic words that auditorily imitate the sounds of cats and dogs.

Although iconic, onomatopoeia are not primitive or immature. They follow systematic patterns. For example, "*sara-sara*" may be an adverb as in "A brook is running sara-sara (smoothly)," or an adjective as in "Your skin is *sara-sara* (smooth)." Intriguingly, the accent pattern differs between the two cases. When the word is used as an adverb, its pitch pattern is high-low-low-low. When it is used as an adjective, its pitch pattern is low-high-high-high. The same holds true for other adverbial and adjectival onomatopoeia.

Onomatopoeia have attracted particular attention since the beginning of the 21st century. Look at the two figures drawn below. Now, if you had to name one of them "bouba" and the other "kiki," which one would be "bouba" and which would be "kiki"?

There are linguistic sounds that match spiky figures and those that go well with rounded figures. Please note that the figures shown above were drawn by the author of this article with reference to Fig. 7 in the paper published by V. S. Ramachandran and E. M. Hubbard in 2001.(1)

Interestingly, most people pick "kiki" for the left figure and "bouba" for the right figure in a wide range of languages. Visual impressions and verbal sounds are two different types of sensory information, but they are interconnected. This phenomenon is called the "bouba/kiki effect," which was named as such by V. S. Ramachandran and E. M. Hubbard in a paper published in 2001.(1) When humans started using words, perhaps they might have systematized them into language through the accumulation of such phenomena. It is difficult to prove this hypothesis, and there are many competing theories on the matter. Nevertheless, the paper captured the spotlight at that time as a clue to the origin of language.

Dr. Akita thinks that the bouba/kiki effect is closely related to onomatopoeia, in that it concerns the iconicity of visual and auditory information just as onomatopoeia do. As a natural consequence, he has been investigating the relationship between onomatopoeia and the origin of language. The relationship is difficult to prove because you cannot trace back the changes in language over a hundred thousand years. Dr. Akita himself confesses that it is somewhat scary to work on this huge issue. Nevertheless, he boldly explored this topic, which led to the book *Gengo no Honshitsu: Kotoba wa Doo Umare Shinka Shita ka*,(2) which he co-authored with Dr. Mutsumi Imai. While quoting from the book, the next section will give some examples of how language begins with highly iconic words such as onomatopoeia and then gradually loses iconicity as it becomes systematized.

(1) Ramachandran, V. S. & Hubbard, E. M. (2001). Synesthesia: a window into perception, thought, and language. *Journal of Consciousness Studies*, 8: 3-34.
(2) *Gengo no Honshitsu: Kotoba wa Doo Umare Shinka Shita ka* Co-authored by Mutsumi Imai and Kimi Akita, Chuko Shinsho, First edition published on May 24, 2023

How are highly iconic words systematized?

"In fact, surprisingly many 'ordinary words' that we currently do not consider to be onomatopoeic were once onomatopoeic words" (p. 141). The language we use today did not suddenly come into existence one day as a complete system. For example, the onomatopoeic words "*tat-tat*" and "*fuu*" are said to be the origins of certain ordinary words. According to Dr. Nakami Yamaguchi, a leading researcher on the history of Japanese onomatopoeia, "*tat-tat*" and "*fuu*" were joined with "*ku*," an archaic Japanese suffix making verbs, changing into "*tataku*" (hit) and "*fuku*" (blow), respectively. The onomatopoeia "*kara*" and "*ugui*," which transcribe animal sounds, were joined with "*su*," a suffix that indicates a bird, becoming "*karasu*" (crow) and "*uguisu*" (Japanese bush warbler), respectively. Through the addition of affixes or through conjugation, many onomatopoeic words were changed into ordinary words, allowing them to be used as nouns and verbs.

Nicaraguan Sign Language is a famous example of the way highly iconic words are systematized over generations. It attracts the attention of researchers as an example of a language whose changes were observed almost in real time in the modern age; they took place within the last 50 years.

Nicaragua, a Central American country, used to have neither an education system for deaf children nor a standard sign language. Sometime between 1970 and 1980, an environment was developed for such children to study at school. The first generation of these children created a sign language as a means of communication, which was passed on to the next generation. One of the changes that occurred during this process was "the division of gesture into elements, and the recombination of these divided elements" (p. 147). For example, when signing the concept "rolling down," first-generation children used a highly iconic gesture that precisely portrayed the action visually. But then, how would you sign a concept similar to "rolling down," say, "sliding down"? If you followed the same method, you would have to keep creating and memorizing an infinite number of signs so that you could convey small differences between similar but different actions. To avoid this problem, second-generation children divided the gesture "rolling down"

into the elements “rolling” and “down,” and then combined the two to express “rolling down,” and the same way was used to describe “slipping down.” Putting existing divided words back together made it possible to efficiently express other concepts. Nicaraguan Sign Language is now internationally recognized as an official sign language.

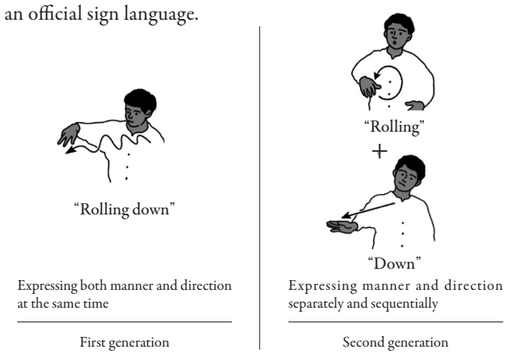


Fig. 5-2: Change in **Nicaraguan Sign Language** from the first generation to the second generation

Gesture which at first precisely visualized a concept was later divided into elements and then used in combination. Source: *Gengo no Honshitsu: Kotoba wa Doo Umare Shinka Shita ka*, p. 150, Fig. 5-2.

A group of highly iconic Japanese onomatopoeic words show traces of changes similar to those undergone by Nicaraguan Sign Language. An example is the difference between “*ban*” and “*batan*.” Both express a single impact sound, but while “*ban*” can be used for a variety of strong impact sounds such as a collision or an explosion, the use of “*batan*” is usually limited to the sound of a flat object falling or shutting. In fact, the consonant /t/ in “*batan*” indicates hitting or contact, as in “*dotan*” (the sound of a heavy object falling), “*goton*” (the sound of a hard object hitting against something), “*boto-boto*” (the sound of large drops dripping), and “*gotsun*” (the sound of a heavy object hitting hard against something). The consonant /t/, which represents one of the subdivided categories of strong impact sounds, has created different meaning from “*bashan*” (the sound of fluid collisions), “*bachan*” (the sound of fluid hitting flat object), or “*baran*” (the sound of a bundle of thin objects unravels). Onomatopoeia are highly iconic but systematic, as mentioned at the beginning.

The last topic to cover in this section is the question of why onomatopoeia differs depending on the language or dialect. First, for the understanding of this topic, guess what animal is represented by all these words: “*chako*,” “*tako*,” and “*guruu*.” Believe it or not, the answer is a cat. “*Chako*” is a Tohoku region dialect term. In that region, “*cha*,” a tutting sound used to attract a cat, has been joined with “*ko*,” a suffix for something adorable, making “*chako*.” While it remained “*chako*” on the Yamagata prefecture (Japan Sea) side of the region, on the Miyagi prefecture (Pacific) side, it changed in sound to “*tako*.” “*Guruu*” is a dialect term of Kikai Island in Kagoshima Prefecture. It evolved as such from “*guru-guru*,” the way a cat purrs. Many onomatopoeic words are transcriptions of actual sounds made by objects, but they can be completely different depending on which sounds of the objects are transcribed. Differences in onomatopoeia between languages is also attributed to the phonological system of the individual languages. For example, in English, “brrr” is the transcription of a shiver, while “vrrr” is that of a car engine sound. In contrast, Japanese speakers do not distinguish between [b] and [v], and they may not be able to accurately grasp the difference in nuance.

This book also argues that the cause of these changes lies in our ability to handle metaphors and metonymies. These are only a few examples of the views the book presents from various perspectives. You should definitely pick it up and read it.

New possibilities of onomatopoeia in cross-disciplinary research

Onomatopoeic words such as “*zuki-zuki* (throbbing),” “*kiri-kiri* (splitting),” and “*chiku-chiku* (tingling)” are useful and familiar expressions you may use when explaining your poor physical condition. For example, a patient may tell the doctor s/he has a “*chiku-chiku* (tingling)” pain. A report shows that patients feel relieved if the doctor repeats the same onomatopoeic word in agreement, in this example by saying, “I know it’s *chiku-chiku*.” On the other hand, because of their highly subjective nature, onomatopoeic words that describe physical condition are believed to be difficult to associate with specific symptoms, and doctors find it hard to know how to handle these words. There is room for research into onomatopoeia in medical settings, but much less knowledge has been accumulated so far than you may think.

“It used to be believed that onomatopoeic expressions were vague and varied so much from person to person,” Dr. Akita remarks, “but my study has suggested that inter-personal variability may not be as great as we have expected.”

Onomatopoeia, which are nothing new and have always been used casually, are actually part of language in themselves with their own set of meanings and system. Digging into them deeper may enable you to unearth hidden possibilities.

“By verbalizing your sensation, you can organize it, become more aware of it, and share it easily with others,” Dr. Akita points out. “Onomatopoeic words may be difficult to handle at times, but I am sure they have positive aspects and, if used properly, are applicable to medical care.”

オノマトペの沼へようこそ！過去をさかのぼれば言語の起源、未来を見通せば異分野への応用が見えてくる

秋田　喜美
名古屋大学大学院
人文学研究科 人文学専攻 准教授

著書に、単著『オノマトペの認知科学』、共著『言語の本質-ことばはどう生まれ、進化したか』がある。後者は20万部を超えるベストセラーとなっている。オノマトペを中心としつつ、分野横断的な研究も展開している。

実は奥深いオノマトペの法則性と言葉の成り立ち

「オノマトペの研究を続けている理由は、その不思議さですね。直感的で言語らしくないのに、よく見ると法則があります」

オノマトペとは、「さらさら」、「ごつごつ」、「そろりそろり」といった、音や状態、動作などを表現する言葉で、特に日本語ではなじみ深い。その定義は一筋縄にいかないが、「“アイコン”的な言葉」といった捉え方がある。ここでの“アイコン”とは、感覚情報を直接的に写し取った記号のことをいう。たとえば、「(^_^)」は人の笑顔の特徴を視覚情報として写し取ったアイコンである。同じように、「にゃーにゃー」、「わんわん」といったオノマトペはそれぞれ、猫と犬の鳴き声を聴覚情報として写し取ったアイコン的な言葉と考えることができる。

また、アイコン的ではあるものの、原始的というわけではない。体系化された法則が見られるのも特徴だ。たとえば、「小川がさらさらと流れる」と言う場合と、「肌がさらさらだ」と言う場合では、「さらさら」のアクセントが変わるのに気づくだろうか。「さらさら」のあとに「と」がつく場合は、「さ↘らさらと」、「だ」がつく場合は、「さ↗らさらだ」となり、これは他のオノマトペでも同様だ。

秋田さんと今井むつみさんによる著書『言語の本質-ことばはどう生まれ、進化したか(1)』では、オノマトペの体系的な特徴や、オノマトペがアイコン性を失い汎用性の高い言葉へ変化していく道筋がいくつも紹介されている。

たとえば、「バン」と「バタン」の違いを考えたことがあるだろうか。どちらも共通して一つの衝撃音を表しているが、「バン」はぶつかった音や爆発音など多様な強い衝撃音に使える一方、「バタン」は平面的な物体が倒れたり閉まったりするときの音に限定して使う。実は、「バタン」に含まれる子音/t/は、「ドタッ」、「ゴトッ」、「ボトボト」、「ゴツン」のように打撃・接触を表す役割をもつ。意味が細分化された子音/t/を用いることで、「バシャン」、「バチャン」、「バラン」とは異なる意味合いを表し分けている。

また、「実は、現在私たちがオノマトペとみなさない『普通のことば』(一般語)の中には、昔はオノマトペだったものが驚くほどたくさんある」(p.141)とあるように、私たちが使う言葉は、ある日突然完成された体系として現れたものではない。身近なものではたとえば、「タッタッ」、「フー」という擬音語はそれぞれ、ある単語の語源になっているそうだ。オノマトペの歴史研究の第一人者である山口仲美さんによると、古語で動詞化するための接辞「く」を末尾につけて、「たたく」、「ふく」へ変化したという。鳴き声を写す擬音語「カラ」、「ウグイ」に、鳥であることを示す接辞「ス」をつけて、それぞれ「カラス」、「ウグイス」となる。オノマトペを名詞や動詞として使うために、接辞をつけたり活用させたりして一般語とする変化が多くの単語で起こっている。

身近なオノマトペに秘められた分野横断研究の可能性

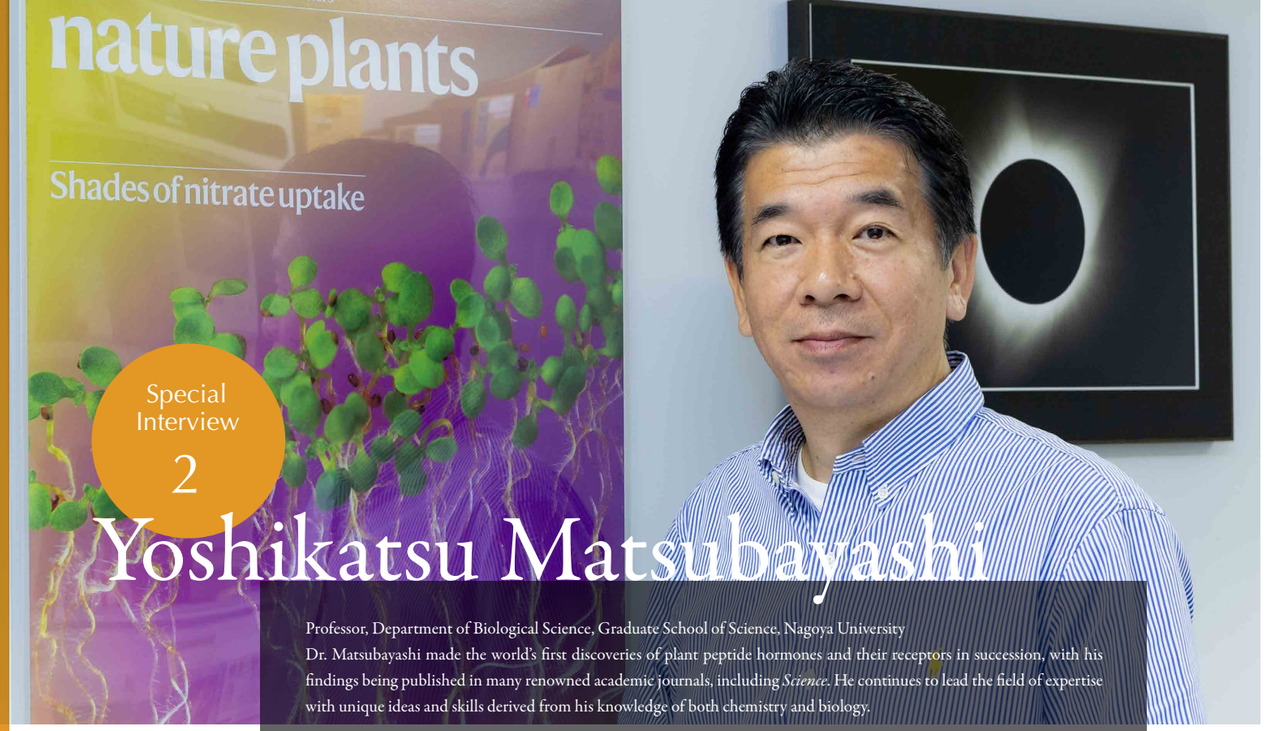
「ズキズキ」、「キリキリ」、「チクチク」といったオノマトペは、自分の体調不良を表現するときに便利でなじみ深い言葉だ。また、患者の「チクチク痛みます」に対して、医師が「チクチクしますよね」と同じオノマトペで同意を返すと患者は安心する、という報告もあるそうだ。一方、主観性の高いオノマトペで表現する身体情報は症状との紐づけが難しく、扱いが難しい言葉とも考えられている。こうした医療場面でのオノマトペは研究の余地があるが、今まで積み重ねられてきた知見は意外と少ない。

「オノマトペの表現は漠然としていて個人差が大きいのではないかと見られていました。実際に調査してみると、個人差は予想していたほど大きくはないようです」

身近でいつも何気なく使ってきたオノマトペも、意味と体系をもつ言語だ。深堀りすることで、秘められた可能性を探し当てることができるかもしれない。

「感覚を言語化することで整理ができます。そうするとその感覚を自覚できるようになるので、情報共有もしやすくなります。ときに扱いづらさもあるかもしれませんが、オノマトペによる痛みの表現には良い面があるはずなんです。そういう意味で、医療への応用も可能かもしれないですね」

(1)『言語の本質-ことばはどう生まれ、進化したか』
今井 むつみ(著)／秋田 喜美(著)／中公新書／初版刊行日2023年5月24日



Special Interview 2

Yoshikatsu Matsubayashi

Professor, Department of Biological Science, Graduate School of Science, Nagoya University

Dr. Matsubayashi made the world's first discoveries of plant peptide hormones and their receptors in succession, with his findings being published in many renowned academic journals, including *Science*. He continues to lead the field of expertise with unique ideas and skills derived from his knowledge of both chemistry and biology.

Like a painter of unique works, Dr. Matsubayashi explores the world of peptidehormones with unparalleled technological skills.

How do researchers develop their originality?

In 1996, Dr. Matsubayashi made the world's first discovery of the plant peptide hormone PSK (*p*hytos*ulfok*ine), one of the hormones essential for communication between cells. Before that discovery, a lot of attention in the research world had been paid to the existence of a mysterious substance that promoted cell proliferation. It was Dr. Matsubayashi who identified PSK as that substance. Furthermore, at that time, peptide hormones had been believed to exist just in animals, not in plants. Dr. Matsubayashi's discovery was so novel that peer reviewers of his paper were skeptical about it. This achievement opened up a new path for him as a researcher. At least it seemed so, but Dr. Matsubayashi felt unsure.

He confesses, "Researchers of this type were likely to end up as one-hit wonders."

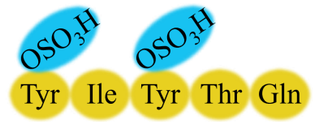
The laboratory that Dr. Matsubayashi belonged to was a group of researchers known as "molecule hunter," who identified active substances in natural products. Their usual move was to pick a phenomenon discovered by other biologists and identify the molecules involved in it. However, there was only a limited number of notable phenomena to pursue, and there was fierce competition in all of those research themes. It was not easy to be the first to discover an unknown hormone, but such tough circumstances did not discourage Dr. Matsubayashi. What should such researchers rely on when making their next move?

His answer to this question is: "I should look back on the path I have taken."

PSK, the above-mentioned peptide hormone, is a small molecule consisting of five amino acids linked in this order: tyrosine-isoleucine-tyrosine-threonine-glutamine. As a point of information, large molecules with a large number of amino acids linked together are called "proteins," while small molecules with a small number of amino acids linked together are called "peptides." After examining all the conditions he could think of, including heat resistance, molecular size, and resistance to enzymatic digestion, Dr. Matsubayashi analyzed the peptide and succeeded in determining the amino acid sequence it contained.

Conceptual diagram of amino acids contained in the peptide hormone PSK

Things did not end there. Mass spectrometry showed that the sequence weighed 846, which was 160 more than five amino acids. This fact led to the discovery of the structure of the sequence: a sulfate group with a weight of 80 was attached to the first and third tyrosines.



Conceptual diagram of the peptide hormone PSK with sulfate groups attached

After being translated from a gene into a molecule made up of amino acids, it needed further modification in order to function. Because peptide hormones are small, they can easily diffuse between cells, making it convenient for the cells to exchange information. On the other hand, with a limited number of amino acids, it is difficult to increase the variation of hormones. These molecular backgrounds are presumed to be one of the reasons why post-translational modifications such as sulfate groups are made, despite the use of energy.

"This is knowledge from organic chemistry," Dr. Matsubayashi remarks. "It is the world of chemistry."

Dr. Matsubayashi has always loved and studied both biology and chemistry, and has utilized their knowledge in his research. His skill in precisely determining chemical structures gave him a great advantage. Furthermore, he incorporated genetic analysis, which was cutting edge at the time, into his research. Dr. Matsubayashi talks about "the perfection of molecule hunter that I would aim for if there were such a thing."

"That would be to search for hormones from the molecular side rather than relying on biologists' papers. The culmination of my research is to use chemistry to explore phenomena that even biologists do not know about."

This is the general process he follows. First, he reads genome information to find candidate genes that are likely to become hormones. After finding molecules that have been translated from genes and modified, he performs mass spectrometry to determine their structures. Finally, he synthesizes the molecules and investigates the biological phenomena they cause. Dr. Matsubayashi has established this process as his original research style. It is in the reverse order to the normal molecule hunter's approach, which uses biological phenomena as a starting point.

One of the mass spectrometers he regularly uses. By watching technicians who came for repairs, Dr. Matsubayashi learned how to do simple repairs.

"Ideas spread in an instant, but skills cannot be easily copied," Dr. Matsubayashi explains. "Researchers need both ideas and skills, but I believe that skills are just as important, if not more so, than ideas."

His discovery of a receptor defied the common wisdom in the world

If a hormone is compared to a ball, it needs a receptor, just as a ball needs a glove.

"Looking back, I think I did a great job," Dr. Matsubayashi recollects. "After the discovery, I started to get recognized little by little."

At the time, the world was still skeptical about recognizing PSK as a hormone. In fact, Science passed to publish his paper on PSK at the time. The tide changed, however, in 2002, when the team of Dr. Matsubayashi discovered the receptor for PSK. He skillfully manipulated PSK to purify a PSK-binding protein, from which he derived genetic information, and he confirmed that it contained information on sites commonly found in receptors. Dr. Matsubayashi also confirmed that excessive production of this protein promoted cell proliferation. The protein proved to be the receptor for PSK. The results of this study were published in *Science*, and Dr. Matsubayashi was brilliantly vindicated six years after the discovery of PSK.

The skills they developed in this finding were important for subsequent research. Hormones and receptors exist in pairs. If one side of a pair is identified, that is a powerful clue to finding the other side of the pair. It is also possible to tell when and where certain cells communicate, and this knowledge is useful for elucidating specific mechanisms. For example, it was predicted at the time that two molecules, CLV1 and CLV3 (*clav*ata 1 and 3), were involved as hormones and receptors in the continued production of the cells from which stem tips derive their leaves and flowers. However, no one had been able to prove it. Dr. Matsubayashi's research group investigated the structures of these two molecules and found that CLV3 is a peptide hormone and that CLV1 is a receptor, and they bind directly. His group had unparalleled momentum that no other research group could match.

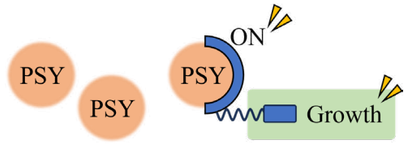
"Science is art": Using unique skills, Dr. Matsubayashi pursued the mystery of the peptide hormone PSY for 15 years

Of course, not all of his research projects went smoothly. One

of his uphill struggles was research on the new peptide hormone PSY (plant peptide containing sulfated tyrosine). Based on the characteristics including the post-translational modification of sulfate groups, Dr. Matsubayashi made the discovery of PSY and published it in 2007. He found that PSY promotes root growth and cell proliferation, and that it has a role similar to that of PSK, the first peptide hormone he discovered. However, elucidation of PSY's specific function did not go as smoothly as expected. After a 15-year struggle, he finally got the whole picture in 2022.

"I was uneasy about whether it was really a hormone," Dr. Matsubayashi recalls. "But at the same time, I was confident. Although the function was still unknown, there was post-translational modification, and the receptor had been identified. These facts had helped me stay motivated for 15 years."

When a hormone binds to its receptor, a certain function is turned on. According to this idea, for example, when the peptide hormone PSY binds to its receptor, root growth must be promoted. In fact, Arabidopsis plants that cannot properly produce PSY have shorter roots. In order to confirm the hypothesis, Dr. Matsubayashi added artificially synthesized PSY to them, and the roots grew long.

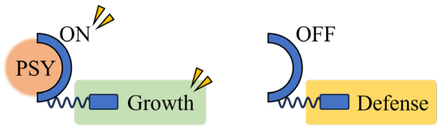


Conceptual diagram of PSY binding to its receptor. In this case, the roots grow long.

So, what happens in the case of Arabidopsis plants that have PSY but lack a receptor? The PSY has no receptor to bind to, so here again, there is no PSY-receptor pair. Despite this, the Arabidopsis plants that lacked the receptor grew roots steadily.

Conceptual diagram of receptor deficiency. In this case, the roots grow long.

Is there any unknown receptor that PSY binds to? Or does PSY have another function? Then, Dr. Matsubayashi created Arabidopsis that could not produce PSY or its receptor. Again, the roots grew longer than expected. This indicated that he was missing something about the receptor. As a matter of fact, the receptor had the ability to put a "brake" on growth when it was not bound to PSY. When bound by PSY, the receptor releases the brake, allowing growth. Accordingly, when the receptor is missing, so is the brake, and in this case too, the roots grow long.



Conceptual diagram of switching based on PSY-receptor binding. When the receptor is not bound by PSY, it puts a brake on growth, and, as described below, the cells prioritize stress responses.

Further genetic analysis revealed that when growth is put on hold by the receptor, energy is preferentially spent to deal with stresses, such as high salt concentration, high temperature, or disease. Under normal conditions, individual cells constantly release PSY, which binds to the receptor in other cells, causing the plant to keep growing. In contrast, when a cell breaks down, the cells around it undergo a decrease in PSY concentration. Then, the receptor in these surrounding cells is unable to be bound by PSY, preparing for stress responses rather than growth. In other words, there proved to be a mechanism to detect that something strange had happened in the event of a loss of "regular reports" between cells.

Plants have steadily evolved to adapt to various environmental changes, but such a sophisticated mechanism is beyond our imagination. In this way, the research group led by Dr. Matsubayashi uncovered another plant mechanism that could almost be called artistic, as a result of the constant ambitious efforts they had made while believing in the skills they had built up by themselves.

Dr. Matsubayashi's research group has a variety of unique skills, including the precise determination of molecular structures based on chemical knowledge, genetic analysis, and the search for candidate molecules that are pairs of peptide hormones and receptors. Mainly through research with members of his own group, Dr. Matsubayashi pursues what he is eager to know.

"To me, science is art, not business," he argues. "If I compare my team to a group of painters, we do not divide our work too finely, like assigning the sketching to painter A and the coloring to painter B. Each person works on what they want to depict, and they want to see it through to the end. We want to write an academic paper that we would want to frame and display. If our papers were displayed anonymously, they would probably be recognizable as ours."

唯一無二の研究を描く
―圧倒的な技術力で切り拓くペプチドホルモンの世界

松林　嘉克
名古屋大学大学院
理学研究科 理学専攻 生命理学領域 教授

植物ペプチドホルモンとその受容体を世界に先駆けて発見し続け、SCIENCE誌など有名学術誌への掲載多数。化学と生物両方の知見から生み出す独自のアイデアと技術で専門分野を牽引し続けている。

松林さんがはじめに所属していた研究室は、"もの取り屋"と呼ばれる研究一派。ほかの生物学者が見つけた現象をピックアップし、関与する分子を取り出すことがセオリーだった。たとえば昔、「細胞増殖を促す謎の物質がある」と研究界で注目されていた。1996年、世界に先駆けて松林さんが突き止めた分子が、細胞同士のコミュニケーションに欠かせないホルモンの一つ、植物ペプチドホルモンPSK（phytosulfokine）だった。しかし、「私が目指す、もの取り屋の完成形があるとしたら」と松林さんは話す。

「生物学者の論文に乗っかるのではなく、分子側からホルモンを探す。こんな現象は生物屋も知らないよ、というところに、化学をつかって攻め込むのが自分の研究の到達点と考えました」

昔から生物も化学も好きで両方学び、研究に生かしてきた。松林さんには、分子の質量を分析し、化学構造を精密に決定する技術があった。

「アイデアは一瞬で拡散します。ですが、技術というのはそう簡単に真似されません。研究はアイデアと技術の両方が大事ですが、技術はアイデア以上に大事だと僕は思っています」

愛用する質量分析計の一つ。修理に来た技術者のようすを観察して、今では簡単な修理なら自身でできるようになった

まずはゲノム情報を読み、ホルモンになりそうな遺伝子候補を見つける。次に遺伝子から翻訳された分子の質量分析を行い、構造を特定する。そして分子を人工的に合成し、最後に関連する生物現象を調べる。これが大まかな一連の流れだ。生物現象を出発点とする"もの取り屋"の方法とは逆の順序。今では独自の研究スタイルとして確立し、松林さんの研究グループは世界が驚く研究成果を生み出し続けている。

もちろん、すべての研究が順調にいったわけではない。その一つが、ペプチドホルモンPSY（plant peptide containing sulfated tyrosine）の研究だ。化学的なアプローチにより最初に発見したのは2007年。しかし、その具体的な機能の解明が思うように進まなかった。苦節15年。その全容が明らかになるのはなんと2022年のことだった。

植物は、環境変化ストレスや病害虫からの攻撃を受けたとき、成長に回していたエネルギーを防御に振り分ける必要がある。組織的に動くためには細胞が、「危険が迫っている」と隣の細胞に次々と知らせなければならない。危機に陥った細胞がシグナルを出し、別の細胞がそれを受け取ることで伝達されるというのが一般的な理解だった。

しかし、壊れゆく細胞にそのシグナルを出す余裕があるだろうか。実は、危険を伝える方法にはもう一つある。ペプチドホルモンPSYは定時連絡に必要な分子だったのだ。危険が迫っていない通常時はペプチドホルモンPSYが各細胞から常に分泌され、一定の濃度が保たれている。ところが、ある細胞が急に壊れると、その周辺の濃度が下がる。つまり、定時連絡が途絶えたとき、「何か問題が起きている」とほかの細胞が察知する仕組みがあったのだ。

植物は様々な環境変化に順応するよう進化を積み重ねてきた。しかし、これほど巧みな仕組みを備えているとは驚きだ。松林さん率いる研究グループは、自ら積み上げてきた技術への信頼を頼りに挑戦を続け、もはや芸術的ともいえるような植物の機構をまた一つ、明らかにした。

松林さんの研究グループには、化学の知見をもとにした精密な分子構造の決定、遺伝子解析技術、ペプチドホルモンとそれをキャッチする受容体をセットにした候補分子の探索など、多様な独自の技術がある。知りたいことを、自身の研究グループを中心に追及している。

「サイエンスはビジネスではなくアートだと思います。絵描きにたとえるなら、下絵はあなた、色付けはあなた、のような過度な分業はしません。自分が表現したいことを描きます。自分が見届けたくて、学術論文を書いて、額に飾りたいくらい。私たちの論文は、著者を隠されても、私たちのものだとわかると思います」

Special Interview 3

Mizuki Tada

Professor, Laboratory of Inorganic Chemistry, Research Center for Materials Science / Graduate School of Science, Nagoya University

Studying the solid catalysts of inorganic materials, Dr. Tada works on both the synthesis of new catalysts and the visualization of active catalyst structures and catalysis. She organizes various collaborative researches with industry such as fuel cell for automobiles and rubber tire.

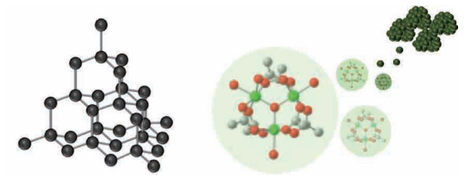
Meeting people, Learning societal needs, and Arranging new "Chemical Reactions"

Addressing longstanding challenges in catalyst research

"Many catalysts have been used in modern society, but solid catalysts are complicated. It is quite difficult to understand the structures of active species in real catalysis."

For examples, diamond has a crystalline structure in which carbon atoms are orderly arranged in a particular pattern. In contrast, the structures of solid catalysts that Dr. Tada studies are complicated and heterogeneous. A solid catalyst is composed of particles, whose sizes and structures are heterogeneous, and they are attached on a support material. However, this heterogeneity is essential in real catalysis. How do they work? Where do catalytically active sites locate? To understand them on a fundamental level, it is necessary to utilize not only synthetic approach but also techniques to "visualize" working catalysts.

There are various approaches in studies on catalysts and catalysis, and various knowledge and skills have been required, such as the synthesis of new materials, the developments of reaction processes. In general, catalysts are prepared by the huge repetition of synthetic trial-and-errors and catalyst tests. The details of their active structures and catalysis are often found

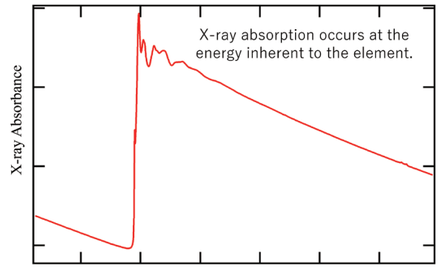


(Left) The crystal structure of diamond. (Right) An image of a Ru3 complex precursor and a Ru cluster catalyst prepared from the precursor. There are various Ru clusters in a variety of sizes and shapes, and they are dispersed on the surface of a solid oxide support. (Dispersed Ru nanoclusters transformed from a grafted trinuclear Ru complex on SiO_2 for selective alcohol oxidation, S. Muratsugu, M. H. Lim, T. Itoh, W. Thumrongpatanaraks, M. Kondo, S. Masaoka, T. S. A. Hor, and M. Tada, *Dalton Trans.*, 42, 12611-12619 (2013))

afterwards. Most of present catalysts currently used are still black box without understanding their catalysis.

The laboratory Dr. Tada belonged when she started her research activities focused on the developments of new physicochemical methods for catalysis researches, and developed measurement techniques to identify the local structures of solid catalysts, called X-ray Absorption Fine Structure (XAFS). This method uses high-energy hard X-rays and the transmission and absorption behaviors of X-rays depend on materials being irradiated. For examples, in X-ray

imaging applied for medical diagnosis, parts that strongly absorb X-rays appear white (e.g. bones), while parts with weak X-ray absorption through the sample appear black. XAFS data is measured by changing the energy of X-rays and recorded X-ray absorption at each energy, which suggest us the amount of a particular element and neighboring atoms. It is a powerful technique for identifying the local structures of catalysts.



A typical XAFS spectrum of a copper compound. The horizontal axis represents X-ray energy (unit: eV), while the vertical axis represents X-ray absorption. Analyzing the sharp jump in the X-ray absorption (absorption edge) and subsequent oscillations indicate bonding with neighboring atoms.

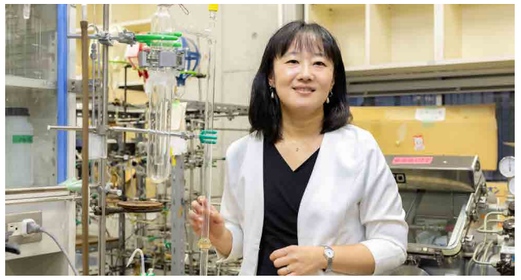
"When I was a Ph.D. student, I would like to synthesize new catalysts and then out of necessity, I also became involved in the characterization of catalysts. I'm always interested in what synthetic researchers would like to know for their researches on material synthesis."

Method to discern the individuality of catalyst

"Catalyst composed of multiple materials contains multiple structures with different activity. I thought that it was necessary to visualize the individuality of catalyst to understand real catalysis."

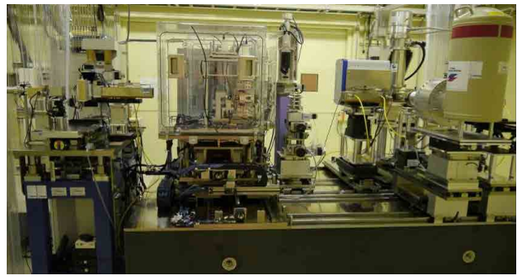
Although the XAFS method has been widely developed over the past 30 years, there have been still challenges in identifying structural differences inside an individual catalyst particle because of the limitation of the X-ray beam size, which was too thick to catch a single catalyst particle. There are large distributions of catalyst particles and the location of active sites and large X-ray beam cannot tell us the individual information of the catalyst particles.

In 2008, when Dr. Tada moved to the Institute for Molecular Science, she happened upon a state-of-the-art technique for her study. The X-ray nano-beam, which was focused X-ray



beam with nano size, was developed at the large synchrotron radiation facility SPring-8. She asked the collaboration using the X-ray nanobeam and brought her samples whose catalyst particles were spread on a support surface. She finally succeeded in revealing the active structure of an individual catalyst particle for the first time, using the X-ray nanobeam.

SPring-8, a large synchrotron radiation facility, located in the Harima Science Garden City in Sayo-cho, Sayo-gun, Hyogo Prefecture, Japan (Copyright: RIKEN)



Equipment at the beamline Dr. Tada used for her experiments

Personal drive is the criterion of research

"Practical issues at industrial frontlines will also accelerate basic research."

While conducting advanced imaging research using the XAFS methods, she met researchers of an automobile company. She was overwhelmed by their desperate efforts to deal with various issues facing in their research and development of hydrogen-powered fuel cell vehicles. As the actual operation of fuel cell vehicles progressed, new development issues rapidly appear. However, it is not easy to look inside a fuel cell under operation. Where are degraded parts inside a fuel cell? How do they find and diagnose them rapidly? To find any hint for better understanding of the practical issues, collaborative research was proposed to Dr. Tada.

"I decide the action of my research by personal drive."

At the time, Dr. Tada had never been involved in research about fuel cells, and she didn't know basic research terms in the field. Nevertheless, she participated in the collaborative research without hesitation. Personal drive with eagerness and energy moves researchers and a great team conducts great research. This belief is her unwavering criterion in deciding the action of collaborative research, even to this day.

“Even with a sophisticated research theme, there will always be a big wall at difficult turning points. During such moments, the strong motivation and drive of researchers break through the difficulties to achieve the goal. Moreover, it’s essential that everyone involved shares the clear vision of the goal.”

In addition, when she starts collaboration with a company, she considers that understanding of basic research is important. As long as her research is conducted at a university, obtained results are common and widely available to the public. Collaboration with a company with understanding of basic research provides the progress of research that cannot be done by university or company alone and strong relationship between academia and industry generates that allows for mutual development.

The collaborative project finally led to large-scale national research and development programs. Now, she enabled to visualize reactions and degradation in fuel cells in three dimensions using the powerful X-rays of SPring-8 and researchers in all over the world can use this method.

These researches subsequently promoted the fusion of basic research and industrial applications using synchrotron radiation. As seen in the development of the next-generation synchrotron radiation facility, NanoTerasu, scheduled to commence operation in April 2024, research using synchrotron radiation has now become a major platform attracting researchers from both academia and industries.

Next-generation synchrotron radiation facility, NanoTerasu, located at the Tohoku University Aobayama New Campus in Aoba-ku, Sendai City, Miyagi Prefecture. The energy and properties of X-rays are different from SPring-8.

“What is the request from society?” The importance of meeting people and understanding their perspectives

Dr. Tada has been engaged in fusion research with researchers in different fields of expertise and collaborative research with various companies even now. It is impressive that she participates in extensive collaborations across diverse fields while maintaining a solid foundation in her original field of expertise.

“People who constantly keep their ear to the ground of outside fields can stay stron g. Those who merely wait until the time is right within their own fields are difficult to acquire a new approach.”

Of course, there is a path of refining one’s knowledge and skills to master in the same field for 40 or 50 years. However, greatness is comparative, taking the lead among pioneers in that field is a daunting challenge. While emphasizing the importance of making efforts and building a foundation supporting one’s research within affiliated laboratory, Dr. Tada also looks outside her own field. She often recognizes surprisingly that what is common in her field is unknown elsewhere. She thinks that it is important to learn what people in other fields would like to know and what values they hold.

Dr. Tada has an anecdote from her student days, when she actively explored various adjacent fields outside her chemistry area.

“My supervisor at the time often told me that when we get older, we will tend to avoid embarrassment more so that when you are young, you should explore and present your research in different fields anyway.”

In her fourth year of university, her first academic conference was one organized by the Chemical Society of Japan, but she joined that of the organic chemistry session not of the catalytic chemistry session. “I was fearless,” she says. She later attended meetings and conferences when and wherever she was called by, such as those of the Physical Society of Japan, engineering science societies, and national or international companies. She was surprised by difference in atmosphere, with everyone wearing suits at conferences of the Chemical Society of Japan and otherwise with no one wearing formal at those of the Physical Society of Japan. Positions vary between basic and applied, and between disciplines. Even the choice of words to describe the same research in different fields is completely different.

“I met various researchers. Chemists have their own way of thinking, as do physicists, and engineers. Knowing different values will help understanding my own field strengths and weaknesses.”

Different individuals from various backgrounds construct community, and create new values. The crux lies in how much one can understand what society currently needs.

“Always keeping antennas tuned to the outside world, maintaining a solid foundation in one’s research field of expertise while cultivating interest in diverse subjects, and not being afraid to ask questions of others and learn from them—these three elements are crucial. Surprisingly, there seem to be few people who are willing to ask others to teach them something they don’t know.”

人と出会い、社会が求めていることを知り、新しい化学反応を起こす

唯　美津木
名古屋大学 物質科学国際研究センター／
大学院理学研究科 無機化学研究室 教授

無機材料の触媒を中心に、その合成と反応開拓、および触媒構造と反応の可視化など幅広い研究を行う。自動車の燃料電池やタイヤゴム開発などの産業分野との共同研究も多数手がけている。

研究は人で決まる〜壁を突破する情熱はあるか

「触媒は実際に「使える」ことが重要で、反応機構や原理はよくわかっていないものもたくさんあるのが現状だ。そうした触媒の構造を捉える計測技術の一つにXAFS（ザフス；X線吸収微細構造）法がある。エネルギーを変えながらX線を試料にあて、その吸収を測定することで、特定の元素の量や結合の状態を分析できる。2008年ごろには大型放射光施設SPring-8（スプリングエイト）を活用する機会に恵まれ、さらに精密な新しい分析方法の開発にも成功した。極細のX線ビームを応用し微細な粒一つひとつにあて、世界で初めて、触媒一粒の活性種の結合を明らかにすることができた。

大型放射光施設SPring-8。兵庫県佐用郡佐用町の播磨科学公園都市に設置されている(提供:国立研究開発法人理化学研究所)

XAFS法を使った先端研究を進める中で、自動車会社の研究者と出会った。研究開発で壁にぶつかっている様々な課題を何とかしたいと向き合うその必死な姿に圧倒された。水素を燃料とした燃料電池車の開発。動作中の電池の中のどこがどのように悪いのか、その場で診断する方法がなかった。当時、唯さんは燃料電池を触ったこともなく、基礎的な研究用語もわからなかった。新しいことをやろうとする熱意に動かされ、躊躇することなく、共同研究を開始した。

研究はやがて、国の大型研究開発プログラムへと発展した。SPring-8の強力なX線を使い、電池内で起こる反応や劣化の様子を、電池が「動いている」その場で三次元的に可視化できるようになり、国内外の研究者がこの方法を使うようになった。この研究成果はその後、放射光を利用した基礎研究と産業応用を後押しすることとなる。2024年4月に運用が開始される次世代放射光施設ナノテラスの整備に見られるように、今やX線をはじめとした放射光を利用する研究は、様々な業界の研究者が集まる大舞台となっている。

次世代放射光施設ナノテラス。SPring-8と比較すると、X線のエネルギーや性質が違い、SPring-8は硬X線、ナノテラスは軟X線を得意とする。宮城県仙台市青葉区の東北大学青葉山新キャンパスに整備されている

「社会が知りたいことは何か？」人と出会い、相手の立場に立つ大切さ

自身の分野では当たり前であることが他の分野では案外知られていない、ということも多い。他の分野の人は何を知りたいのか。どんな価値観を持っているのか。「まずは所属した研究室でスキルを積み重ね、自分の研究の軸となる基盤を作ることが大切」としつつも、少し外の分野も顔を出してみるのだそうだ。そんな唯さんには、化学から飛び出て近隣分野に切り込んでいった学生のころのエピソードがある。

大学4年生のころ、初めて出た学会は日本化学会。ただし、触媒化学のセッションではなく、有機化学のセッションだった。「怖いもの知らずでした」と、その後も物理学会から工学系の学会、国内外の企業など声がかかるたびにどこへでも赴いた。日本化学会はスーツで行くが、物理学会では誰も正装していないなど、その雰囲気の違いにも驚いたそうだ。基礎と応用の違い、分野の違いなど、立場は様々。同じ研究でも、それを表現する言葉の選び方すら全く異なる。

「いろんな先生と知り合いました。化学の人には化学の人の考え方がある。物理には物理、工学には工学。様々な価値観を知ることで、自分の専門の強さと弱さがわかります」

立場が違う人たちが社会をつくり、そして新たな価値を生む。いま社会が求めていることを、どれくらい知ることができるのかが勝負どころだ。

「常にアンテナを外の世界に張ること。専門の軸足はきちんと持ちつつ何でも興味をもつこと。知らないことを人に聞き、教えてもらうのを恐れないこと。この三つが大切です。案外、知らないことを『教えてください』と言える人は少ない気がしますね」

Nagoya University's Institute for Advanced Research (IAR) was able to organize several on-site events this year, including international conference.

The 6th Institute for Advanced Webinar × MEBINAR

A special edition of Nagoya University Online Seminar "MEBINAR" and IAR Webinar "The truth revealed by Egyptian archaeology and cosmic ray imaging" was held on March 20, 2023.

Dr. Yukinori Kawae and Dr. Kunihiro Morishima, two researchers from different fields, were invited, and the discussion was streamed through online. Dr. Kawae specializes in Egyptian archaeology and is trying to clarify the structure of the three great pyramids of Giza using precise three-dimensional measurements, and Dr. Morishima specializes in cosmic ray imaging and is developing technology that allows him to see through the interior of huge structures like an X-ray by observing muons, which is a type of cosmic ray. After the introduction of their research, they discussed various topics, such as an explanation of the news announced on March 2, 2023, which identified an unknown space in the world's largest Pyramid of Khufu.

Celebrating Interdisciplinary Excellence: Dr. Zahi Hawass Receives Honorary Doctorate at Nagoya University

On September 29, 2023, Nagoya University's School of Humanities and IAR hosted an event to confer an honorary doctorate on Dr. Zahi Hawass, a renowned Egyptologist. The ceremony took place at Sakata-Hirata Hall. The day began with a courtesy visit to University President Dr. Naoshi Sugiyama, followed by the award ceremony, moderated by Tatsuro Ayatsuka, a science communicator. Dr. Yoshiyuki Suto, Dean of the School of Humanities, delivered the opening remarks, and then President Sugiyama delivered his insightful speech, which highlighted the University's interdisciplinary ethos, particularly in Egyptology. Vice President Dr. Kenji Kadomatsu extended his congratulations. This was succeeded by Dr. Hawass's eagerly anticipated lecture that was fully attended, reflecting the high interest and respect for Dr. Hawass's work. The lecture delved into recent archaeological findings in the Giza area. Associate Professors Dr. Kunihiro Morishima and Dr. Yukinori Kawae further enriched the program with their presentations, underscoring the collaborative and interdisciplinary nature of their research on the Great Pyramid at Giza. Dr. Kunio Awaga, Director of the IAR, delivered the closing remarks, and this was followed by a luncheon organized by NTP Seventh Co, LTD. The ceremony and lecture showcased Nagoya University's commitment to blending scientific research with the humanities, and the full attendance at Dr. Hawass's lecture spoke volumes about the academic community's enthusiasm for Egyptology and interdisciplinary studies.

The 10th IAR Symposium

October 11, 2023

The IAR symposium aims to communicate Nagoya University's established, novel, and cutting-edge research to the wider university community and beyond. This 10th symposium focused on the rapidly evolving potential of AI in recent years, particularly exploring the theme of whether AI brings about new discoveries in academia, and discussions took place among researchers in various fields related to AI. Dr. Takeda from the Graduate School of Informatics spoke about generative AI and its impact; Dr. Tsugida from the Graduate School of Informatics discussed the large language model from the perspective of linguistic philosophy; Dr. Ito from the Graduate School of Informatics and Engineering at the University of Electro-Communications addressed Shogi, Go, and AI; Dr. Sugishita from the Graduate School of Science at Kyoto University delved into the intersection of physics and AI; and Dr. Katsuno from the School of Medicine presented on the use of AI in medicine. In addition, with Dr. Tanimura from the Graduate School of Informatics serving as the moderator, panel discussions on the themes of AI and language/culture and AI and science/humanity were conducted featuring speakers.

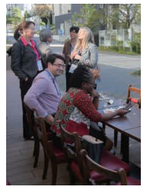
University-Based Institutes for Advanced Study (UBIAS) Directors MeetingUniversity

The UBIAS Directors Meeting, hosted by IAR, took place from October 30 to November 1, 2023, bringing together esteemed directors of Institutes for Advanced Study and scholars from around the world. The event commenced at the Center for Asian Legal Exchange Plaza with a reception and opening session, including welcome addresses by Nagoya University representatives and the UBIAS Coordination team: Prof. Olivier Bouin from the French Network of Institutes for Advanced Study (Paris, France), Profs. Grace Diabah and Susann Baller of the Merian Institute for Advanced Study in Africa (Accra, Ghana), and Prof. Kunio Awaga, Director of Nagoya IAR. The first day focused on the evolution and reach of UBIAS, featuring a panel discussion about its foundation,

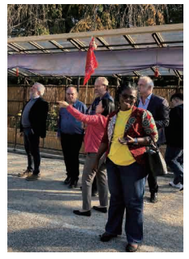



development, future, and global impact. Key topics included promoting interdisciplinary scholarship, fostering global diversity in scientific exchanges, and supporting young scholars. The evening concluded with a dinner gathering. The second day's sessions were held at the historic Yagoto-san Koushoji temple, commencing with a traditional Japanese tea ceremony. This day's agenda revolved around thematic sessions, starting with "Sensing Invisibles and Society Change." The session highlighted Nagoya University's expertise in visualization technologies and their applications in understanding complex phenomena like environmental contamination and pandemic impacts. This was followed by a session on "Digital Humanities" and "Artificial Intelligence," exploring the intersection of technology with humanities and the transformative impact of AI across various sectors. The afternoon saw discussions on "Energy/Environmental Transitions," addressing critical global challenges such as climate change and sustainable energy solutions. The final day, located at the Center for Asian Legal Exchange Plaza, was dedicated to the UBIAS Business Meeting. Key topics included membership, decentralized operations,










prospects for ICA 5, the Topic of the Year 2024, and new collaborative initiatives. The meeting concluded with an excursion to Nagoya Castle, providing a moment of relaxation and reflection. Throughout the event, thematic sessions included Nagoya University faculty's opening speeches, followed by UBIAS members' presentations and panel discussions. Overall, the UBIAS Directors Meeting was a testament to the power of interdisciplinary research and global collaboration in academia, addressing contemporary challenges and fostering innovation for a better future.



2023 Young Leaders Cultivation (YLC) Program

The YLC program is a strategic program of Nagoya IAR based on the premise that it is crucial to secure an appropriate quantity and quality of young researchers to sustain the development of outstanding education and research in the future. The Nagoya IAR recruits and trains young faculty members regularly and systematically. In the academic year 2023, Dr. Keiko Kawano (Graduate School of Humanities), Dr. Satoshi Ikegaya (Graduate School of Engineering), Dr. Jia Wang (Institute of Materials and Systems for Sustainability), Dr. Atsushi Usami (Institute of Transformative Bio-Molecules), Dr. Shohei Saga (Kobayashi-Maskawa Institute), Dr. Yuki Sugiyama (Graduate School of Science), Dr. Shohei Iyoshi and Dr. Koyo Tsujikawa (Graduate School of Medicine), and Dr. Fanny Bellegarde (Graduate School of Bioagricultural Sciences) were newly employed as designated assistant professors of the YLC program.

YLC Seminar

The YLC seminar aimed to provide members with opportunities in order to understand each other's research interests to assist in interdisciplinary collaboration research. The 30th YLC seminar was organized in Hybrid on March 3, 2023. Dr. Su Matthew Paul (Graduate School of Science) talked about "Exploring the mechanisms linking the circadian clock, hearing and copulation in mosquitoes," and Dr. Hideki Umehata (Graduate School of Science) talked about "Cosmic web filaments and galaxy evolution." The 31st YLC seminar was organized in Hybrid on June 9, 2023. Dr. Minoru Hirose (Graduate School of Mathematics) talked about "Exploring the world of multiple zeta values," and Dr. Sanae Ito (Graduate School of Humanities) talked about "State communications in the Assyrian Empire." The 32nd YLC seminar was organized in Hybrid on December 1, 2023. Dr. Elena Kozgunova (Graduate School of Science) talked about "Cells within a cell: novel chloroplast

division gene discovered through genetic screening," and Dr. Satoshi Ikegaya (Graduate School of Engineering) talked about "Topological condensed matters and beyond: Multi-locational Majorana zero modes."

YLC Collaborative Research Grant

The YLC collaborative research grant was launched in 2018 to support the interdisciplinary collaboration between YLC faculties. YLC faculty voluntarily organized the grant contents, schedule, and selection process. In this year, YLC selected two research groups: one group was led by Dr. Sanae Ito (Graduate School of Humanities) with the title "Analyzing and Contextualizing Solar Eclipses in the Ancient East" and the other by Dr. Yuichiro Tada (Graduate School of Science) with the title "Physics meets Mathematics."

"Invitation to the Advanced Researches" IAR Lecture Series

This lecture series includes lectures by the IAR academy and faculty members, IAR fellows, and Nagoya University researchers and targets Nagoya University students. This series aimed to communicate the fun of academic research. In the academic year 2023, there were 15 lectures that occurred online:

1."Science Started from Observation,"
Prof. **Sumio Iijima**
(Guest Professor at Nagoya University and Professor at Meijo University)

2."The Dark Side of the Universe,"
Prof. **Naoshi Sugiyama**
(President of Nagoya University)

3."What are building blocks of the universe?,"
Prof. **Yoshitaka Itow**
(Institute for Space-Environmental Research)

4."Material Science—Fun and Useful,"
Prof. **Ichiro Terasaki**
(Graduate School of Science)

5."The Present in Historical Studies: Excavate the Hellenism Civilization,"
Prof. **Yoshiyuki Suto**
(Graduate School of Humanities and Eighth Director of IAR)

6."Analyzing society and economy through the eyes of game theory,"
Prof. **Akihiko Yanase**
(Graduate School of Economics)

7."Exploring underground structure with seismic wave,"
Prof. **Koushun Yamaoka**
(Graduate School of Environment)

8."Analyze Democracy,"
Prof. **Hiroko Takeda**
(Graduate School of Law and Deputy Director of Nagoya IAR)

9."Fascination with an Introduction to the History of Thought,"
Prof. **Takaho Ando**
(Chukyo University and Sixth Director of Nagoya IAR)

10."Physical chemistry of energy and the environment,"
Prof. **Kunio Awaga**
(Director of IAR and Graduate School of Science)

11."Mechanisms underlying the mysterious existence life,"
Prof. **Kazuhiro Nakamura**
(Graduate School of Medicine)

12."Unraveling life systems using chemical and genetic approaches,"
Prof. **Shigeki Kiyonaka**
(Graduate School of Engineering)

13."Signaling Molecules Make Plant Life Resilient,"
Prof. **Hitoshi Sakakibara**
(Deputy Director of IAR and Graduate School of Bioagricultural Sciences)

14."Next-Generation Bio-imaging,"
Prof. **Shigehiro Yamaguchi**
(Graduate School of Science and Institute of Transformative Bio-Molecules)

15."Concluding the Course of Invitation to the Advanced Researches,"
Prof. **Yoshiyuki Suto**
(Eighth Director of IAR)

Short-Term Fellowship Program

To facilitate international scientific cooperation, this program supports short research visits of overseas researchers (maximum of 4 weeks), including related activities such as holding a symposium. In the academic year 2023, Dr. Alstair Phillips (Professor at Warwick University), Dr. Sakiko Okumoto (Associate Professor at Texas A&M University), and Dr. Yavuz Duvarici (Professor at Izmir Institute of Technology) were selected for this fellowship.

Foreign Principal Investigator Fellowship Program

The Foreign Principal Investigator Fellowship Program invites excellent researchers from foreign countries with outstanding research achievements for 3–4 months of fellowship to promote the Universities' academic research. In the academic year 2023, Dr. Guy Le Lay (Emeritus Professor at Aix Marseille University) was selected for this fellowship.

Awards

Dr. Kazuo Shonozaki
(Riken/Nagoya University) received the Japan Academy Prize (June 2023), The Order of the Sacred Treasure, Gold and Silver Star (November 2023), Highly Cited Researchers 2023, Clarivate (November 2023), and Best Scientists in the World 2023, Research.com (December 2023).

Dr. Hitoshi Sakakibara
(IAR/Graduate School of Bioagricultural Sciences) received Ishii Kenichiro Award (December 2023), Medal with Purple Ribbon (November 2023), Highly Cited Researcher (November 2023), and JSPP Award (March 2023).

Dr. Minoru Hirose
(IAR/Graduate School of Mathematics) received Frontiers of Science Award/International Congress of Basic Science (January 2023).

Dr. Hisashi Hayakawa
(IAR/Institute for Apace-Earth Environmental Research) received Young Scientists' Award from The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology (April 2023).

Dr. Koyo Tsujikawa
(IAR/Graduate School of Medicine) received Medical Research Award 2022 (February 2023).

Dr. Hideki Umehata
(IAR/Graduate School of Science) received MEXT The Young Scientists' Award (April 2023).

Dr. Atsushi Usami
(IAR/Institute of Transformative Bio-Molecules) received Award for Excellence/The Public Foundation of Chubu Science and Technology Center (December 2023) and Konica Minolta Research Planning Award/The Society of Synthetic Organic Chemistry, Japan (December 2023).

Uncover the function of epigenetic regulation in plants nitrate nutrition stresses and its memory

Fanny BELLEGARDE

Designated Assistant Professor of Young Leaders Cultivation Program
Graduate School of Bioagricultural Sciences/ Institute for Advanced Research, Nagoya University
E-mail: fannyb@nuagr1.agr.nagoya-u.ac.jp

INTRODUCTION

In natural environments, nitrate concentration of the soil fluctuates greatly and often limits plant growth and development. Therefore, the ability of plants to respond to changes in nitrate availability is essential for adaptation. Plants integrate local sensing and long-distance signaling to adapt their growth depending on nutrient availability.

Transcriptional regulation of gene expression is one of the most important processes plants use to adapt the properties of the root system in response to local and long-distance signaling [1]. The access to DNA information is controlled by the chromatin (association of DNA with histone protein), which different modifications, called epigenetic marks, target. These marks organize the genetic information by modulating the accessibility to DNA (Fig. 1). Epigenetic regulation is vital during plant development and in plant adaptation to stresses. Most epigenetic studies have been focusing on plant development. However, only a few studies investigated epigenetics' function in nutritional stresses.

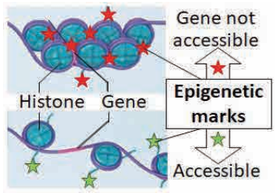


Figure 1. Epigenetic marks regulate access to DNA

EPIGENETIC FUNCTION IN LIMITED AND EXCESSIVE NITRATE NUTRITION STRESSES

To address this gap, I studied whether epigenetics regulates DNA expression of the main root nitrate transporter NRT2.1. This transporter is involved in absorbing nitrate from the soil to the root, especially when nitrate is limited. We showed that a strong repressive epigenetic mark (H3K27me3) deposited by the methyl-transferase CLF directly regulates the NRT2.1 gene, in a context where it is strongly expressed, to temper its expression [2]. This regulation reveals a novel non-canonical role for this mark as a safeguard for expressing highly expressed genes (genome-wide). We recently revealed that suppressing this limitation leads to massive RNA degradation and finally completely stops gene expression [3]. This work reveals the importance of fine-tuning expression by epigenetics for plant physiology, although it is not involved directly in nutritional regulation.

Then, we investigated the function of epigenetics in excessive nitrate stress response. We highlighted that excessive nitrate uptake leads to oxidative stress. Strong deleterious effects emerge if epigenetic regulations, the activation of detoxifying proteins counteracting oxidative stress, do not occur [4].

Our results show that epigenetic regulations protect plants from limited and excessive nitrate stresses.

EPIGENETIC FUNCTION IN PLANT ADAPTATION TO A FLUCTUATING NITRATE ENVIRONMENT

While researching epigenetic function in nitrate nutrition, I developed a research project studying epigenetic involvement in regulating an important plant growth hormone for long-distance nitrate signaling, the cytokinin (CK).

To this end, I performed a time-course experiment during nitrate fluctuation (nitrate-starvation-nitrate resupply). My results revealed that nitrate fluctuation modifies epigenetic profiles at IPT3 gene, a key CK biosynthesis gene. Mis-regulations of epigenetic settings strongly impact IPT3 regulation by nitrate fluctuation and CK content, revealing that the epigenetic modification constitutes a regulatory mechanism of IPT3 depending on nitrate availability (Fig. 2) [5].

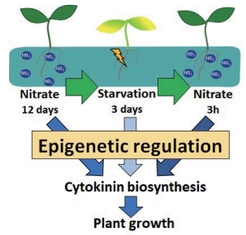


Figure 2. Epigenetic dynamically regulates hormonal synthesis depending on nitrate availability

CURRENT FOCUS

Accumulating evidence reveals that epigenetic regulation can also constitute a stress-induced environmental memory. Recently, I found that the first controlled starvation stress event can prime the plant to resist a second longer stress. Therefore, my current project aims to elucidate mechanisms by which plants can remember a past nitrate starvation stress event to tolerate a future, longer stress by studying the molecular, hormonal, and physiological changes during repeated nitrate fluctuation stress. My research focuses on the model plant Arabidopsis, as a tool of explorative research, to understand how this memory is set and connect epigenetic regulation with tolerance to nitrate fluctuation stress. Then, this knowledge will be employed to guide the research on crop species and develop a technology for producing tolerant-to-nitrate-fluctuation-stress seedlings.

REFERENCES

[1] Bellegarde F., Gojon A., Martin A., (2017) Signals and players in the transcriptional regulation of root responses by local and systemic N signaling in Arabidopsis thaliana. J. Exp. Bot. 68(10): 2553-2565.
[2] Bellegarde F., Herbert L., Séré D., et al., (2018). Polycomb Repressive Complex 2 attenuates the very high expression of the Arabidopsis gene NRT2.1. Sci. Rep. 8(1): 7905.
[3] Séré D., Cassan O., Bellegarde F., et al., (2022) Loss of Polycomb proteins CLF and LHP1 leads to excessive RNA degradation in Arabidopsis. J. Exp. Bot. 73(16) :5400-5413.
[4] Bellegarde F., Maghiaoui A., Boucherez J., et al., (2019). The chromatin factor HNI9 and ELONGATED HYPOCOTYL 5 maintain ROS homeostasis under high nitrogen provision. Plant Physiol. 180(1): 582-592.
[5] Bellegarde F., Tjahjono O., Shibutani M., et al. Fluctuation in nitrate availability impacts histone modifications of the cytokinin biosynthesis gene IPT3 in Arabidopsis roots (in preparation)

Topology in Superconducting Proximity Effects

Satoshi IKEGAYA

Designated Assistant Professor of Young Leaders Cultivation Program
Graduate School of Engineering / Institute for Advanced Research, Nagoya University
E-mail: ikegaya@rover.nuap.nagoya-u.ac.jp

INTRODUCTION

When a metal is attached to a superconductor, Cooper pairs which are quasi-particles responsible for the superconductivity penetrate the attached metal from the superconductor and subsequently modify the electromagnetic properties. This phenomenon is referred to as the superconducting proximity effect [1] and has been a central research topic in the physics of superconductivity since the 1950s. From the beginning of the 2000s, the proximity effects of anisotropic superconductors, such as high-Tc cuprate superconductors, have been studied intensively. In 2004, the proximity effects from spin-triplet nodal superconductors, a kind of anisotropic superconductors, were extremely unconventional. Specifically, in a junction of a spin-triplet nodal superconductor and a disordered metal, the differential charge conductance G at zero-bias voltage quantizes robustly at a very high value containing only universal constants and an integer number as

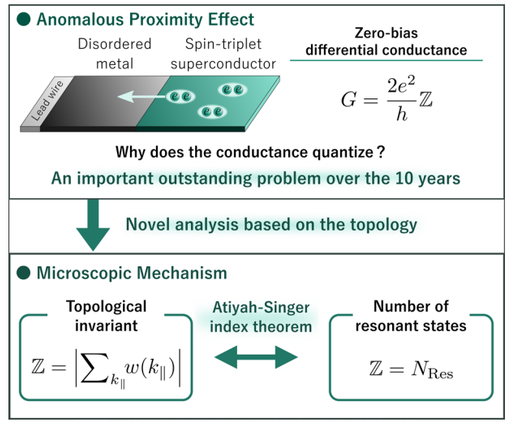
ven though the conductance of the disordered metal by itself is extremely low [2]. Here, e denotes the elementary charge, h is the Planck constant, and Z represents an integer number. Such dramatic proximity effect of spin-triplet nodal superconductors has been referred to as an anomalous proximity effect. In the 2010s, it was widely recognized that the anomalous proximity effect is related to exotic quasi-particles, such as Majorana particles [3] and odd-frequency Cooper pairs [4]. Therefore, the anomalous proximity effect became interesting in this research field. Nevertheless, a fundamental question, "why does the conductance quantize?", has remained unresolved for over ten years.

INDEX THEOREM

The quantization of physical quantities is sometimes related to mathematical invariants. For instance, when a strong magnetic field is applied to a two-dimensional electron gas, the Hall conductivity is quantized to a value characterized by a topological invariant called the Chern number [5]. The robustness of the quantization against impurities can be explained by the fact that the topological invariant is independent of the strength of the disordered potentials. Here, we have come to suppose that the conductance quantization of the anomalous proximity effect may be understood by employing some kind of topological invariants.

At first, by using quasi-classical Green's function techniques, we have obtained the analytical expression for the integer number characterizing the anomalous proximity effect:

where k_ represents a wave number parallel to the junction interface we consider. More importantly, we find that w(k_) is a one-dimensional winding number, a topological invariant characterizing the topological properties of the superconductor in the clean limit. Here, we see that the anomalous proximity effect is



indeed related to the topology [6,7].
The Atiyah-Singer index theorem mathematically relates a topological invariant with an invariant defined in terms of solutions of a differential equation. By combining this mathematical theorem with the Bogoliubov-de Gennes equation, a fundamental equation describing superconducting systems, we have proved that the topological invariant Z is exactly consistent with the number of the resonant states at zero energy, N_Res, which contributes to the charge conductance quantization [8,9]:
Z=N_Res.

CONCLUSION

We have microscopically understood the anomalous proximity effect by employing the Atiyah-Singer index theorem. Eventually, it turns out that the anomalous proximity effect is a novel type of topological quantization phenomena, an important research topic in condensed matter physics today.

REFERENCES

[1] A. F. Andreev, Sov. Phys. JETP 19, 1228 (1964).
[2] Y. Tanaka and S. Kahiwaya, Phys. Rev. B 70, 012507 (2004).
[3] N. Read and D. Green, Phys. Rev. B 61, 10267 (2000).
[4] Y. Tanaka and A. A. Golubov, Phys. Rev. Lett. 98, 037003 (2007).
[5] D. J. Thouless, et. al., Phys. Rev. Lett. 49, 405 (1982).
[6] S. Ikegaya, Y. Asano, and Y. Tanaka, Phy. Rev. B 91, 174511 (2015).
[7] S. Ikegaya, et. al., Phy. Rev. B 94, 054512 (2016).

Let the fat out of the bag: Revealing the role of adipose tissues as minions of ovarian cancer

Shohei IYOSHI

Designated Assistant Professor of Young Leaders Cultivation Program
Graduate School of Medicine / Institute for Advanced Research, Nagoya University
E-mail: iyoshi.shohei@med.nagoya-u.ac.jp

INTRODUCTION

Ovarian cancer (OvCa) is one of the most prognostically unfavorable tumors in gynecologic oncology. Due to the lack of noticeable symptoms and the absence of an established screening method, many cases are found in advanced stages with multiple metastatic nodules in the abdominal cavity, called peritoneal dissemination. In the formation of peritoneal dissemination, OvCa cells are known to exhibit a tropism to the tissues rich in adipocytes, including the greater omentum and mesentery. Removing all metastatic lesions completely during the initial surgery is difficult, and most cases experience recurrence. Therefore, understanding and controlling the pathophysiology of peritoneal dissemination are crucial in overcoming OvCa. Concerning the mechanism of how adipose tissues play roles in the peritoneal dissemination of OvCa, there are still a lot of unclear points. In this context, the crosstalk between adipose tissue and OvCa was investigated from basic and clinical research approaches.

DEDIFFERENTIATION OF ADIPOCYTE

When adipocytes obtained from surgically resected omentum were co-cultured with OvCa cells, it was observed that lipid-droplets were fallen out from adipocyte and the fibroblast-like cells appeared [1]. The obtained cells were named omental adipocyte-derived fibroblasts (O-ADF), and the characterization of O-ADF by flow cytometry analysis revealed that OADF possesses mesenchymal stem cell and myofibroblast-like features. Wnt/β-catenin pathway was identified as a key signaling pathway involved in this dedifferentiation process. Then, the effects of O-ADF on OvCa cells were examined, and co-culturing with O-ADF was confirmed to promote the growth and enhance the migration ability of OvCa cells. Supplementation of TGF-β1, known to exit in higher concentration in malignant OvCa ascites, showed further activation of O-ADF and increased these protumoral abilities. Upon pathway enrichment analysis with proteomic dataset of the OvCa cells co-cultured with O-ADF, pro-tumoral cellular pathways, such as glycolysis/gluconeogenesis, pentose phosphate pathway, and DNA replication, were confirmed to be enriched. These tumor-supportive roles of O-ADF were also confirmed in vivo using OvCa-disseminated mouse models. From this basic research approach, O-ADF induced by OvCa cells contributed to the neoplastic growth of OvCa at adipocyte-rich tissues in the abdominal cavity (Figure 1).

OBESITY AND THE STEALTH MICRO-METASTASIS

The effect of adipose tissue upon the sprout of OvCa from stealth micro-metastasis was analyzed using a multicenter retrospective clinical study [2]. The study used data from approximately 5,000 patients with malignant ovarian tumors collected over 35 years in the Tokai Ovarian Tumor Study Group. Patients with stage IIB to IIIC (meaning that they experienced

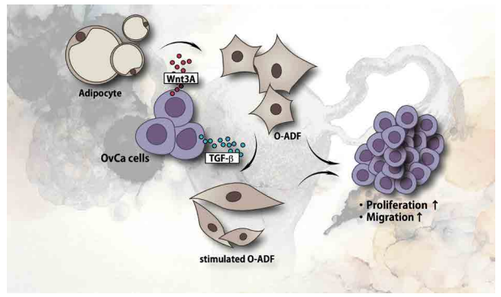


Figure 1. Induction of omental adipocyte dedifferentiation by OvCa cell, and the effect of generated O-ADF on OvCa cells in the tumor microenvironment at omental dissemination

peritoneal metastasis) epithelial OvCa who had achieved complete resection of the visible lesion were included. A total of 280 patients who satisfied the study criteria were included in the study and classified into 3 groups based on their body mass index (BMI) at diagnosis. In addition to overall survival and progression-free survival, peritoneum-specific recurrence-free survival was evaluated. The results showed that peritoneum-specific recurrence-free survival and overall survival were significantly shorter in the high BMI group than in the normal BMI group (p = 0.028 and 0.018, respectively). Multivariate analysis identified obesity as an independent prognostic factor. This clinical research approach revealed that, upon recurrence from hiding OvCa cells, adipose tissue plays pro-tumoral roles and supports their sprout from micro-metastatic sites.

CONCLUSION

From obtained results, it is speculated that OvCa cells utilize the adipose tissue in the abdominal cavity as a way-stop point. They hide and acquire supporters there to create a foothold for further metastasis. Peritoneal dissemination is also frequently observed in other cancer types, including gastric colorectal cancer, indicating that novel therapies targeting adipose tissue may apply to various cancers. The development of such treatment is strongly desired, and I would like to open the way.

REFERENCES

[1] Iyoshi, S. *et al*. Pro-tumoral behavior of omental adipocyte-derived fibroblasts in tumor microenvironment at the metastatic site of ovarian cancer. *Int. J. Cancer* **149**, 1961–1972 (2021)
[2] Iyoshi, S. *et al*. Obesity contributes to the stealth peritoneal dissemination of ovarian cancer: a multi-institutional retrospective cohort study. *Obesity* **30,** 1599–1607 (2022)

Art in modernity and Diderot's philosophy

Keiko KAWANO

Designated Assistant Professor of Young Leaders Cultivation Program
Graduate School of Humanities / Institute for Advanced Research, Nagoya University
E-mail: kawano.keiko.n8@f.mail.nagoya-u.ac.jp

INTRODUCTION

Diderot is the leading philosopher of the 18th-century French Enlightenment and is known for editing the *Encyclopaedia*. His thought spanned a wide range of fields, from socio-political theory to natural science, language theory, and art theory. France in the 18th century was a period when eminent philosophers, such as Rousseau and Montesquieu, were active, and their thoughts were also transcendental. However, Diderot's interest in art is more exceptional than those philosophers. Why did Diderot attach so much importance to art theory? This is the fundamental question I am currently tackling in my research.

WEIGHTLESSNESS IN WORKS OF ART

In Western thought, the existence of God was absolute. Everything, the world works, the origin of man, the origin of language, etc., were all explained by God. In the 18th century Enlightenment, however, after Locke's empiricism, man was finally freed from the superstition of God and began to search for the truth of the world on his own and through his own senses. Therefore, the philosophers of this period must define all things in the world, social systems, nature, language, etc., without the existence of God. This is why the scope of their thought naturally expanded. Diderot was no exception, and at the root of his thought was a strong self-consciousness as a modern man freed from God. Nevertheless, art theories in this period were often written by painters or theorists of literature rather than philosophers. So, why did Diderot make art theories part of his philosophical field of thought? In the field of art, Diderot is famous as a pioneer of art criticism. Diderot repeatedly refers to the issue of the representation of the weight of objects and gravity in works of art when he is involved in the art criticism of the exhibition called Salon, organized by the Royal Academy of Fine Arts. For example, he notes that the "flying figures" in the upper right-hand corner of the painting *Ulysses Invoking the Spirit of Tiresias* (Figure 1) are floating, despite having bodies similar to ours, yet these figures do not shock but delight the modern viewer (1).

The background to Diderot's point is still the problem of modernity. In particular, the development of natural science in the modern era. When God existed, the view of nature accepted weightlessness, such as the flight of God or the flying and leaping of angels. However, the perception of modern man, who now lives in an age in which God has been lost, is essentially governed by the law of gravity and should only accept the weight of objects and the existence of objects to the extent that they conform to the laws of nature. For example, Blake painted Newton assimilating with a rock and moving a compass on the ground (Figure 2). Yet Diderot, a modern man, is delighted, rather than shocked, to see flying figures in the paintings. How is such a thing possible? What is art for modern people? This is one of the central questions of Diderot's theory of art. Therefore, it seems that for Diderot, art theory was an important field to interrogate the mysterious human cognitive capacity or imagination, which, even in modern times dominated by natural science, is still freely invoked without regard to natural laws.

ART AND RELIGION IN MODERN

Should we consider the question of imagination in Diderot's philosophy? I will relate this question to religion in modernity. In modernity, God has been lost, and natural science has become the new paradigm. Nevertheless, only the human imagination is not bound by the laws of nature and still imagines an absent entity. This paradox is a major problem for Diderot's theory of art, which he attributes to his

Figure I. Bouchardon, *Ulysses Invoking the Spirit of Tiresias bouchardon*,1738, Musée du Louvre. (cut-out part) © Musée du Louvre

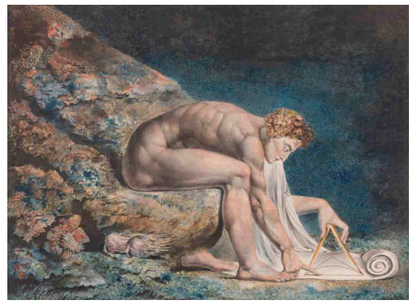


Figure 2. William Blake, *Newton*, 1795-c. 1805, Tate Britain. Photo: Tate in the 18th century, the philosopher Newton was depicted as assimilating with the ground.

strong interest in Pascal, the giant of early modern natural philosophy and theology. While Pascal, as is well known, made great achievements in natural philosophy, he also expounded a belief in God, which is essentially contradictory to natural philosophy, in his chapter-based work *Pensées.* In 1746, Diderot wrote *Pensées philosophiques*, which imitated Pascal's chapter style of writing and ridiculed theological thought, and in his later years, he wrote *Pensées sur l'interprétation de la peinture*. This suggests that Diderot had Pascal, the giant of the natural sciences and theology, in his mind, and that in the modern age when God had been lost, "art" was placed alongside the natural sciences in place of God, and he philosophically questioned the mysterious cognitive abilities of human beings. Based on this hypothesis, I will try to elucidate Diderot's theory of art from various perspectives based on his natural science theory and religious theory.

REFERENCES

[1] Denis Diderot, Sur Bouchardon et la sculpture , 1766, *Œuvres complètes, Arts et lettres: 1739-1766 : critique I*, t.13 , éd. Jean Varloot [et al.], Paris, Hermann, 1979, p. 331.

Understanding the dynamics of the large-scale structure of the Universe

Shohei SAGA

Designated Assistant Professor of Young Leaders Cultivation Program
Kobayashi-Maskawa Institute / Institute for Advanced Research, Nagoya University
E-mail: saga@kmi.nagoya-u.ac.jp

INTRODUCTION

Recent cosmological observations have revealed that the dominant matter component of the Universe is unknown cold dark matter (CDM), which interacts solely through gravitational force and hence is never seen with light. The nature and origin of CDM have been extensively discussed through theoretical and observational ways. So far, in particular, observations of the cosmic microwave background radiation have successfully extracted cosmological information, indicating the existence of CDM and dark energy which drives accelerated expansion. Meanwhile, my focus lies on the large-scale structure of the Universe, the largest structure in the Universe formed by galaxies. A characteristic web-like structure is observed when we make a three-dimensional map of galaxies, which are used as points of sources, we observe a characteristic web-like structure. This large-scale structure of the Universe is seeded by fluctuations in the early Universe during inflation and has developed as a result of the gravitational force of CDMs. Therefore, investigating the large-scale structure of the Universe offers a captivating opportunity to unveil the nature of dark matters and extract the information about the primordial Universe. Constructing accurate theoretical models is crucial for extracting cosmological information from observations of the large-scale structure of the Universe. However, the non-linearity of gravity in CDM evolution poses a significant challenge to achieving this.

DYNAMICS OF COLD DARK MATTERS

The *cold* nature of dark matter implies that the initial velocity dispersion is negligibly small and the phase space of CDM (a six-dimensional space representing the distribution of dark matter positions and velocities) exhibits a three-dimensional sheet structure. Therefore, even if the sheets have a simple structure without folds initially (referred to as single stream region, see the left panel in Fig.1), non-linear growth due to gravity causes self-intersections of the sheets, called shell crossing (center panel in Fig.1). As a result, they form complex structures called multi-stream flow (right panel in Fig.1). During the early stages, we can follow the CDM evolution using perturbative treatment, which has successfully predicted statistics related to the large-scale structure of the Universe and facilitated comparisons with observations. However, the perturbative treatment breaks down at shell crossing and in the multi-stream regions. Therefore, it is crucial for future cosmological observations to accurately predict statistical quantities of the large-scale structure of the Universe by properly following the evolution of the CDM.

IMPROVING THE ANALYTICAL PREDICTIONS

To improve the analytical prediction in the vicinity of the shell crossing and/or in the multi-stream region, we have investigated

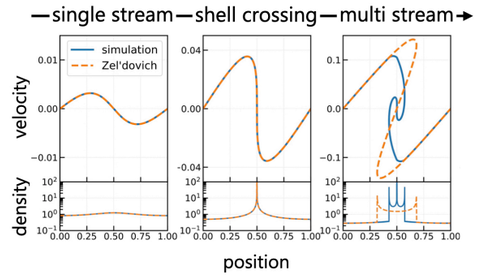


Figure 1. Dynamical evolution of CDM in phase space, i.e., velocity-position space, [top panels] and its density field in real space [bottom panels]. The time evolution is shown from the left to the right panels, with the left and right panels showing the early and late stages, respectively. The CDM is initially set to have a small peak at the origin, and the surrounding CDMs fall towards the center due to gravity. Blue and orange lines show the simulation results and Zel'dovich solution, a simple prescription to describe the evolution of CDM.the evolution of CDM.

the convergence property of the perturbative approach by using the very high-order perturbation order, specifically the 15th order in 3D space[1, 2]. Owing to having the high-order perturbative solutions, we have found the *resummation* technique for the perturbative series and then extrapolated the perturbative order to infinity, leading to the non-perturbative analytical predictions. Our approach's prediction remarkably agrees with the simulation results in the phase-space structure. We have further investigated the CDM dynamics shortly after shell-crossing time. One of the prominent features in the multi-stream regime is the presence of the vorticity fields (rotation of velocity fields), absent in the single-stream regime. The vorticity fields serve as interesting observables for understanding CDM dynamics. We developed a method to predict the multi-stream quantities relying on the perturbative prediction at the shell-crossing time. This method allows us to predict the vorticity fields, which agree with the simulation measurements. Our advancement in perturbative approaches can be a fundamental technique for predicting CDM motion even beyond shell crossing and in the multi-stream regime. Then, in future works, our results will qualitatively improve the analytical prediction of the statistical quantities in the large-scale structure of the Universe, and extract the cosmological information to reveal the nature of dark matters.

REFERENCES

[1] Saga S, Taruya A, and Colombi S, *Physical Review Letters* 121, 241302 (2018)
[2] Saga S, Taruya A, and Colombi S, *Astronomy & Astrophysics* 664, A3 (2022)

Revealing autolytic mechanisms of sieve element differentiation

Yuki SUGIYAMA

Designated Assistant Professor of Young Leaders Cultivation Program
Graduate School of Science / Institute for Advanced Research, Nagoya University
E-mail: sugiyama.yuki.d8@f.mail.nagoya-u.ac.jp

RESEARCH BACKGROUND

To gain special functions, cells sometimes lose something. For instance, the animal sperm achieves high motility due to the lack of most cytoplasm and organelles. In flowering plants, the sieve elements (SEs), the individual component of the phloem sieve tube, lose most of the cytoplasm and organelles, as well as part of their cell wall (Figure 1). Degradation of the cytoplasm and organelles results in a nearly hollow structure, allowing the sieve sap, containing photosynthetic products and signaling molecules, to pass through. In parallel, spatially controlled degradation of the cell wall generates small holes, namely sieve pores, at both ends of the cell, enabling the SEs to connect to each other. Although these drastic rearrangements of cellular components have been shown as crucial steps for the sieve tube to function, the molecular basis underlying these dramatic changes is still elusive.

The poor progress in the molecular and cell biology of SEs is mainly due to the extreme difficulty of observing these cells. Since SEs lack morphological features other than somewhat thick cell walls, it is hard to distinguish them from surrounding cells. Furthermore, their deep location within the tissue is a major obstacle to confocal live imaging. Fortunately, recent advances in genetics and experimental techniques have dramatically improved today's situation. Multiple genes specifically expressed in SEs have been identified and their promoters can now be used to visualize SEs at various developmental stages. In addition, identifying transcription factors such as *APL* and *NAC45/86* allowed us to follow the behavior of downstream molecules by transcriptome analysis (1).

Besides, developing an induction system, called VISUAL, has made it possible to transdifferentiate model plants Arabidopsis thaliana leaf mesophyll cells into SE-like cells (2). The cells induced by VISUAL undergo remodeling of cellular components, including nuclear degradation and callose deposition, a cell wall component abundant in SEs. These cells also express several SE marker genes, suggesting that they can be considered as SEs. While this system is truly innovative because it can easily and efficiently induce SEs, it still is not good enough for analysis from a cell biology perspective. The reason is that the base mesophyll cells are also small and located deep in the tissue and are therefore not as suitable for live imaging as the original SEs. Another disadvantage is that the sparse presence of mesophyll cells in the first place makes it difficult to form interconnected structures, or sieve plates, between cells.

MY PROJECT

I applied the VISUAL technique to *Arabidopsis* hypocotyl cells rather than leaf mesophylls to develop a new induction system (Figure 2). I found that the combination of VISUAL and hypocotyl can address the weaknesses of the conventional VISUAL. Compared to the original technique using leaf mesophylls, hypocotyl cells are more similar in their shape to SEs and are therefore more likely to maintain the top-down cell polarity and cell division direction. This also allows detailed imaging of the intracellular dynamics of SE differentiation by inducing the formation of large, easily observable SEs. Several SE markers, including *APL* and *NAC86*, are indeed expressed in induced SEs. The gradual disappearance of

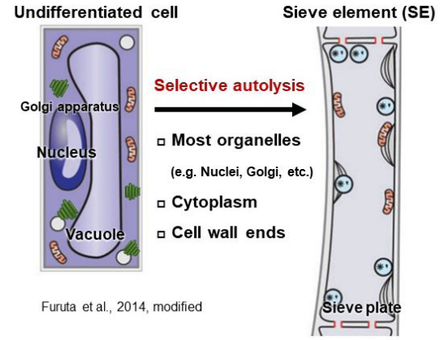


Figure 1. A schematic diagram of SE differentiation.

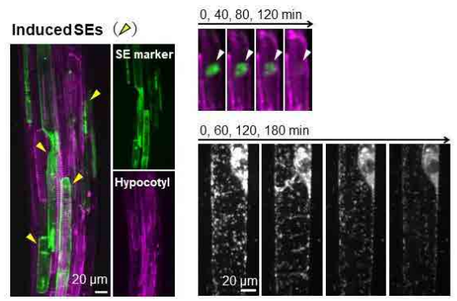


Figure 2. Induced SEs in a hypocotyl (left). Time-course imaging of Nuclei (top right) and Golgi (bottom right) degradation.

the nuclear and Golgi signals was well observed by live imaging in induced cells (Figure 2). Further electron micrographs showed that structural changes characteristic of SE differentiation, such as the occurrence of cytoplasm clearance and formation of sieve plates, were largely reproduced in induced cells. Therefore, the induced cells in hypocotyls have sufficient morphological evidence to be considered SEs. Using this system, I will intricately visualize organelle degradation during SE differentiation and find key factors to reveal the molecular mechanisms.

REFERENCES

[1] Furuta K. M. *et al.*, *Arabidopsis* NAC45/86 direct sieve element morphogenesis culminating in enucleation. *Science* **345**, 933-937 (2014).
[2] Kondo Y. *et al.*, Vascular cell induction culture system using Arabidopsis leaves (VISUAL) reveals the sequential differentiation of sieve element-like cells. *Plant Cell* **28**, 1250-1262 (2016).

Integrating genomics and biophysics to comprehend tauopathy

Koyo TSUJIKAWA

Designated Assistant Professor of Young Leaders Cultivation Program
Graduate School of Medicine / Institute for Advanced Research, Nagoya University
E-mail: tsukoyo@med.nagoya-u.ac.jp

INTRODUCTION

Mammalian cell cytoskeleton comprises microtubules, actin filaments, and intermediate filaments. Tau is a microtubule-associated protein that stabilizes microtubules and mediates actin-microtubule interaction. Tauopathies are a heterogeneous group of neurodegenerative disorders characterized by abnormal protein aggregation of tau in the brain, including Alzheimer's disease (AD), the most common dementia worldwide, and progressive supranuclear palsy (PSP), which typically presents postural instability with falls, supranuclear gaze palsy, and dementia.

Patients with PSP usually die 5–10 years after onset because of the lack of effective treatment, and their serious physical and mental disabilities increase their caregiver's burden. While amyloid-β enhances tau pathology in AD brains, pathological findings of PSP lack amyloid-β deposits. The molecular mechanism driving abnormal tau in PSP brains remains inconclusive, and genetic animal models that phenocopy PSP are unavailable.

FILAMIN-A

Recently, we showed that the actin-binding protein *filamin-A* is abundant and co-localized with the aggregated tau in the PSP brains (1). We identified duplication of *filamin-A* gene in monozygotic twin males concordant for PSP. Our genomic analyses for multiple Japanese cohorts of tauopathy, including J-ADNI and JALPAC, showed that some patients with PSP and AD have rare variants (minor allele frequency < 1%) of *filamin-A* gene, including seven missense variants (p.S2523N, p.A2334C, p.V2191M, p.T2101M, p.A2075S, p.A2003H, and p.L1980V) and one splicing variant (c.4755 + 5G > A). An association study using the dataset of 312 PSP cases and 499 normal controls demonstrated that the rare variants of *filamin-A* gene can contribute to the risk of PSP with the odds ratio of 3.91.

We also provided biochemical evidence that increased filamin-A levels enhance the phosphorylation and sarkosyl-insolubility of tau through interacting actin filaments. Also, reducing filamin-A corrected aberrant tau levels in the culture cells from cases with PSP. We further generated an original transgenic mouse expressing human filamin-A (FLNA-Tg). The brains of the 5-month-old FLNA-Tg mice showed sarkosyl-insoluble tau and co-localization of filamin-A with tau in the neurons and glial cells like the PSP brains. Finally, primary cortical neurons from the FLNA-Tg mice showed tau phosphorylation and defective neurite outgrowth rescued by lentiviral short hairpin RNA-mediated knockdown of filamin-A. Our data highlight that filamin-A promotes tau aggregation, providing a potential mechanism by which filamin-A contributes to the PSP pathology.

DRUG DISCOVERY

We filed a patent application (PCT/JP2021/001026) before the industry-academia collaboration. We are currently evaluating the potential of filamin-A as a therapeutic target for tauopathy with a pharmaceutical company.

Furthermore, we collaborate with Assoc. prof. Ryuji Kato, at Graduate School of Pharmaceutical Sciences, Nagoya University, and conduct the morphological analysis for filamin-A-overexpressing neuronal cells using AI-based high-throughput methods to develop drug screening assay. To generate an animal model for PSP and other tauopathies, we comprehensively analyze the FLNA-Tg mice by integrated multi-omics approaches, such as epigenomics, transcriptomics, proteomics, metabolomics, and phenomics. The 5-month-old FLNA-Tg brains show decreases in the major neurotransmitter metabolites and a gene expression profile suggestive of neuronal hyperexcitability in the early phase of neurodegeneration.

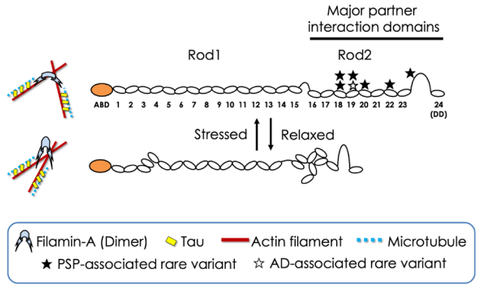


Figure 1. Structure and dynamics of filamin-A.
ABD = actin-biding domain, DD = dimerization domain.

BIOPHYSICS

Filamin-A is a dimeric actin filament cross-linking protein with N-terminal actin-biding domain and 24 immunoglobulin-like repeat domains (Ig1–24). Ig1–15 is referred to as Rod 1, and 16–23 as Rod 2. Filamin-A acts as a central mechanotransduction element that converts mechanical stimuli into chemical signals. For example, mechanical force changes the conformation of Rod 2 and its interaction with its binding partners. Interestingly, tauopathy-associated rare variants of filamin-A are mostly located in Rod 2 (Figure), suggesting that the perturbation of filamin-A mechanotransduction can be involved in the pathogenesis of tauopathy. We collaborate with Prof. Takayuki Uchihashi, at Graduate School of Sciences, Nagoya University, and apply atomic force microscopy to visualize and characterize single-molecule dynamics of filamin-A.

In addition, we focus on developing mouse models of repetitive traumatic brain injury (TBI) to understand the mechanical stress transfer from the brain tissue to the neuronal cytoskeleton and its effect on the filamin-A mechanotransduction. We also investigate the involvement of the filamin-A mechanotransduction on chronic traumatic encephalopathy, a tauopathy in concussed athletes and military veterans with TBI.

Analyzing tauopathy from a biophysics viewpoint offers unique perspectives on the molecular mechanisms and provide a deeper understanding of the mechanical and dynamic aspects of neurodegenerative processes to guide the development of therapeutic approaches.

ACKNOWLEDGMENTS

We thank Prof. Masahisa Katsuno and Assoc. prof. Kentaro Sahashi at Department of Neurology, Graduate School of Medicine, Nagoya University, for great support.

REFERENCES

[1] **Tsujikawa K**, Hamanaka K, Riku Y, et al. Actin-binding protein filamin-A drives tau aggregation and contributes to progressive supranuclear palsy pathology. *Science Advances*. **8**, eabm5029 (2022).

Exploring the Potential Applications of Biocatalysts

Atsushi USAMI

Designated Assistant Professor of Young Leaders Cultivation Program
Institute of Transformative Bio-Molecules (ITbM) / Institute for Advanced Research, Nagoya University
E-mail: usami.atsushi.y5@f.mail.nagoya-u.ac.jp

INTRODUCTION

Biocatalysts exist in all organisms, including humans, plants, and microorganisms. Above 3,000 types exist. Enzymes and microorganisms are typical biocatalysts. This bioproduction using biocatalysts can synthesize substances inaccessible through organic synthesis under ordinary temperature and pressure conditions. Therefore, biocatalyst-based production (bioproduction) technologies for useful substances are currently attracting attention in various fields. However, the enzymes involved in an unstable substance, such as a flavor compound, their metabolites, and the bioproduction of functional flavor compounds have not been established. I have been studying biocatalysts and their bioproduction involved in flavor compounds.

METABOLISM OF FLAVOR COMPOUNDS

Flavor compounds are empirically recognized to exhibit "relaxation," "analgesia," and "cosmetic effects." Many of these compounds exhibit significant biological activities, and the non-invasive effects of "fragrance odor" have been widely expected to prevent and treat diseases. However, volatile oils containing flavor compounds are found in trace amounts (<0.1%) in natural products, and their components, flavor properties, and functionality remain elusive. Furthermore, it is known that flavor compounds are metabolized by cytochrome P450 (P450 or CYP) and other xenobiotic-metabolizing enzymes after being taken into the body, but the P450 molecular species involved and the metabolizing compounds are not elucidated. We extracted volatile oils from a total of 21 natural products, identified flavor compounds, and clarified their functionality [1,2]. In addition, we characterized the human P450 molecular species involved in the metabolism of xenobiotics in the human liver using microsomes and 11 molecular species [3]. Moreover, we constructed a library of flavor compound-derived metabolites by biotransformation using different biocatalysts (bacteria and insects) [4].

BIOPRODUCTION OF HIGH-VALUE-ADDED FLAVOR COMPOUND

Bioproduction employing biotransformation is among the ways to produce high-value oxygenated derivatives, making it possible to realize environmentally safe, energy-saving, and regio- and stereo-selective production under mild conditions. In particular, gas-phase bioproduction, where chemical reactions proceed in the gas phase using immobilized biocatalysts, is attracting researchers' attention as a green process. However, biocatalysts are usually more unstable than chemical catalysts and require stabilization techniques, such as immobilization operations. We overcame this problem by constructing a gas-phase bioproduction system by metabolically engineering the Gram-negative bacterium Acinetobacter sp. Tol5, which has adhesive bacterionanofiber proteins and can be easily immobilized on various material surfaces [5].

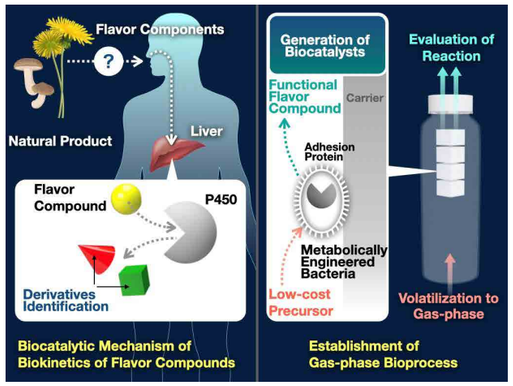


Figure. Utilization of Biocatalysts Targeting Naturally Occurring Compounds

FUTURE FOCUS

My research focuses on the biotransformation of non-naturally occurring compounds, such as nanocarbons. Nanocarbons have been the most active research area of materials in recent years, and biotransformation using microorganisms and purified enzymes has been attempted from the viewpoint of green technology. However, dealing with an individually distinguishable and identifiable single "molecule" has been difficult since most nanocarbons are mixtures of different sizes and structures. Moreover, using biocatalysts with nanocarbons as substrates is only for biodegradation. Therefore, I will develop a biotransformation system using single molecular nanocarbons as substrates to produce valuable compounds. Therefore, we can expect breakthrough results as an approach to implement the production of useful compounds while considering environmental conservation.

REFERENCES

[1] Usami A., Motooka M., Takagi A., Nakahashi H., Okuno Y., Miyazawa M., *J. Oleo Sci*., **63**, 723-730 (2014).
[2] Usami A., Motooka R., Nakahashi H., Marumoto S., Miyazawa M., *Chem. Biodivers*., **12**, 1734-1745 (2015).
[3]Nakahashi H., Yamamura Y., Usami A., Rangsuvigit P., Malakul P., Miyazawa M., *Biopharm. Drug Dispos*., **36**, 565-574 (2015).
[4] Usami A., Motooka R., Miyazawa M., *Biocatal. Biotrans*., **32**, 285-289 (2014).
[5] Usami A., Ishikawa M., Hori K., *Green Chem*., **22**, 1258-1268 (2020).

Observation of Mg-intercalated GaN Superlattice Nanostructures

Jia WANG

Designated Assistant Professor of Young Leaders Cultivation Program
Institute of Materials and Systems for Sustainability / Institute for Advanced Research, Nagoya University
E-mail: wang.jia.t4@f.mail.nagoya-u.ac.jp

INTRODUCTION

Gallium nitride (GaN) - a wide bandgap(WBG) semiconductor- is widely used in solid-state lighting and holds significant potential as power electronics alternatives to silicon. It is one of the essential semiconductors for realizing a carbon-neutral society. Generally, doping and carrier transport play pivotal roles in the operation of semiconductor devices. For various functionalities, realizing not only n-type but also p-type realization is essential. Since the demonstration of p-type GaN through magnesium (Mg) doping during epitaxial growth and electron beam irradiation at Nagoya University more than 30 years ago, there has seen rapid and comprehensive development. However, like many of today's WBG semiconductor materials, GaN still struggles with insufficient hole concentration and mobility, posing significant challenges for societal implementation. On the other hand, the physical and electrical behaviors of Mg, the only acceptor-type dopant impurity for GaN up to now, have gradually been clarified. Nevertheless, the relationship between GaN and Mg remains a captivating tale of mystery.

OBSERVATION OF MIGS

Recently, we discovered that a monolayer of Mg atoms (or a two-dimensional (2D) Mg sheet) spontaneously intercalates into the GaN lattice, forming a so-called 2D Mg-intercalated GaN superlattice (MiGs) nanostructure, as shown in Figure 1. Typically, intercalation is crucial for creating artificial layered structures, with applications found in the exfoliation of two-dimensional materials, energy storage, superconductivity, and thermal conductivity control. Two-dimensional materials are often chosen as host materials for the intercalation process due to their weak van der Waals layers, which allow easy insertion of foreign atoms, ions, and molecular sheets without inducing excessive strain. Conversely, intercalating atomic sheets into single-crystal ceramics with strong ionic or covalent bonds, such as semiconductor materials with a wide bandgap, was believed to be challenging. Yet, in this study, Mg metal was found to intercalate into the hexagonal wurtzite structure of GaN, creating a unique state wherein a monatomic Mg layer or two-dimensional Mg layer intercalates every few GaN layers, forming a superlattice. Such metal intercalation into semiconductor is the first of its kind observation in the world. As shown in Figures 1d and 1e, Mg occupies the C position (interstitial site) in the otherwise ABAB stacking arrangement of wurtzite-type GaN. The existence of the two-dimensional metallic Me sheet was confirmed by Figure 1d and other associated figures.

ASSOCIATED PHYSICAL EFFECTS

In general, uniaxial compressive strain along the c-axis of wurtzite-type GaN can modify its band structure. This change can induce interesting physical effects beneficial for energy-saving technology in power device applications, such as an increase in the state density of the valence band, hole concentration, hole mobility, and thermal conductivity. In group III nitrides, hole mobility and transport are limited because of the high electron affinity of nitrogen atoms and weak spin-orbit interaction, leading to a considerable effective mass for holes. However, applying significant strains to the wurtzite GaN lattice can reverse the valence band structure, resulting in a split hole band with a light effective mass of holes at the top of the valence band. This leads to an accumulation of holes in the split-off hole band, enhancing hole mobility. Specifically, when a uniaxial compressive strain of -4.3% in the c-axis direction is applied to wurtzite GaN, first-principles calculations indicate a hole mobility of 200cm^2/(V•s) at room temperature. The increase in hole mobility due to the reversal of the crystal field splitting energy has long been sought after, especially since introducing high strain into the GaN lattice is challenging. The MiGs nanostructure appears most promising for achieving high hole mobility and concentration simultaneously. Additionally, strained GaN is theoretically predicted to increase thermal conductivity in the direction of uniaxial compressive strain. Moreover, since the superlattice structure results from the spontaneous diffusion of Mg into GaN under high temperature and atmospheric pressure, we believe this structure to be thermodynamically stable under a broad range of conditions. Our next phase of research will focus on enhancing our understanding of superlattices formed from dissimilar materials, like wide bandgap semiconductors and metals. We aim to explore effects such as hole mobility enhancements by strain-induced valence band inversion and polarization-induced hole doping due to polarity inversion, and their technological implications – including Ohmic contacts to p-type GaN and AlN. This knowledge will contribute to the development of innovative electronic devices, like deep ultraviolet light emitters and p-channel power transistors, leveraging the potential of wide and ultra-wide bandgap semiconductor materials.

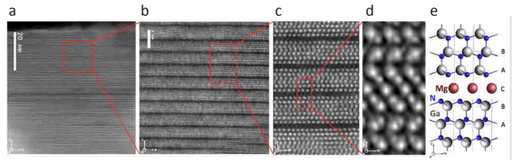


Figure 1. 2D Mg-intercalated GaN superlattice (MiGs) nanostructures: a-c, High-angle annular dark field scanning transmission electron microscope (HAADF-STEM) images with different magnifications. d, Atomically resolved integrated differential phase contrast (iDPC)-STEM image showing the relative positions of N, Ga and Mg atoms. e, Schematic illustration of a repeating unit of the MiGs nanostructure.of the MiGs nanostructure.

ACKNOWLEDGEMENT

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REFERENCES

[1]Amano, H. Nobel Lecture. Reviews of Modern Physics 87, 1133 (2015).
[2]Wang, W., Lu, S. & Cai, W. *et al.*, Ohmic Contact to p-Type GaN Enabled by Post-Growth Diffusion of Magnesium. IEEE Electron Device Letters 43, No.1, 150-153 (2021).
[3]Poncé, S., Jena, D. & Giustino, F. Route to High Hole Mobility in GaN via Reversal of Crystal-Field Splitting. Physical Review Letters 123, (2019).

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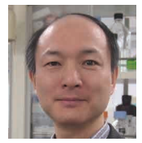

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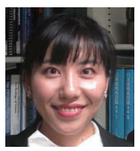
Research Field : Molecular biology, Plant reproduction

Manabu BESSHO-UEHARA

Affiliation : Designated Assistant professor at Nagoya IAR and Graduate School of Science
Research Field : Biology, Evolution, Bioluminescence



Hanako HAGIO

Affiliation : Designated Assistant professor at Nagoya IAR and Graduate School of Bioagricultural Sciences
Research Field : Fish Neuroscience

Hisashi HAYAKAWA

Affiliation : Designated Assistant professor at Nagoya IAR and Institute for Space-Earth Environmental Research
Research Field : Space Weather, History, Solar Activity

Tomoya NAKAYAMA

Affiliation :Designated Assistant professor at Nagoya IAR and Graduate School of Bioagricultural Sciences
Research Field : Animal physiology, Molecular biology

Ryo HIGUCHI

Affiliation : Designated Assistant professor at Nagoya IAR and Graduate School of Humanities
Research Field : History of Architecture

Minoru HIROSE

Affiliation : Designated Assistant professor at Nagoya IAR and Graduate School of Mathematics
Research Field : Number Theory

Jie HUANG

Affiliation : Designated Assistant professor at Nagoya IAR and Graduate School of Humanities
Research Field : Cultural anthropology

Matthew Paul SU

Affiliation :Designated Assistant professor at Nagoya IAR and Graduate School of Science
Research Field : Mosquito neuroscience and behavior

Yuichiro TADA

Affiliation : Designated Assistant professor at Nagoya IAR and Graduate School of Science
Research Field : Early Universe

Hirotaka IIJIMA

Affiliation : Designated Assistant Professor at Nagoya IAR and Graduate School of Medicine
Research Field : Rehabilitation medicine, Mechanobiology, Aging, Systems biology

Sanae ITO

Affiliation : Designated Assistant Professor at Nagoya IAR and Graduate School of Humanities
Research Field : Assyriology

Elena KOZGUNOVA

Affiliation : Designated Assistant Professor at Nagoya IAR and Graduate School of Science
Research Field : Plant cell division

Masamichi MIYAJI

Affiliation : Designated Assistant Professor at Nagoya IAR and Graduate School of Science
Research Field : Theoretical Physics

Hideki UMEHATA

Affiliation : Designated Assistant Professor at Nagoya IAR and Graduate School of Science
Research Field : Astronomy, Astrophysics

Akira YOSHINARI

Affiliation : Designated Assistant Professor at Nagoya IAR and Institute of Transformative Bio-Molecules Sciences
Research Field : Plant Biology

Fanny BELLEGARDE

Affiliation : Designated Assistant Professor at Nagoya IAR and Graduate School of Bioagricultural Sciences
Research Field : Plant nutrition, Hormone biosynthesis, Epigenetic

Satoshi IKEGAYA

Affiliation : Designated Assistant Professor at Nagoya IAR and Graduate School of Engineering
Research Field : Condensed Matter Physics (Theory)

Shohei IYOSHI

Affiliation : Designated Assistant Professor at Nagoya IAR and Graduate School of Medicine
Research Field : Cancer Biology, Chemical Biology

Keiko KAWANO

Affiliation : Designated Assistant Professor at Nagoya IAR and Graduate School of Humanities
Research Field : Art Philosophy

Shohei SAGA

Affiliation : Designated Assistant Professor at Nagoya IAR and Kobayashi-Maskawa Institute (KMI)
Research Field : Observational cosmology

Yuki SUGIYAMA

Affiliation : Designated Assistant Professor at Nagoya IAR and Graduate School of Science
Research Field : Plant Cell Biology

Koyo TSUJIKAWA

Affiliation : Designated Assistant Professor at Nagoya IAR and Graduate School of Medicine
Research Field : Neurology, Genome biology

Atsushi USAMI

Affiliation : Designated Assistant Professor at Nagoya IAR and Institute of Transformative Bio-Molecules (ITbM)
Research Field : Biotechnology

Jia WANG

Affiliation : Designated Assistant Professor at Nagoya IAR and Institute of Materials and Systems for Sustainability (iMaSS)
Research Field : Novel P-type Doping of Nitride Semiconductors

IAR Visiting Professor & Associate Professor

Takaho ANDO

Affiliation : Visiting Professor at Nagoya IAR / Professor at Chubu University
Research Field : History of Social Thoughts

Yasuro ABE

Affiliation : Visiting Professor at Nagoya IAR
Research Field : Medieval Japanese Culture and Texts

Dapeng CAI

Affiliation : Visiting Professor at Nagoya IAR / Professor at Nanzan University
Research Field : International Economics

Atsushi J. NISHIZAWA

Affiliation : Visiting Associate Professor at Nagoya University /Associate Professor at Gifu Shotoku Gakuen University
Research Field : Observational Cosmology, Astronomy

IAR Honorary Directors

Ryoji NOYORI

2001 Winner of the Nobel Prize in Chemistry University Professor, Nagoya University Establishment of chirally catalysed hydrogenation reactions

Yuan Tseh LEE

1986 Winner of the Nobel Prize in Chemistry Ex-President, ICSU Honorary Doctorate, Nagoya University Clarification of the dynamics of chemical elementary processes

IAR Academy

Hiroshi AMANO

2014 Winner of the Nobel Prize in Physics Professor, Nagoya University Invention of blue light-emitting diodes

Sumio IIJIMA

2009 Order of Culture, Japanese Government Distinguished Invited University Professor, Nagoya University Discovery of carbon nanotubes

Tsuneko OKAZAKI

2021 Order of Culture, Japanese Government University Professor, Nagoya University Discovery of Okazaki fragments

Makoto KOBAYASHI

2008 Winner of the Nobel Prize in Physics University Professor, Nagoya University Discovery of the Kobayashi-Maskawa theory

Shoichi SATO

2002 The Japan Academy Prize, Professor Emeritus, Nagoya University Creation of the science of textual configuration

Kazuo SHINOZAKI

2016 Person of Cultural Merit, Japanese Government University Professor, Nagoya University Study on molecular mechanisms of stress response in plants

Masahiro SUGIURA

2009 Person of Cultural Merit, Japanese Government University Professor, Nagoya University Determining the DNA sequence of the tobacco chloroplast genome

Masatoshi TAKEICHI

2004 Person of Cultural Merit, Japanese Government University Professor, Nagoya University Discovery of Cadherins, the molecular basis governing cellular adhesion

Ryoji NOYORI

2001 Winner of the Nobel Prize in Chemistry University Professor, Nagoya University Establishment of chirally catalysed hydrogenation reactions

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INSTITUTE FOR ADVANCED RESEARCH, NAGOYA UNIVERSITY
Telephone. +81-52-789-3933 E-mail. iar@t.mail.nagoya-u.ac.jp
http://www.iar.nagoya-u.ac.jp/