The CATALYST

Helping you react with chemical reactions

Issue 6
December 2021

Mirror-image molecules?

How chiral molecules and asymmetric catalysts interact

ICReDD
Institute for Chemical Reaction Design and Discovery
HOKKAIDO UNIVERSITY

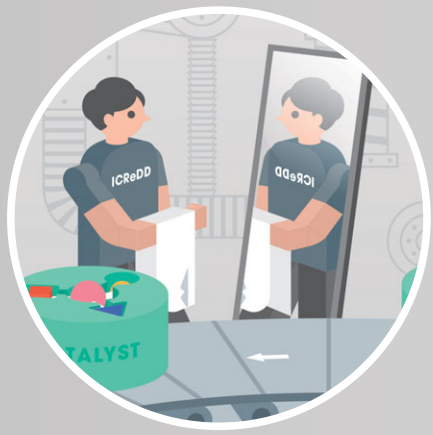
Mirror-image molecules?
How chiral molecules and asymmetric catalysts interact

LIST, Benjamin
Principal Investigator

ICReDD Prinicipal Investigator and Specially Appointed Professor Benjamin List received the 2021 Nobel Prize in Chemistry. ICReDD's philosophy of "aiming to create a new way of discovering chemical reactions by utilizing the strengths of researchers from different fields" resonated strongly with Professor List, and he has been involved in ICReDD's planning and activities as a Prinicipal Investigator since ICReDD was established.
In the 5th issue of The CATALYST, we learned about catalysts, and in this issue we will learn about a topic related to Professor List's prize-winning research on asymmetric organic catalysis. Specifically, we will learn what "asymmetric" means in the world of chemistry and how it is related to catalysts.

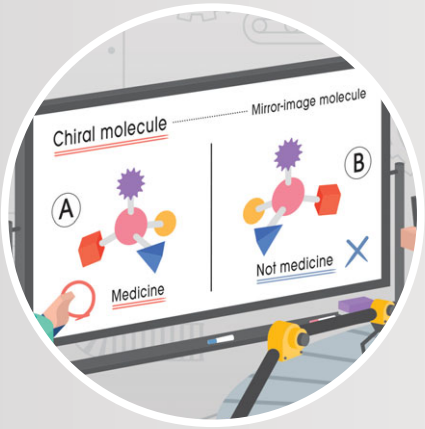
1. Your Reflection in the Mirror

Chances are you've probably looked at yourself in the mirror before. Have you ever noticed anything weird when looking at your reflections? Like that the writing on your T-shirt looks backwards in the mirror, or that when you hold your right hand to a mirror, the reflection looks like your left hand? Well that's because a mirror image is distinct and different from the original object. The two cannot be placed in a way that they perfectly overlap in the same orientation.



2. Molecular Reflections

The same goes for molecules when they look in the mirror. They see a different version of themselves, where their arrangement in 3D space is reversed, like the letters on your T-shirt. Molecules that are mirror images of each other but cannot be placed so that they perfectly overlap in the same orientation are called chiral molecules. All of their atoms and bonds are the same, so they mostly have the same physical properties, like their melting or boiling point. However, the different relative arrangement of the atoms and bonds in 3D space can cause each mirror image version of a molecule to react differently with other molecules. This can have some very important consequences.



3. Controlling Chemical Reflections

One of the big challenges in chemistry is that reactions often produce both mirror images versions of a molecule! Solving this problem is very important for developing new medicines, as our bodies can be very picky about which mirror image they will interact nicely with. Including the wrong mirror image in a medicine can make it less effective, or even have the opposite effect and actually cause harm! In our last issue, we talked about catalysts, and a special type of catalyst, called an asymmetric catalyst, can guide a reaction so that it produces only one of the mirror images.

4. State-of-the-Art Control

It was thought that asymmetric catalysts had to have metal in them, but Professor List developed an organic type of these catalysts that do not contain metal and are cheaper and more friendly to the environment. Researchers at ICReDD are exploring the frontiers of what organic asymmetric catalysts can do, so that more reactions can be carried out with these greener catalysts. This includes ICReDD using machine learning and an advanced calculation method called AFIR to rationally design more complex catalysts than previously possible, opening up even more possibilities. With more advanced catalysts that can produce only one of the mirror image molecules, we can discover even more reactions that could lead to new medicines.

Activation!

Quiz

Chiral molecules are molecules that are almost the same, except that they have different _____.

Send us your answer!

- **A** Atoms
- **B** 3D arrangements
- **C** Bonds
- **D** Melting Points

Check our Instagram highlights for the answer to the quiz!
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ICReDD News

December 2021

New Researchers

Mengfei Wang

Photochemical reactions

Yong Zheng

Physical properties of soft materials

Dennis Chung-Yang Huang

Transition metal catalysts and photo-responsive materials

Selected Publications

(from September 2021 to November 2021)

An Elastic Metal–Organic Crystal with a Densely Catenated Backbone
(J. Pirillo, Y. Hijikata)
DOI: 10.1038/s41586-021-03880-x

Confinement-Controlled, Either syn- or anti-Selective Catalytic Asymmetric Mukaiyama Aldolizations of Propionaldehyde Enolsilanes
(N. Tsuji, B. List)
DOI: 10.1021/jacs.1c07447

Carboxylation of a Palladacycle Formed via C(sp^3)–H Activation: Theory-Driven Reaction Design
(Y. Harabuchi, H. Takano, H. Hayashi, S. Maeda, T. Mita)
DOI:10.1002/asia.202100989

Mechanochemical Synthesis of Magnesium-Based Carbon Nucleophiles in Air and their Use in Organic Synthesis
(A. Hu, Y. Pang, S. Maeda, K. Kubota, H. Ito)
DOI: 10.1038/s41467-021-26962-w

Enhanced Fusogenicity and Pathogenicity of SARS-CoV-2 Delta P681R Mutation
(M. Tsuda, L. Wang, S. Tanaka)
DOI: 10.1038/s41586-021-04266-9

Symposia (invited and more)

- Science Agora 2021, "New Science: Cutting-edge Research Made Possible by Information Science, AI, and Big Data" (I. Takigawa)

〈Co-organized Symposium〉

- ICReDD-Hokkaido University Faculty of Medicine Joint Symposium
- The 7th Hokkaido University Cross-Departmental Symposium

ICReDD-Hokkaido University Faculty of Medicine Joint Symposium

Awards

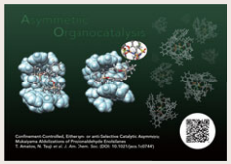
- Best Poster Award, The 7th Hokkaido University Cross-Departmental Symposium (H. Hayashi)
- Nobel Prize in Chemistry 2021 (B. List)

LIST, Benjamin
Principal Investigator

A press conference was held at ICReDD the day after the Nobel Prize in Chemistry was announced.

Outreach

- Monthly news postcards
- Quarterly news poster
  The CATALYST 5th issue



Monthly news postcards

The CATALYST
5th issue

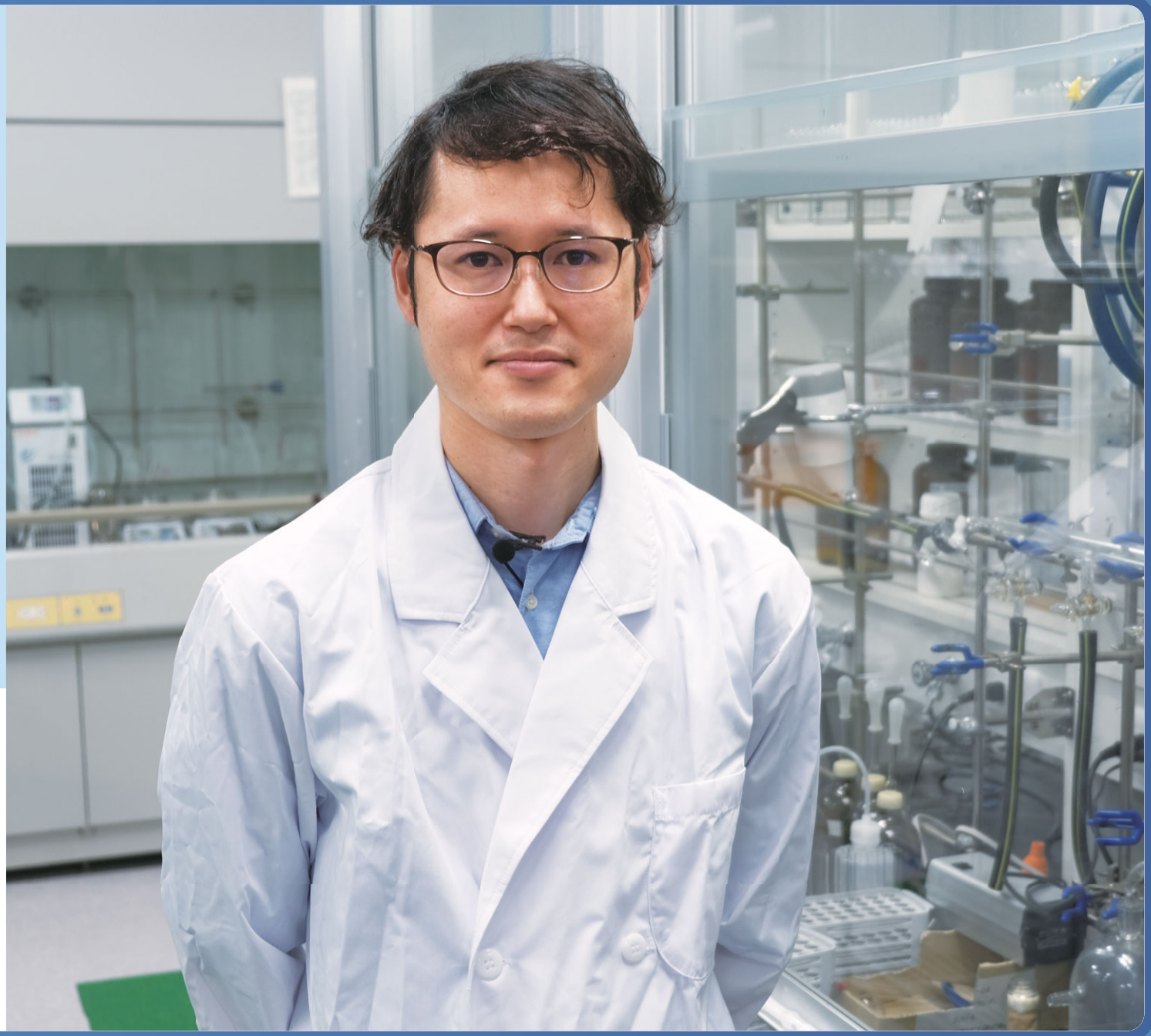
Researcher Profile

vol.6

Nobuya Tsuji

Assistant Professor Tsuji develops asymmetric chemical reactions that utilize organic acid catalysts and uses computational chemistry to analyze reaction mechanisms. In particular he researches reactions that asymmetrically activate low reactivity functional groups such as alkenes.

Representative Papers:
JACS, 2021, 143, 14475–14481; JACS, 2021, 143, 675–680; Science, 2018, 359, 1501



Short Biography

ICReDD Specially Appointed Assistant Professor and List Group Co-PI. He received his Masters in 2014 from the Kyoto University Graduate School of Pharmaceutical Sciences and his PhD in 2018 from the Max Planck Institut für Kohlenforschung. In 2019, he completed postdoctoral research at University of California-Berkeley and then started his current position in January 2020.

About ICReDD

The development of new chemical reactions is intrinsically entangled with the prosperity of humanity and the preservation of the environment. A recent example of such transformative chemical reactions with profound impact is cross-coupling reactions, the discovery of which was awarded with the 2010 Nobel Prize in Chemistry. These reactions are used to produce approximately 20% of all medicinal reagents, and almost all liquid crystalline and organic electroluminescent materials. The industrial use of these chemical reactions contributes ~60 trillion yen per annum to the global economy. The development of new chemical reactions thus significantly affects the evolution of society.

ICReDD is the Institute for Chemical Reaction Design and Discovery, a WPI center at Hokkaido University where researchers from different disciplines combine their strengths to take full control over chemical reactions. The institute was born out of the realization that the purposeful design of chemical reactions requires cross-sectional collaborations at every step. Working on such a fundamental natural process, quantum-chemical computations, information technology, modern experimental techniques, and the development of advanced materials can no longer be separate fields if we want to achieve significant breakthroughs. Rather, they have to become part of a diverse toolbox for truly integrated research.

The Catalyst is inspired by catalysts used in chemistry to bring molecules together, to reduce reaction barriers, and to activate molecules—to make reactions happen faster. In this spirit, this poster series should enable its readers to make the connection between chemical reactions and the wellbeing of our society, and to look at the world in a new way, seeing how chemical reactions and chemistry shape the world around them. And if we can take this opportunity to introduce ourselves, too, this may also catalyze new friendships and opportunities. #ReactWithUs

React With Us!

To stay up to date
with what's happening at ICReDD,
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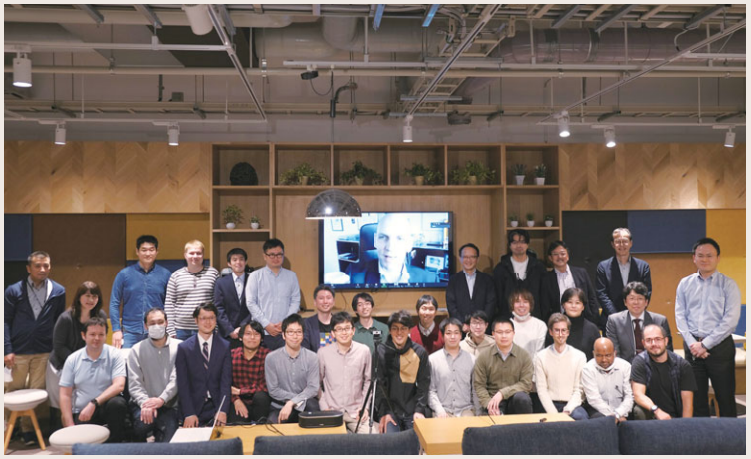

We had the honor of congratulating Professor List over zoom on being awarded the Nobel Prize in Chemistry. Sending all of our best wishes from Sapporo!

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