MOONSHOT Goal # 3

Realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings, by 2050

<Sub-goal: Development of an automated AI robot system that aims to discover impactful scientific principles and solutions, by thinking and acting in the field of natural science, by 2050>

Co-evolution of Human and AI-Robots to Expand Science Frontiers

Project Manager (PM)
Kanako HARADA
Schools of Medicine and Engineering, The University of Tokyo

Vison: a day of a scientist in 2050

I want try the chemicals on the cell.
But it's difficult for me to manipulate the small, soft, and deformable cell…

Out of curiosity of a scientist

Challenging environment & objects

Can you mix A & B and inject it to the cell by varying the quantity and location ?

~~Let me give it a try. I'm bad at~~ mixing, so I'll work with the mixing ~~robot.~~

Dexterous manipulation and intelligent analysis by the AI robot team; self-organization of functions

This is the best condition. Simultaneous injections at these locations worked well.

Explaining how/why it worked

Interesting !
It would work for another type of cell.

Inspiring the scientist

Co-evolution of Human and AI-Robots, propelling "Everybody can be a scientist !"

Science by Human and AI-Robots

AI-Robot scientists

Scientists

- ✓ **Hypothesis & Analysis by AI**
- ✓ **Observation & Manipulation by Robots**

that scientists don't even think of

Collaboration

Interaction

Inspiration

Evolution of Science and AI-Robots

Hypothesis leading to a desired outcome

Hypo-thesis

Design

Experiment design to verify the hypothesis

Discovery of

Better understanding of the system

Strat-egy

Theory

Evolution of Science

Action

Mani-pulation

Action or manipulation on unknown system

Learning of a hidden structure in the sytem

Analy-sis

Obser-vation

Observation of phenomena or reaction

Phenomena

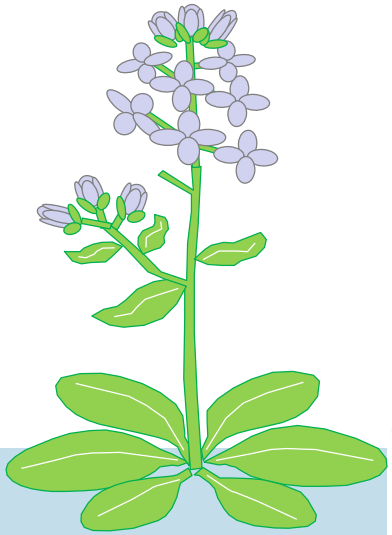
Reaction to manipulation

Evolution of AI-Robot

Examples in this project: Science experiments

Plants

pesticide-free,
drought-resistant



Regenerative

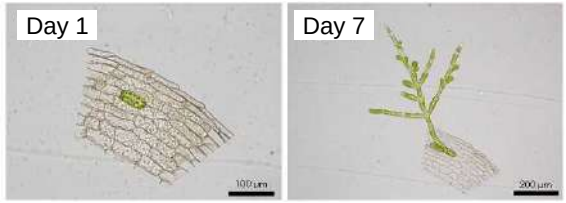
“medicine” for plants

biostimulants

dead resistant

“Nutrition” for plants

Plant regeneration
in an optimal culture medium

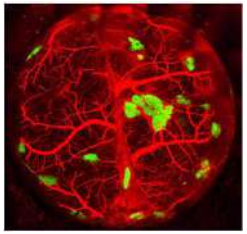


Animals

In toto biology

Observation of organoids
with blood circulation

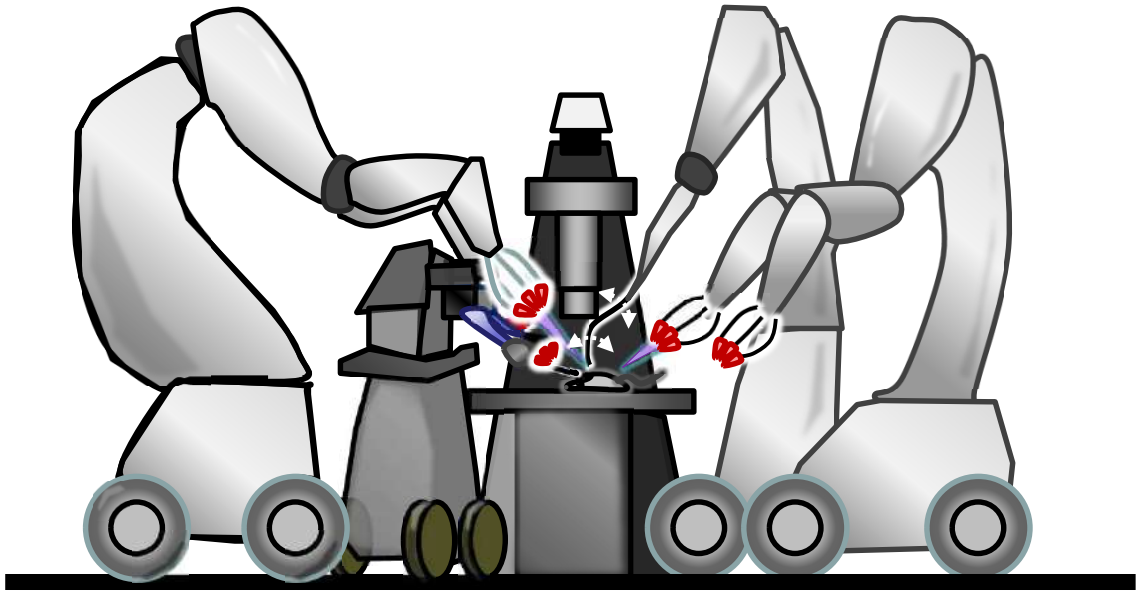
Mechanism of
organ development
Ex. Vascular networking



Challenging environments

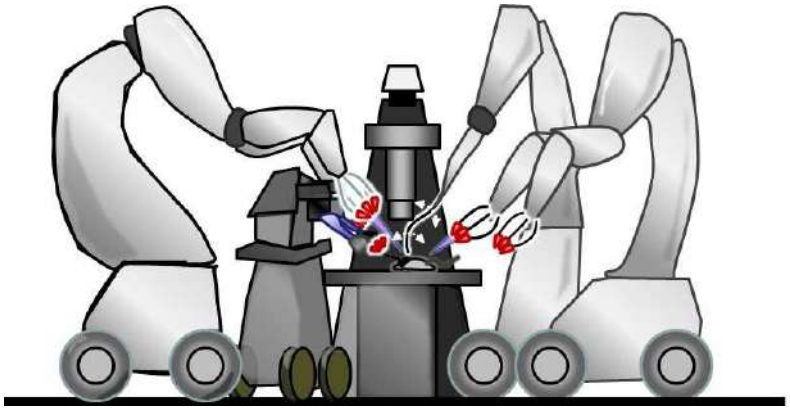
Bio-hazardous,
clean, or low-oxygen
environment

For science experiments on plants and animals in a challenging environment

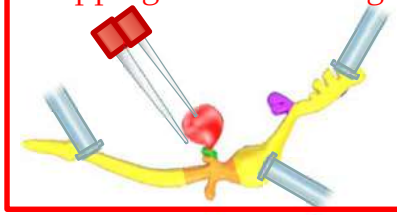


- ✓ **In a challenging environment where people cannot stay or don't want to stay long** (bio-hazardous, clean, etc.)
- ✓ **Large individual differences in samples, manipulation adaptive to the changes in the samples/environment required**
- ✓ **Limited number of available samples (Ethical issues involved)**
- ✓ **Limited time duration allowed for experiment**
- ✓ **Small, soft and deformable samples, in a "wet" condition**
- ✓ **Qualitative metrics often used for evaluation**

Example with the Science AI-Robot team



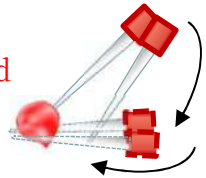
Gripping of a small organ



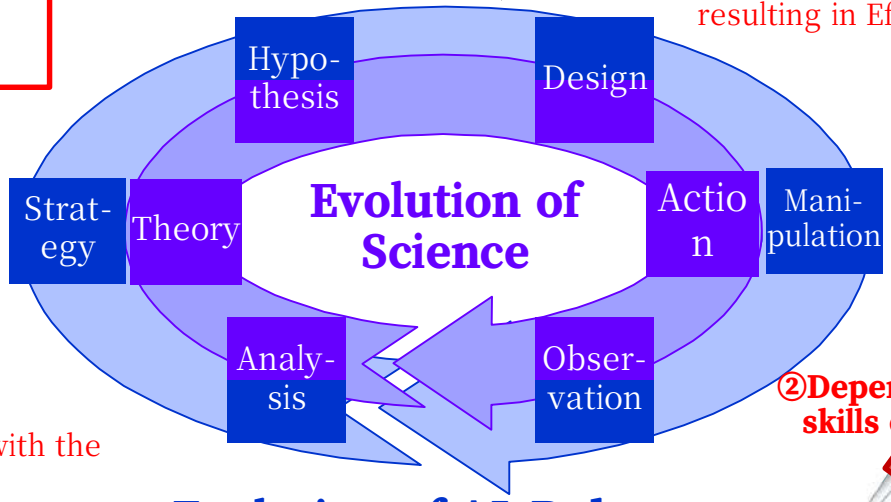
③Strategy
Grip: insert the tool tips underneath the organ→pull up→grip with a small gap

Position to insert: connecting part with the remaining part (Anatomical knowledge)

④Design
Cognition and manipulation

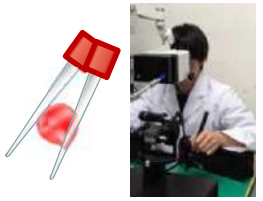


⑤Autonomy
Fast processing of multi-modal big data
Highly-dexterous, accurate manipulation
→Improved success ratio & fast processing, resulting in Efficient Discovery



Evolution of AI-Robot

①Tele-manipulation

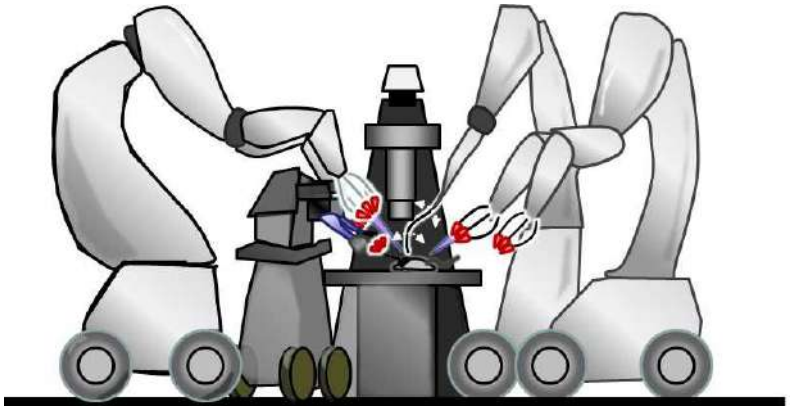


②Dependence of the skills of scientists

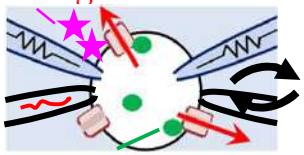
Novice: grip and crush

Expert: grip gently

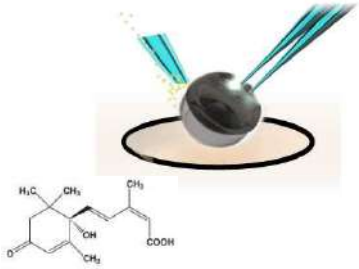
Example with the Science AI-Robot team



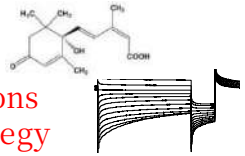
Search for chemicals presenting desired reaction



③Strategy
How to lead to the desired outcomes



④Design
Search for conditions based on the strategy



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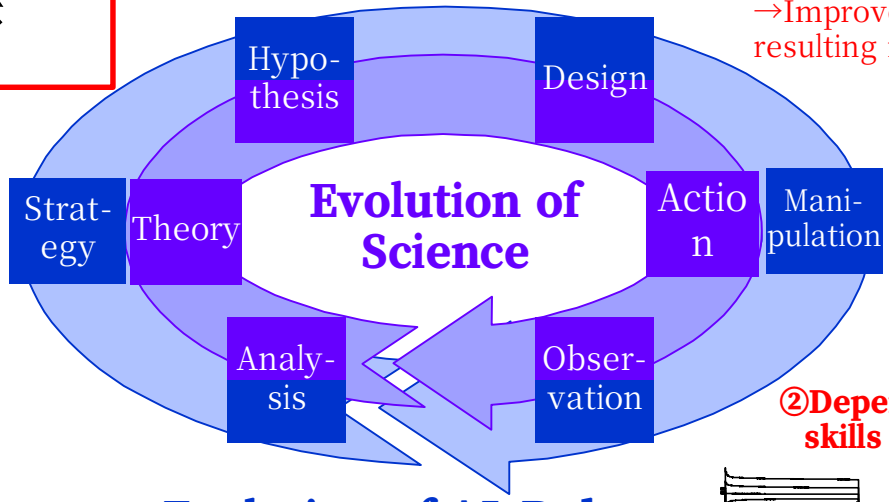
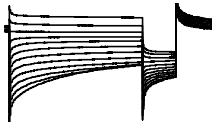


Evolution of AI-Robot

①Planning

②Dependence of the skills of scientists



Novice: small variation in results
Expert: large variation in results

Team organization

Theory → **Implementation** → **Application**

Simultaneously researched

1. Integrated-AI theory

1-1: Intelligence for science

Shogo TANIMURA
Nagoya University

1-2: Mathematical theory for integrated-AI

Yoshihiro MARUYAMA
Australian National University

1-3:Integrated-AI for computational implementation

TBD

1-4: Integrated-AI for AI-Robots

Tadahiro TANIGUCHI
Ritsumeikan University

2. Next-generation AI-Robots

2-1: AI for active learning

Ichiro TAKEUCHI
Nagoya Institute of Technology

2-2: AI for observation and analysis

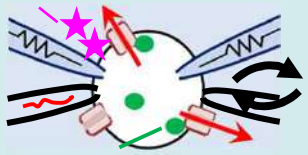
Kensaku MORI
Nagoya University

2-3: Robot manipulation Strategy

Kei OKADA
The University of Tokyo

2-4: Science AI Robot tools

Fumihito ARAI
The University of Tokyo



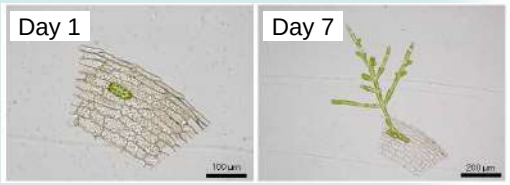
2-5: Science AI-Robot system

Kanako HARADA
The University of Tokyo

3. Science

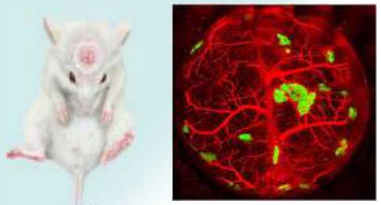
3-1:Sicence for plants

Nobuyuki UOZUMI
Tohoku University



Yoshikatsu SATO
Nagoya University

3-2: Science for animals



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Tokyo Medical and Dental University