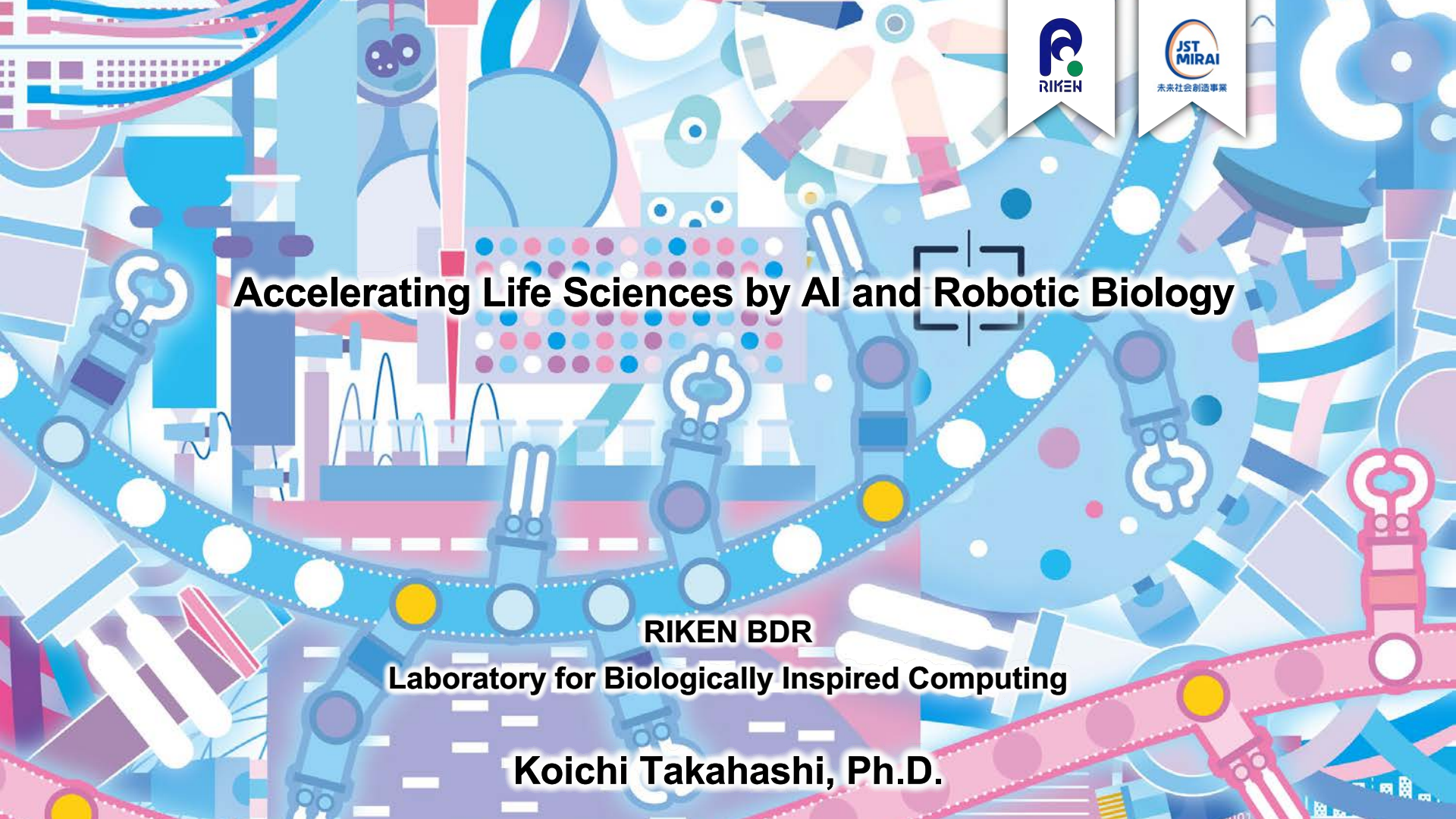


Accelerating Life Sciences by AI and Robotic Biology

RIKEN BDR

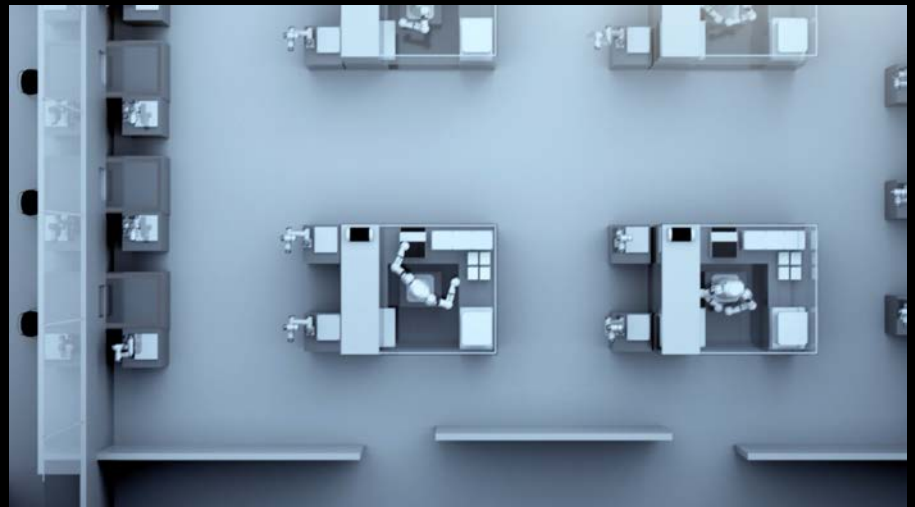
Laboratory for Biologically Inspired Computing

Koichi Takahashi, Ph.D.

The **first** paradigm	Empiricism (experimentation)
The **second** paradigm	Theory
The **third** paradigm	Simulation
The **fourth** paradigm	Data

The fifth paradigm of science： Automation

Robotic Biology Prototyping Laboratory



Robotic Biology

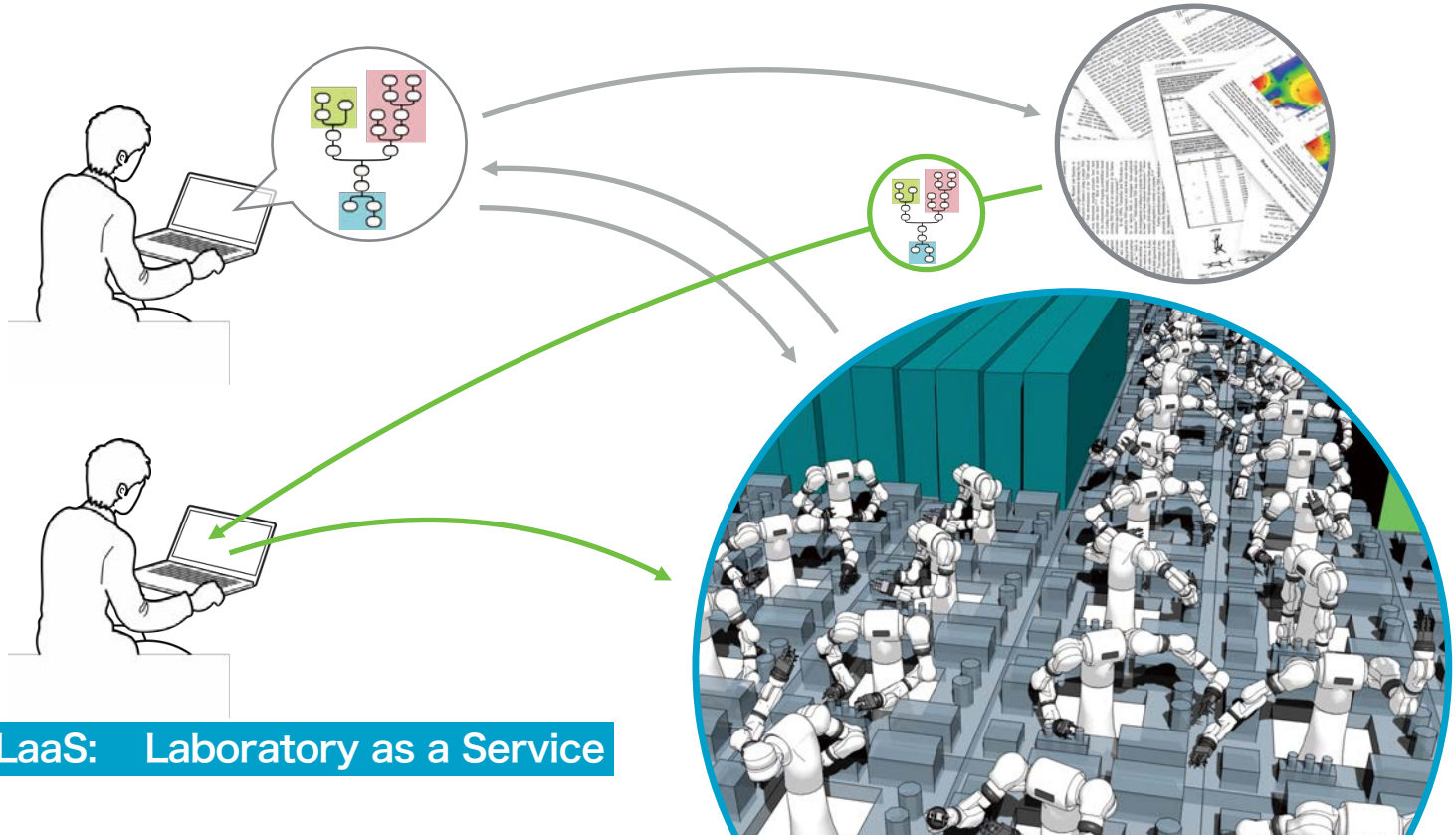
- Lab experiments as programming of physical and chemical processes
- Robots in the cloud execute actions and acquire data

JST MIRAI
project members:

RIKEN
AIST
Tsukuba U.
U. Tokyo
Keio U.
U. British Columbia

RBI / YASKAWA
TECAN Japan
Epistra Inc.

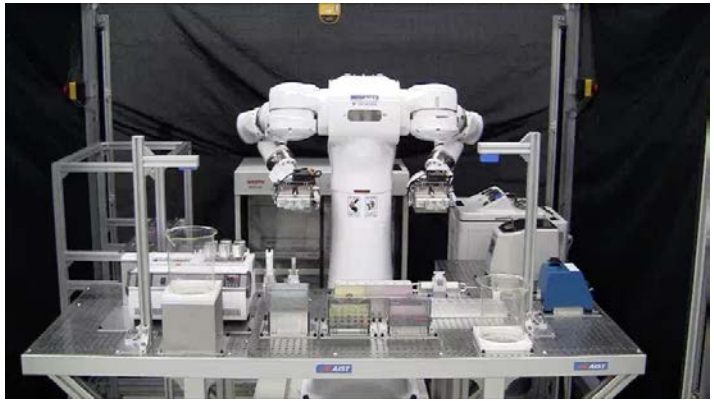
(more to come)



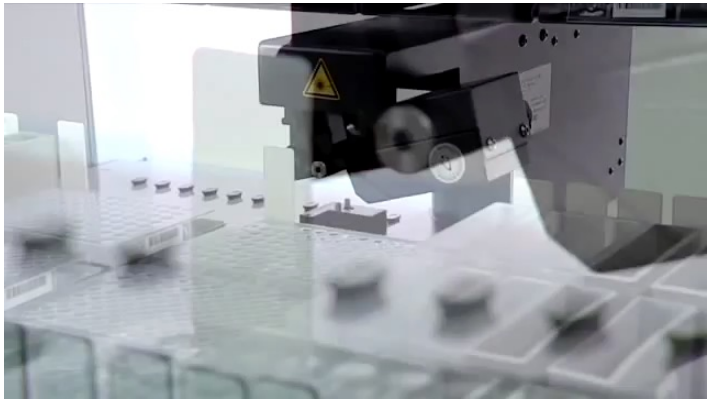
LaaS: Laboratory as a Service

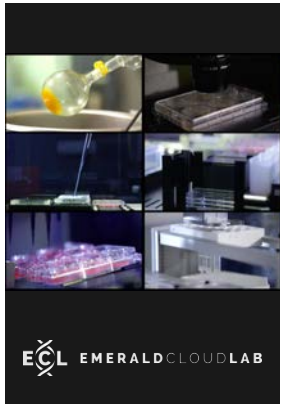
Rapidly emerging robotics for life sciences

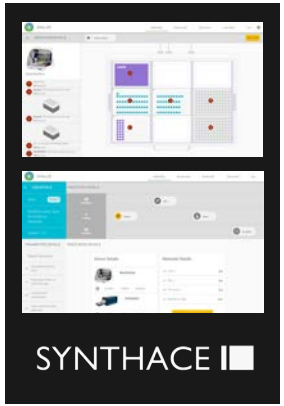
AIST/YASKAWA
LabDroid Maholo

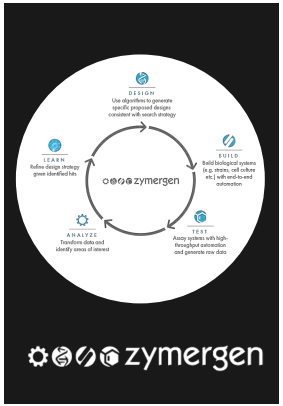


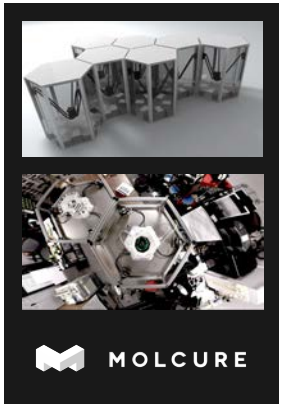
TECAN
Freedom EVO



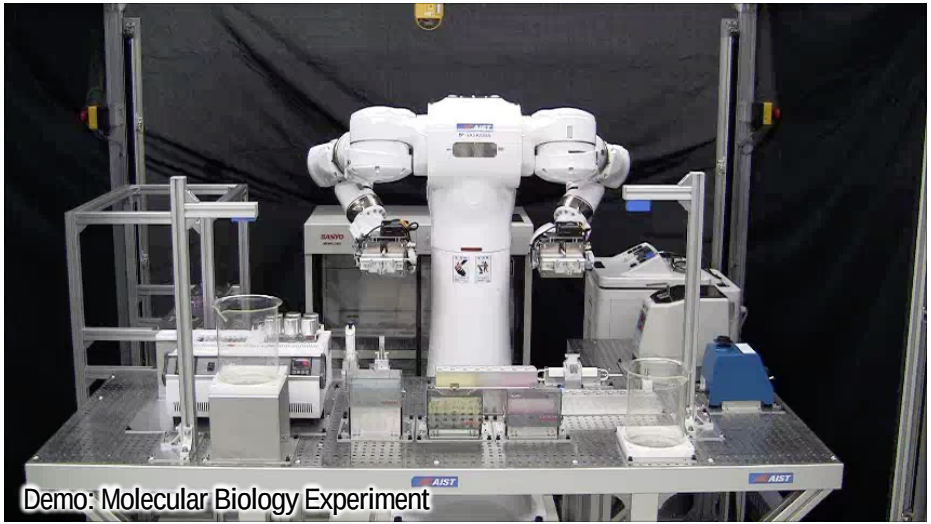


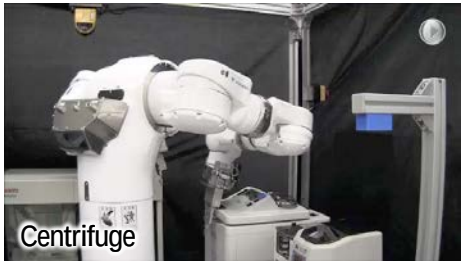


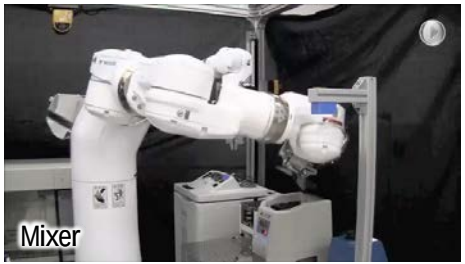


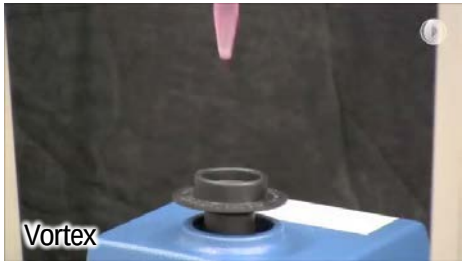


LabDroid Maholo







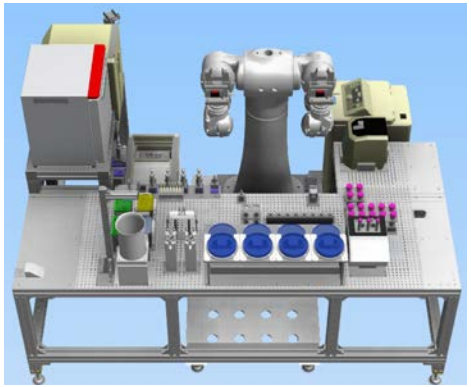


YASKAWA

RBI | Robotic Biology Institute Inc.

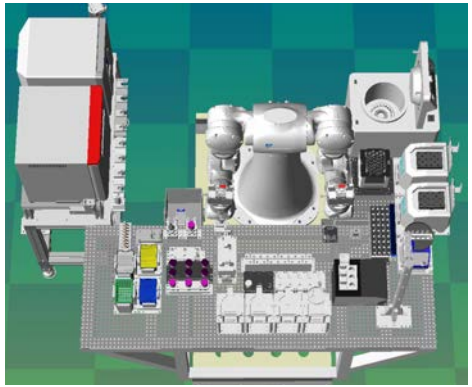
Flexibility for protocol changes

Cell culture

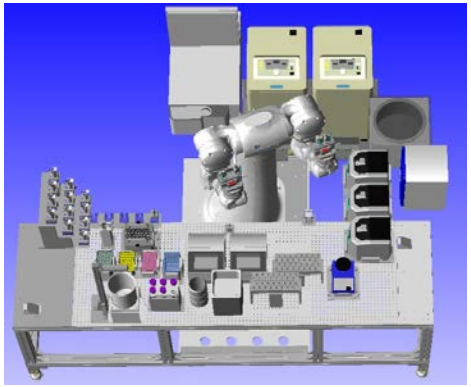


Proteomics

Metabolomics



Genomics



Consortium

nature biotechnology

Robotic crowd biology with Maholo LabDroids

Nozomu Yachie, Robotic Biology Consortium & Tohru Natsume

***Robotic Biology Consortium**

Steering Group: Nozomu Yachie[1-4], Koichi Takahashi[3,6,7], Toshiaki Katayama[8], Takeshi Sakurada[6], Genki N. Kanda[6,7], Eiji Takagi[6], Takako Hirose[6], Tatsuo Katsura[9], Tetsuo Moriya[9], Hiroaki Kitano[10–13], Junichi Tsujii[14,15], Tohru Natsume[5,6]

Robotics Group: Tomoyuki Shiraki[16], Hirokazu Kariyazaki[16], Motohisa Kamei[16], Noriko Abe[16], Takuya Fukuda[16], Yukiko Sawada[16], Yukio Hashiguchi[16], Kenji Matsukuma[6,16], Shinji Murai[6,16], Naoyuki Sasaki[6], Tatsuro Ipposhi[6,16], Hideo Urabe[6,16], Taku Kudo[6,16], Makoto Umeno[16], Seiki Ono[16], Kohei Miyauchi[16], Miki Nakamura[16], Takahiro Kizaki[16], Takashi Suyama[16], Tomohisa Hatta[5], Tohru Natsume[5,6]

Information Technology Group: Tazro Ohta[17], Koichi Takahashi[3,6,7], Yosuke Ozawa[6], Takeshi Sakurada[6], Kenji Matsukuma[6], Shinji Murai[6], Shoji Ihara[18], Satoshi Tamaki[18], Erick Antezana[19], Alexander Garcia-Castro[20], Jean-Luc Perret[21], Soh Ishiguro[1,3], Hideto Mori[1,3], Daniel Evans-Yamamoto[1,3], Nanami Masuyama[1,3], Masaru Tomita[3], Junichi Tsujii[14,15], Toshiaki Katayama[8], Hiroaki Kitano[10–13]

Proteomics Group: Tomohisa Hatta[5], Masaki Matsumoto[22], Hiroshi Nakayama[23], Ayaka Tokunaga[24], Kazutaka Shimbo[24], Naoyuki Yamada[24], Keiichi I. Nakayama[22,25], Tohru Natsume[5,6]

High-Content Cell Screening Group: Takatsune Shimizu[26,27], Hideyuki Saya[27],

Epigenetics Group: Satoshi Yamashita[28], Takahide Matsushima[28], Hiroshi Asahara[28]

Clinical Group: Hidetoshi Eguchi[29], Manabu Mikamori[29], Masaki Mori[29]

LabCode: experimental protocol description language

Before

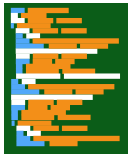
Different vendors, different languages

YASKAWA

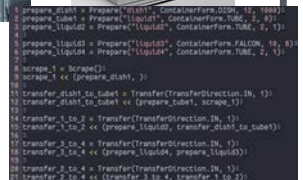
TECAN.

Now

LabCode common language



Common language



Next

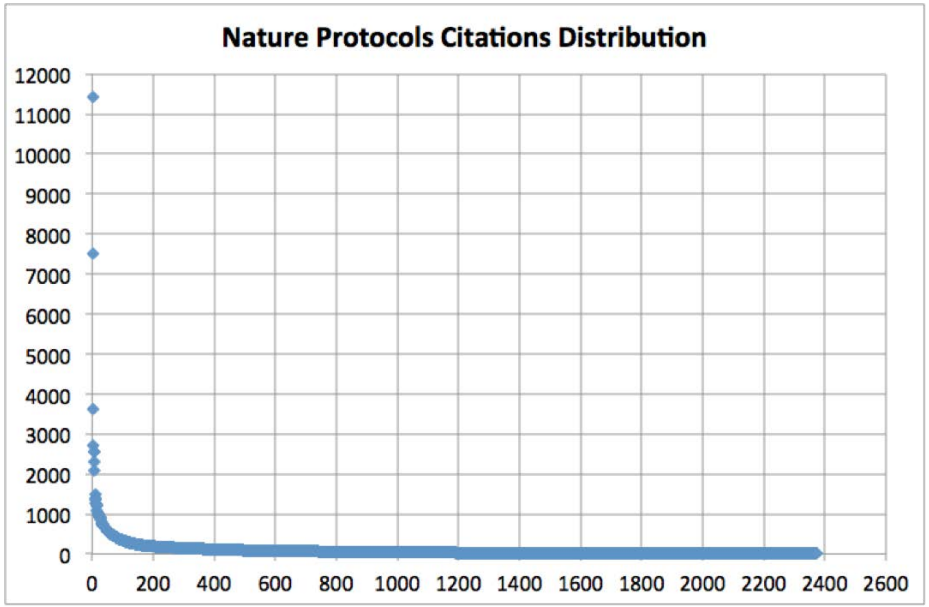
Common workflow

Everything in the facility interprets LabCode

Protocols sharing Users community

Common workflow description from experiments planning, experiments execution, data processing to hypotheses generation.

Pareto principle at work; citations distribution in Nature Protocols



Top１００:４４%、５００:８０%

Data by Ozawa *et al.* (Epistra Inc.)

Major automation burdens in biology

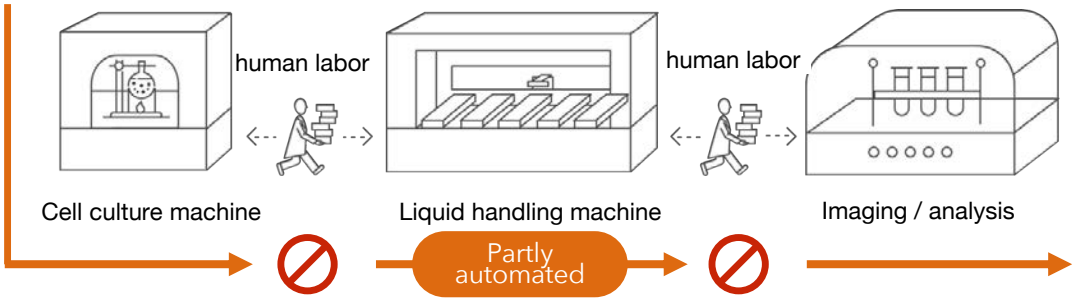
Thousands of different protocols

Frequent protocol changes

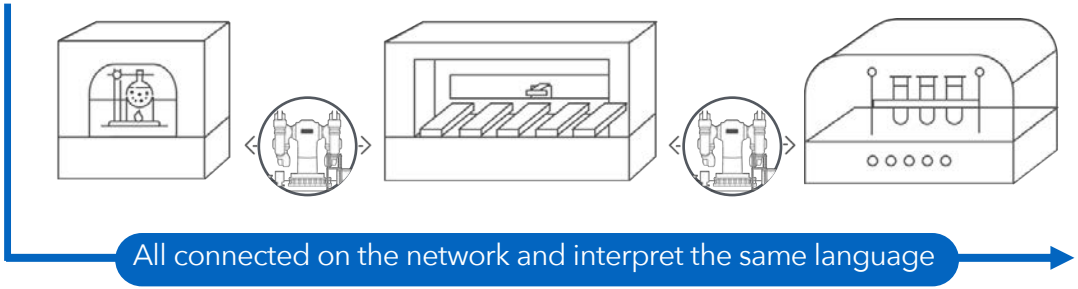
Lots of tacit knowledge

Current laboratory automation is not really lab automation

Status quo: machines do not know each other

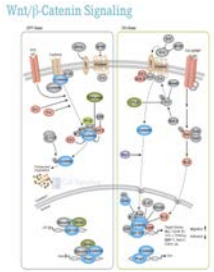


To be: machines work together



Protocols exchange between six robot labs

A remote experimentation PoC



ChIP-MS

ChIP-qPCR

Cell based drug screening

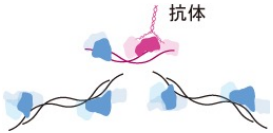
AIST

RBI | Robotic Biology Institute Inc.

TMDU

Keio

High-content Cell-based Screening



Chip

九州大学 KYUSHU UNIVERSITY

Kyushu U.

AJINOMOTO

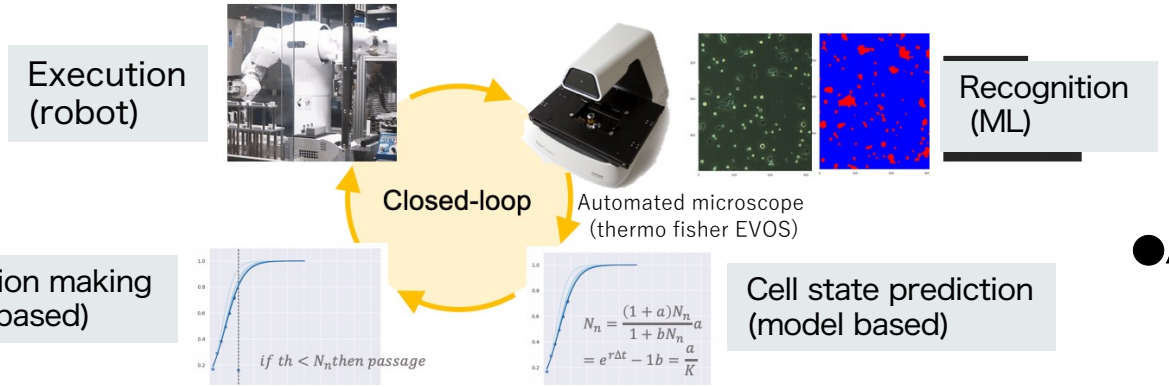
RIKEN

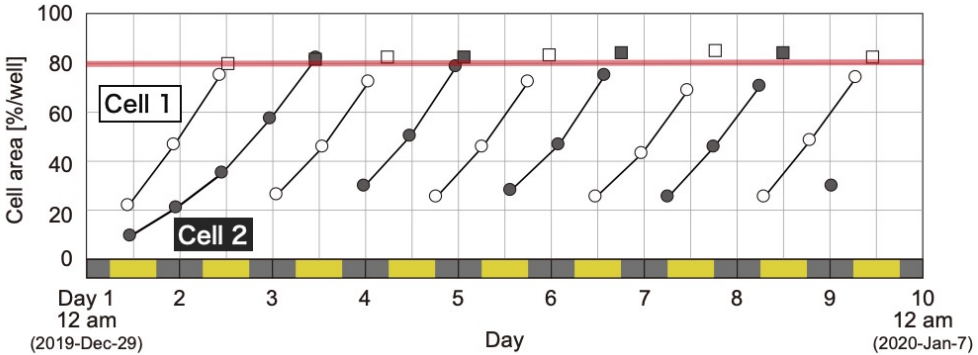
CSRS

Yachie et al. *in prep.*

Autonomous passage culture

-- A minimum prototype of AI-driven life science





- A closed-loop, autonomous system
  recognition – prediction
  - decision making - execution
- HEK293 cells
  (also works with iPS cells)
- Minimizes human labor

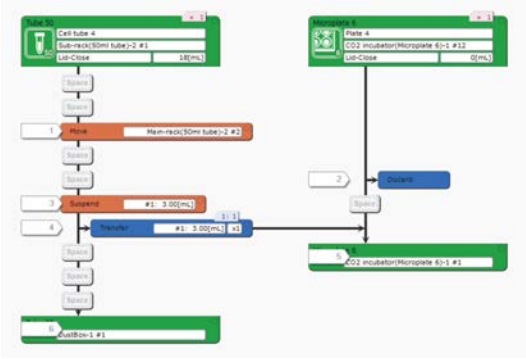
Operation started in Jan. 2020
→ helped protecting precious cell samples under COVID-19 lab-shutdown.

Ochiai, Motozawa et al. *SLAS Technology* 2020.

Implementing tacit knowledge

1. Programming

By robot engineer



2. Modifications and adjustment

By lab expert

before

after

3. AI optimization

・Machine learning of lab expert`s evaluation criteria
・Evaluation function is used in Bayesian optimization

Under development: motion capture

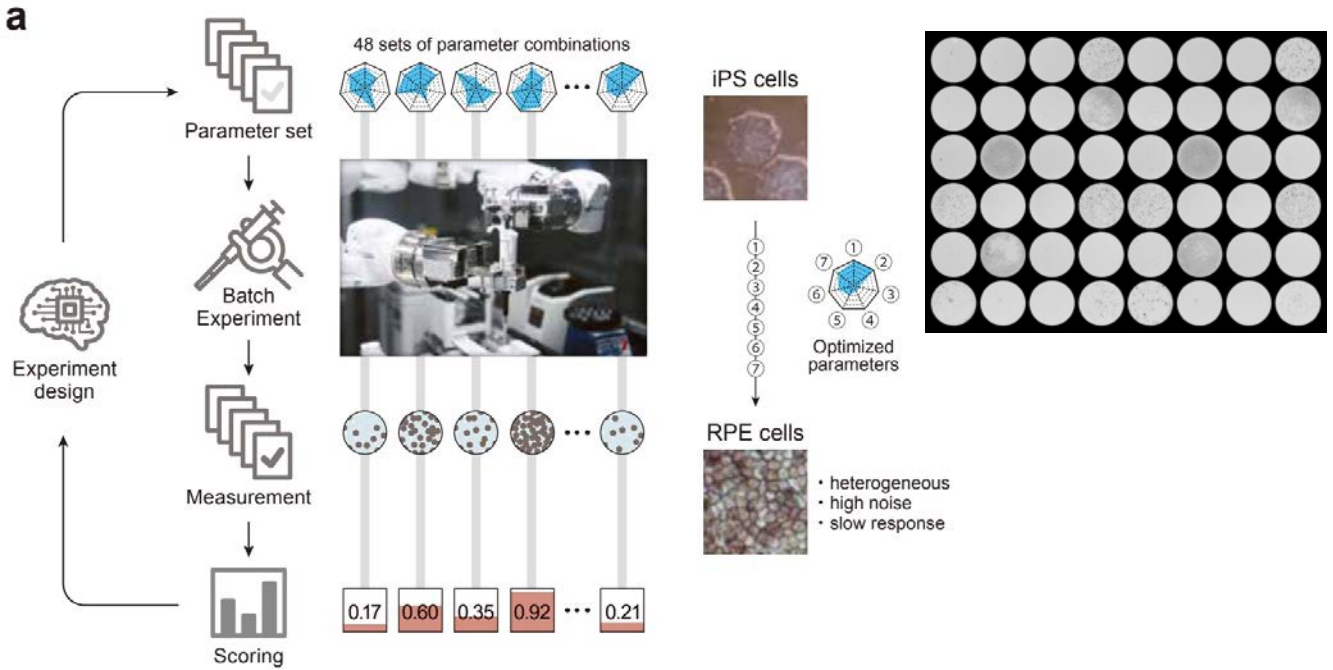
More efficient implementation of step 1 and 2.

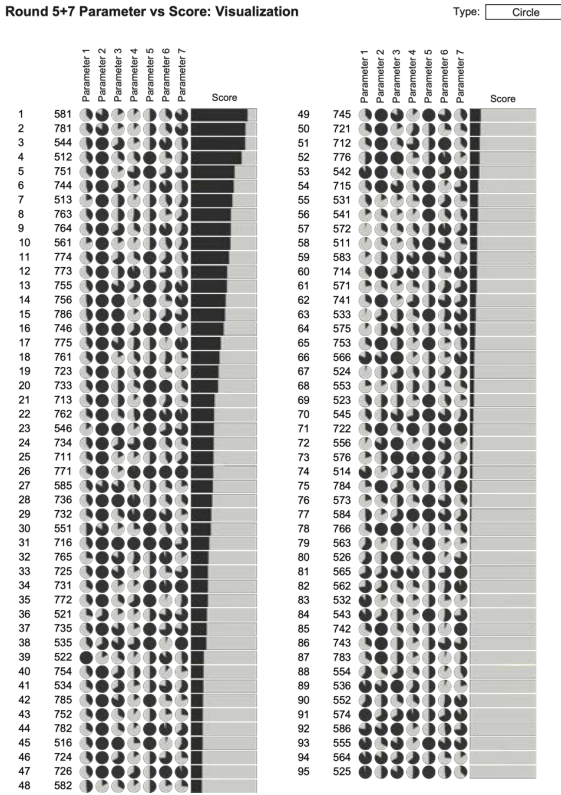
Direct generation of robot trajectory.

Autonomous induction of clinical-grade RPE cells from iPS cells

(RPE: Retinal Pigment Epithelium)

w/ Masayo Takahashi
RIKEN / VC'
Epistra Inc.





Automated expriments planning :

A new method for noisy, highly parallel, and cost- and time-consuming biological experiments (a variant of batch Bayesian optimization)

→ 10x acceleration of research process (five years to a half year)

Kanda et al. bioRxiv 10.1101/2020.11.25.392936v1 (2020), Kanda *et. al submitted.*

Towards the fifth paradigm of science

Automation / AI

Robotic experiments

Automated experiments design

Automated hypotheses generation

Human centric
AI-driven science

Data

Model

Discovery of patterns / laws

Knowledge extraction

Machine learning

Knowledge representation

Prediction

Simulation