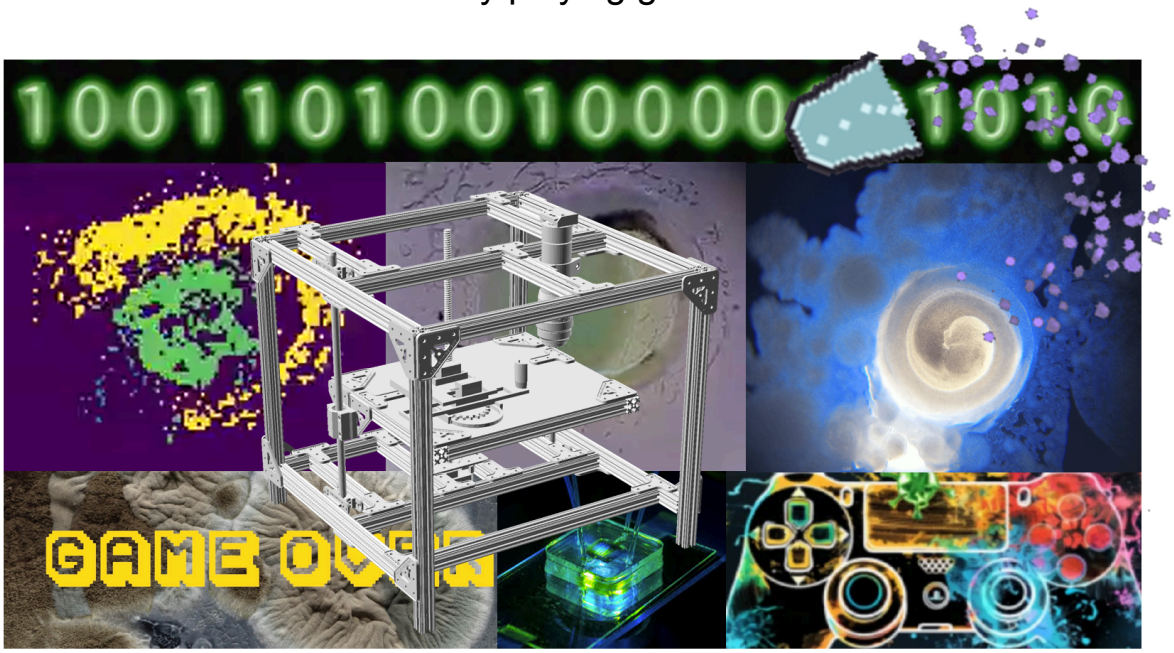
未来研究的游戏化世界 | The Gamified World of Future Research

我们能与微生物玩游戏来做科学研究吗?
Can we do scientific research by playing games with microbes?



Earth 2.0

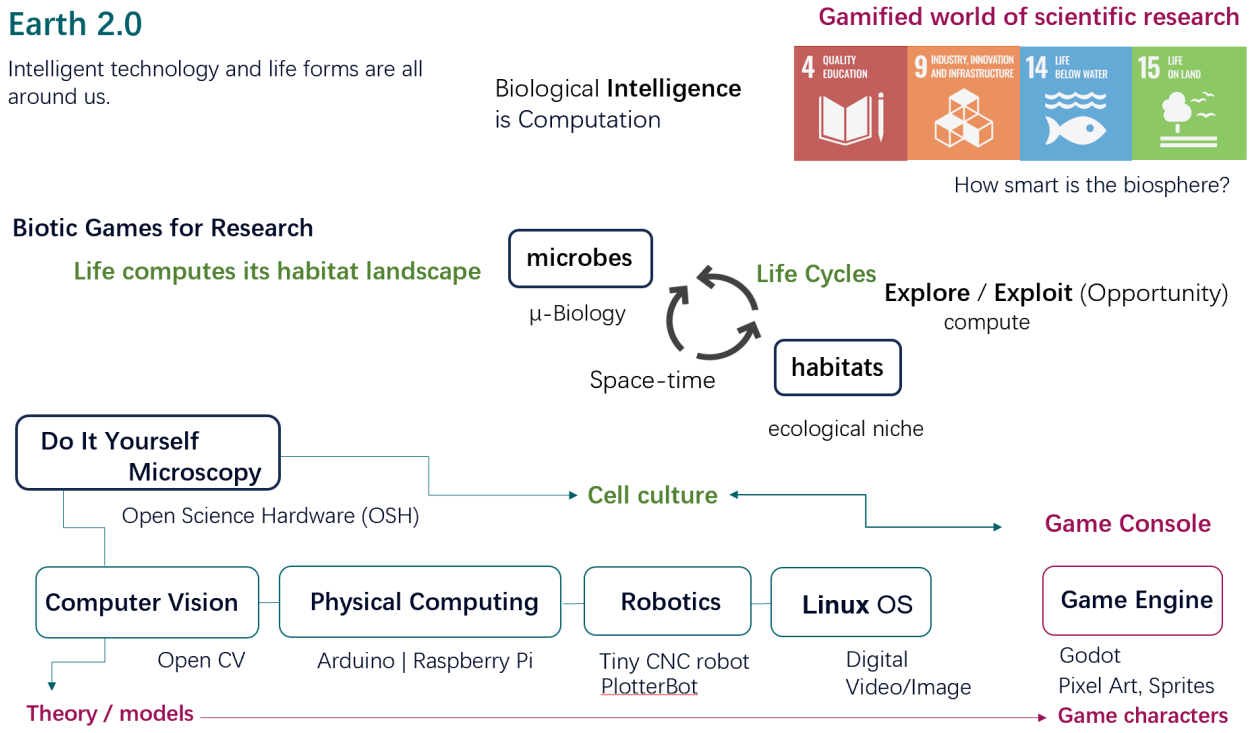
In 2024, out of the 8.1 billion humans on Earth 5.35 billion are connected to the Internet. In the past year, 100 million new users joined in. Most of this connectivity is mobile (96.5%) and mobile users account for roughly half of the Internet's traffic as well as its use time.[1]
We are a collective swarm of living creatures, globally connected and constantly on the move. This is Earth 2.0: A planet full of humans on the brink of a cosmic shift driven by the dominance of **digital technology**. Technology that seems to be *intelligent* and dominated by *information*. At the same time, we are living in a century of unprecedented change, where **biology** is key.
It's key to question these aspects of a changing world: What is intelligence? Is it the biological trait that enables survival and adaptation to an ever-changing environment? Is life the signature of intelligence in nature[2]? What does it have to do with computation? Or with our ability to predict the future? What happens when technology and biology blend into one another?

The world around us is alive and intelligent, and the boundary between 'natural' and 'man-made' is disappearing. As intelligent machines hybridize with natural systems, we discover new forms of biological intelligence and computation. As biology moves from being conceived as an analog phenomena towards a new digital paradigm, ecosystem-machines spread throughout the built environment and the decentralization of physical computation makes us rethink our individuality and our collectiveness. Our collective imagination is the only limit[3].

[1] Our world in data
[2] "Physics, Computation, and Why Biology Looks so Different" *J.Theor.Biol.* (1994) **171**:53-60 by J.J. Hopfield
[3] Sustainable Development Goals (UN), Transforming our world (2030 UN Sustainable Development agenda)

Gamified Future Research

The track is an exploration of how to imagine a future where biological research can be conducted in a decentralized manner by playing and designing biotic games. These are games that incorporate living systems and their supporting ecosystems as part of gameplay.
How clear is the boundary between research and gaming? Can we blur this boundary further? Can scientific instruments built with Open Science Hardware (OSH[4]) be converted into game consoles? We will look into an example of a Do it Yourself (DIY) microscope becoming a game console: HomeScope[5].



We aim to think, build, and hack *hands-on* around this idea while focusing on **microbial ecosystems** in particular as they are at the core of life on land [SDG 15] and below water [SDG 14] as well as a fundamental component of our built environment[6]. Are we made of more microbes than human cells[7]?

In the context of Earth 2.0, we will meditate on **microbial social intelligence**, **computation**, and the hybridization of intelligent machines and evolving ecosystems: How intelligent are microbes?[8] How social are they?[9] Can we harness their intelligence to evolve new technology? Can intelligent machines and microbes co-evolve? Can microbes play games[10]?

[4] Open Science Hardware (UNESCO document)
[5] HomeScope (DIY Microscope)
[6] NYC's subway's microbes (article in Wired Magazine)
[7] Human Microbiomes (iBiology Talk)
[8] Bacterial Intelligence (article in Quanta Magazine)
[9] Social IQ for bacteria (article in Science Daily) and Genius bacteria (article in Phy.com)
[10] Playing Computer Games with Bacteria? (article in Medium)

Can research and education be combined with game design and gameplay? By doing so, Can we create new innovative infrastructure for future industries [SDG 9] and educational paradigms [SDG 4]?

Can we conceive and design **biotic games**[11] that, when being played collectively, contribute to relevant scientific research to achieve a sustainable coexistence between humans and our supporting ecosystems?

What will we learn?

In hands-on PSRT sessions, we will explore different topics around the concepts of [wetware], [hardware], and [software].

[*Wetware*] We will examine how microbial life cycles explore and exploit their habitats by building synthetic spatially heterogeneous landscapes using microfluidics[12] and/or 3D printing techniques as well as patterning chemical repellents/attractants on petri dishes. Equipped with these habitats (ecological niches) where microbes can grow in space and time, we will observe microbial life with a DIY microscope.

[*Software*] To control the DIY microscope we will learn the Linux[13] Operating Systems running the Raspberry Pi[14] computer in charge of video acquisition so we can take digital video recordings and timelapse images. As the HomeScope microscope is not only a computer but also a robotic structure, by playing with a Tiny CNC robot (PlotterBot[15]), we will learn about the world of physical computing using the Raspberry Pi and Arduino[16] GPIOs[17] as well as several sensors, actuators, and machine communication protocols. Furthermore, as we want to make games, we will learn how to abstract microscopy data into game elements (pixel art and sprites[18]) using Computer Vision (OpenCV[19]) algorithms (via OpenCV library bindings written in Python[20] and Processing[21]) and implementing these into your own game using the Godot[22] game engine.

[*Hardware*] The idea is also to hack the hardware and turn a microscope into a biotic game console. Which implementations are needed for your game design?

What is expected?

Students are expected to have fun, observe microbes, hack software and hardware and to propose game concepts including a living microorganism and its habitat. The game concept should touch on a scientific question and the aim is to build a digital prototype to showcase the developed ideas during the Gallery Walk exhibition at the end of the Summer camp.

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[11] "Design, engineering and utility of biotic games" (2011) *Lab on a Chip* **11**(1): 14–22. by I. H. Riedel-Kruse et al.
[12] "Open-source, community-driven microfluidics with Metafluidics" (2017) *Nat.Biotechnol* **35**:523-529 by D.Kong *et al.*
[13] Linux OS
[14] Raspberry Pi computer
[15] PlotterBot (Tiny CNC robot machine)
[16] Arduino microcontroller system and language
[17] General Purpose Input/Output (Raspberry Pi, Arduino)
[18] Making Sprites with Piskel
[19] OpenCV (Open source Computer Vision library)
[20] Python computer language
[21] Processing computer language
[22] Godot (Game Engine)

Conceptual units

The track includes **6 knowledge areas**: (μ)Biology | Synthetic Ecosystems | Microscopy | Robotics | Game Engines | Computer Vision

1. **μ-Biology** [*Wetware*]
   Research objects (microbes) as game characters
   Life cycles: explore or exploit?
   Microbial natural history: Protists (slime molds and μ-algae) and bacteria
   Home and geographic ranges: biological computation in opportunity landscapes

2. **Synthetic ecosystems** [Wetware + Hardware]
   Habitat landscapes and synthetic ecosystems as game terrains/worlds
   Habitat landscapes: biology in space and time
   Island biogeography: patch dynamics habitat topology
   Making synthetic habitats: petri dishes, tests tubes, and microfluidics

3. **Microscopy** [Wetware + Hardware + Software]
   Scientific instruments as game consoles
   HomeScope, a DIY microscope (Open Science Hardware)
   Raspberry Pi and the Linux Shell
   Time-lapse imaging and digital video processing

4. **Robotics** [Hardware]
   Scientific instruments as game consoles
   Physical computing: Arduino and Raspberry Pi GPIOs
   HomeScope's robotic systems
   Sensors [input]
   Push down buttons (resistors), JoySticks and Potentiometers
   Mechanical Endstop breakers
   Actuators [output]
   LED (Voltage and Pulse Width Modulation, PWM), Stepper Motor + EasyDriver (Z axis of motion), PlotterBot, a Tiny CNC robot (XY axis of motion), and LCDs
   Communication [logic, bits, and voltages]
   Serial Port, i2C communication, GPIOs (Logical conversion from 5V to 3.3V)

5. **Computer Vision** [Software]
   Data processing for game play
   The OpenCV library for computer vision.
   Language bindings: Python and Processing

6. **Game engine** (Software)
   The gamified world of scientific research
   Godot, the open game engine. Make your own 2D game: From "*Dodge the Creeps*" to microbial environments?

Schedule

Week 1

General	In-track	7.15 星期一	7.16 星期二	7.17 星期三	7.18 星期四	7.19 星期五	7.20 星期六
09:00-12:00	09:00-09:45	**Opening ceremony** Tea break **Challenge release** [12min intro + 5min Q&A]	**Who is who?** Mapping interests to track topic	**intro PSRT 3**	**intro PSRT 5**	City visit	**Ideation 5** [specialization group]
	09:45-10:00		15' break				15' break
	10:00-11:00		**intro + PSRT 1 [wetware]** Physarum Landscape. *Spatial computation and intelligence*	**PSRT 3 [software]** How do we make what we see digital? *Computer Vision*	**PSRT 5 [software]** Game engines, animations & OOP *Godot*		**Group work** in specialization groups [wetware / software / hardware]
	11:00-12:00						
12:00-14:00		午餐+午休					午餐+午休
14:00-16:00	14:00-14:45	**Track poster gallery + Q&A**	**intro PSRT 2**	**intro PSRT 4**	**Ideation 3** [project group]		Gas station
	14:45-15:00		15' break				
	15:00-16:00		**PSRT 2 [hardware]** OSH (HomeScope) as game consoles. *TinyCNC robot*	**PSRT 4 [wetware]** From Synthetic Ecosystems to Game Terrains. *Habitat design*	**Group work** Shaping the project idea [wetware + software + hardware]		
16:00-17:00	16:00-17:00	In-track **ice breaking** activities					**Open Lab**
17:00-18:00	17:00-17:15		15' break				
	17:15-18:00		**Ideation 1** [joined]	**Ideation 2** [sub groups]	**Ideation 4** [joined]		
18:00-19:30		晚餐					
19:30-21:00		OWL night - ice breaking activities	OWL night Science	OWL night Fire place talk	OWL night Art		**Group work** [project group]

Week 2

General	In-track	7.21 星期日	7.22 星期一	7.23 星期二	7.24 星期三	7.25 星期四
09:00-12:00	09:00-09:45	**Ideation 6** [joined]	**Project sharing** feedback and discussion	**Finishing touch** [project group] and/or [specialization group]	**X-Fusion Junior Camp closing ceremony**	**X-Fusion**
	09:45-10:00	15' break				
	10:00-11:00	**Group work** [project group]	**Project sharing** feedback and discussion			
	11:00-12:00		**Ideation 8** [project / specialization group]			
12:00-14:00		午餐+午休				
14:00-16:00	14:00-14:45	**Ideation 7** [specialization group]	**Group work** [project group]	**Gallery walk**	**X-Fusion Unconference**	**X-Fusion**
	14:45-15:00	15' break				
	15:00-16:00	**Group work** [project group] and/or [specialization group]				
16:00-17:00	16:00-17:00					
17:00-18:00	17:00-17:15	15' break				
	17:15-18:00	**Q&A** [Specialization groups]	**Group work** [project group]			
18:00-19:30		晚餐				
19:30-21:00		**Group work** [project group]	**Group work** [project group]	OWL night Music Festival		

3 types of ideation sessions:

- Joined: Everybody together - learn from each other
- Project group: How do all elements come together in one project
- Specialization group: Tackle specific tasks related to wetware/software/hardware

Detailed schedule

7.15 星期一（第一日）| **Monday July 15th** (day 1)

Morning: Opening ceremony and track releases
Lunch Break
Afternoon: Track Q&A (track poster gallery)
Ice breaking

7.16 星期二（第二日）| **Tuesday July 16th** (day 2)

Morning:
Who is who? Mapping personal interests to track topic
15 min break
PSRT 1 [wetware]
Physarum Landscapes: Explore vs Exploit opportunity. Spatial computation and intelligence.
Hands-on: Make your own synthetic *physarum* habitat and seed them with life! Get familiar with microbial life and their habitats, while looking at range expansion in heterogeneous environments as spatial computation.
Lunch Break
Afternoon:
PSRT 2 [hardware]
HomeScope as a console? Introduction to HomeScope, a DIY robotic and digital microscope, as well as Open Science Hardware (OSH) in general. We will cover The Linux Shell and HomeScope's video/optical systems as well as its Arduino robotics for actuation: translation (XY) and focussing (Z) axes.
How to develop biotic games and the challenge of converting the microscope into a biotic gaming console.
Hands-on: Hack your own Tiny CNC robot (PlotterBot)! Gain familiarity with physical computing using the Arduino microcontroller, sensors, actuators and the serial communication protocol (from voltage to bits).
15 min break
Ideation 1 [joined]
Integrate concepts 1 and 2: Think of microbial habitat landscapes as opportunity (ecological niche) distributed in space and time. Can they become game worlds made of different terrains? In what sense biological systems (life forms) compute their environments? When to exploit and when to explore? Why are biotic games biotic? What are life cycles?

7.17 星期三（第三日）| **Wednesday July 17th** (day 3)

Morning:
PSRT 3 [software]
Microbial intelligence, computer vision and timelapses: Introduction to spatial biology, space utilization and habitat degradation. Why does life need to propagate to new locations seeking opportunity elsewhere? How can this be studied using computer vision and microscopy? What is the mathematics of collective behavior? How can a machine see?

15 min break

Hands-on: How does a machine (HomeScope) observe? Can every OSH become a gaming console? How do we make what we see digital? Exploring Computer Vision and the OpenCV library. Choosing either Python or Processing computer languages, learn the basics of the library's image manipulation functions as well as detecting, segmenting, and tracking algorithms while thinking about microbial space utilization.

Lunch Break

Afternoon:

PSRT 4 [wetware]

Design and construction of a spatial ecology. Habitat heterogeneity and island biogeography. What can we learn from observing the Physarum landscapes? What is a spatial range? What is the difference between home range and geographic range? How can we culture microbes in a spatial system?

15 min break

Hands-on: From synthetic ecosystems to game terrains. Grow swarming bacteria on solid agar plates. How is the habitat being created? Is it homogeneous or heterogeneous? When is space a habitat landscape? How to make a synthetic ecology? Learn about microfluidics, the art of manipulating liquids at the micron scale. What is special about these microcosms? What happens to the physics of liquids? How it can be useful for making game worlds？

15 min break

Ideation 2 [discussion sub groups]

Integrate concepts 3 and 4: How can we use OpenCV algorithms and HomeScope to capture microbial data and model these life forms? How can these representations be embedded in a game world? Can Virtual Reality (VR) or Augmented Reality (AR) be used？How can microbes, humans and machines interact? Can we hack HomeScope to make it happen?

7.18 星期四（第四日）| **Thursday July 18th** (day 4)

Morning:

PSRT 5 [software]

Game Engines, Animations, and Object Oriented Programming (OOP). What is a game engine? Introduction Godot. What are game scenes, animations (sprites) and nodes (objects). Concurrent vs. sequential (structured) computation and the OOP paradigm.

15 min break

Hands-on: Programming a simple 2D game in Godot. Follow the complete tutorial of the game "Dodge the Creeps" in Godot. While learning how to code this game, think about space, territories, characters, and game objects.

Lunch Break

Afternoon:

Ideation 3 [project group]

Who has similar ideas? Join people with different skills and similar interests to assemble a project group (ideally three groups of 5 people) and think of a common biotic game project to present at the Gallery Walk event.

What is science vs what is gaming? Do they have to be different?

Combine wetware + software + hardware: What organisms are you going to

work with? How is its biology/ecology (habitat) related to your game scenes, worlds and terrains?

15 min break

Group work [project group]

Merge it all: Create your game world, scenes, animations and implement its science! How to build the needed Open Science Hardware Gaming/Research console? How to apply what we learned during the PSRT concept sessions? How do we hack these tools to make our game?

15 min break

Ideation 4 [joined]

Where are we & where are we going? Tell each other about the status of group projects. What are the main ideas of each group? Discuss different strategies and the foreseen difficulties. Is your project feasible?

Are microbial colonies like cities? Is a human city a living organism? Tomorrow, while visiting Shenzhen's neighborhoods, give it some more thought! Is there any insight you can use to develop your game?

7.19 星期五（第五日）| **Friday July 19th** (day 5)

Citytrip

7.20 星期六（第六日）| **Saturday July 20th** (day 6)

Morning:

Ideation 5 [joined]

Common challenges, interests and goals. Based on different project ideas, can we identify common challenges, interests and skills? inter-group cross fertilization and the formation of specialization groups (wetware, software, hardware).

15 min break

Group work [specialization group]

Wetware / Hardware / Software Temporarily re-group based on common inter-project tasks to solve. Groups specialized in learning common techniques and/or solving specific common challenges such as growing a particular organism (wetware), using a given computer program (software) or hacking common hardware can join forces to tackle the task at hand .

Lunch Break

Afternoon:

Gas Station

+

Open Lab

Dinner Break

Evening:

Group work [project group]

Process the crossover operations/sessions. After learning from others in the specialization groups as well as exploring the projects of other tracks, process all the feedback and inspiration towards advancing the goal of your own project group. Start developing a prototype of a biotic game. Plan ahead for what you want and think you can achieve to produce for gallery walk day. Play and create!

7.21 星期日（第七日）| **Sunday July 21th** (day 7)

Morning:

Ideation 6 [joined]
Your game concept/prototype: 48 hours for impact! Identify key tasks to focus on and distribute work accordingly to work on your project for the next two days.

15 min break

Group work [project group]
Advance on the strategy planned during ideation session 6. Work as much as you can on the strategy defined. As there are going to be road blocks, identify common issues you could solve in a common fashion working together with other groups.

Lunch Break

Afternoon:

Ideation 7 [specialization group]
Divide and Conquer! Any specific difficulties need to be solved? Specialists from different groups join forces to tackle issues of different nature (wetware/software/hardware).

15 min break

Group work [specialization group] and/or [project group]
Divide and Conquer! While some members keep working on the macro structure of your gallery work presentation, think of assigning members to advance in specialized details which are common to all groups or which might need special focussed help from mentors.

15 min break

Q&A [specialization groups]
Any specific issues, how to solve them?
Specific questions raised while working in specialization groups are addressed.

Dinner Break

Evening:

Group work [project group]
Integrate and plan focus work. Tomorrow is the last day of work we have left to produce the exhibition. Think on how to integrate all relevant results and specific advances into one coherent narrative showcasing your work in a biotic game concept.

7.22 星期一（第八日）| **Monday July 22th** (day 8)

Morning:

Project sharing [joined]
Sharing, Feedback and Discussion Showcase your project to other groups. Learn from each other's approaches and see what you still need to implement or adjust.

15 min break

Project sharing [joined]
Sharing, Feedback and Discussion Showcase your project to other groups. Learn from each other's approaches and see what you still need to implement or adjust.
Ideation 8 [specialization group] and/or [project group]
Finish your prototype and make a poster. Produce your exhibition. Think of a physical representation, some computer graphics, biological data, etc. Highlight

the scientific research related to your game play. Shape your work in an original way into a graphical presentation to convey all these aspects during the gallery walk. Implement different ways to communicate to the audience.

Lunch Break

Afternoon:

Group work [project group]

Focus work towards putting all together. Keep working to produce your prototype and poster representing the group's vision.

15 min break

Group work [project group]

Any help? Any last minute advice needed? If so, this is the moment.

Dinner Break

Evening:

Group work [project group]

Finish and wrap up all work. Prepare for the *Gallery Walk* exhibition. Don't forget to have a good rest. It is important to refresh the mind. Avoid working all night! Rest well and tune all details tomorrow morning.

7.23 星期二（第九日）| **Tuesday July 23th** (day 9)

X-Fusion / Gallery walk junior camp

Morning:

PSRT project ends, performance starts！

Final Tuning of your project group Exhibition/Presentation

Lunch Break

Afternoon:

Gallery Walk

7.24 星期三（第十日）| **Wednesday July 24th** (day 10)

X-Fusion

Morning: Closing Ceremony junior camp

Lunch Break

Afternoon: Unconference

7.25 星期四（第十一日）| **Thursday July 25th** (day 11)

X-Fusion

Morning: Conference

Lunch Break

Afternoon: Conference

Suggested scientific articles[23]

Life as Nature's Computation

"Physics, Computation, and Why Biology Looks so Different" (1994) *J.Theor.Biol.* **171**:53-60 by J.J. Hopfield

"Liquid brains, solid brains" (2019) *Phil.Transactions of the Royal Society B* **374**(1774) by R. Solé *et al.*

"Adaptive behaviour and learning in slime moulds: the role of oscillations" (2021) *Phil.Transactions of the Royal Society B* **376**(1820) by A. Boussard *et al*.

Making Synthetic Microbial Environments with Microfluidics

"Open-source, community-driven microfluidics with Metafluidics" (2017) *Nat.Biotechnol*. **35**:523-529 by D. Kong *et al*.

"Build your own soil: exploring microfluidics to create microbial habitat" (2018) *The ISME J*. **12**(2):312-319 by K. Aleklett *et al.*

Biotic games and Euglena Arcade

"A Biotic Game Design Project for Integrated Life Science and Engineering Education" (2015) *PLoS Biol.* 13(3) by N.J. Cira *et al*.

"Design, engineering and utility of biotic games" (2011) *Lab on a Chip* **11**(1): 14–22. by I. H. Riedel-Kruse et al.

Bacterial Intelligence, motility, and swarming

"A statistical physics view of swarming bacteria" (2019) *Movement Ecology* **7**(9) by A. Be'er & G. Ariel.

"Learning from Bacteria about Natural Information Processing" (2009) *Ann. NY Acad. Sci.* **1178**:78-90 by E. Ben-Jacob.

"Bacterial linguistic communication and social intelligence" (2004) *Trends in Microbiology* **12**(8) by E. Ben Jacob *et al*.

"Genome sequence of the pattern forming *Paenibacillus vortex* bacterium reveals potential for thriving in complex environments" (2010) *BMC Genomics* **11**(710) by A. Sirota-Madi *et al*.

[23] https://git.xinstitute.org.cn/Biology_Laboratory/2024_X_Camp_Junior_Track_6_Suggested_Literature