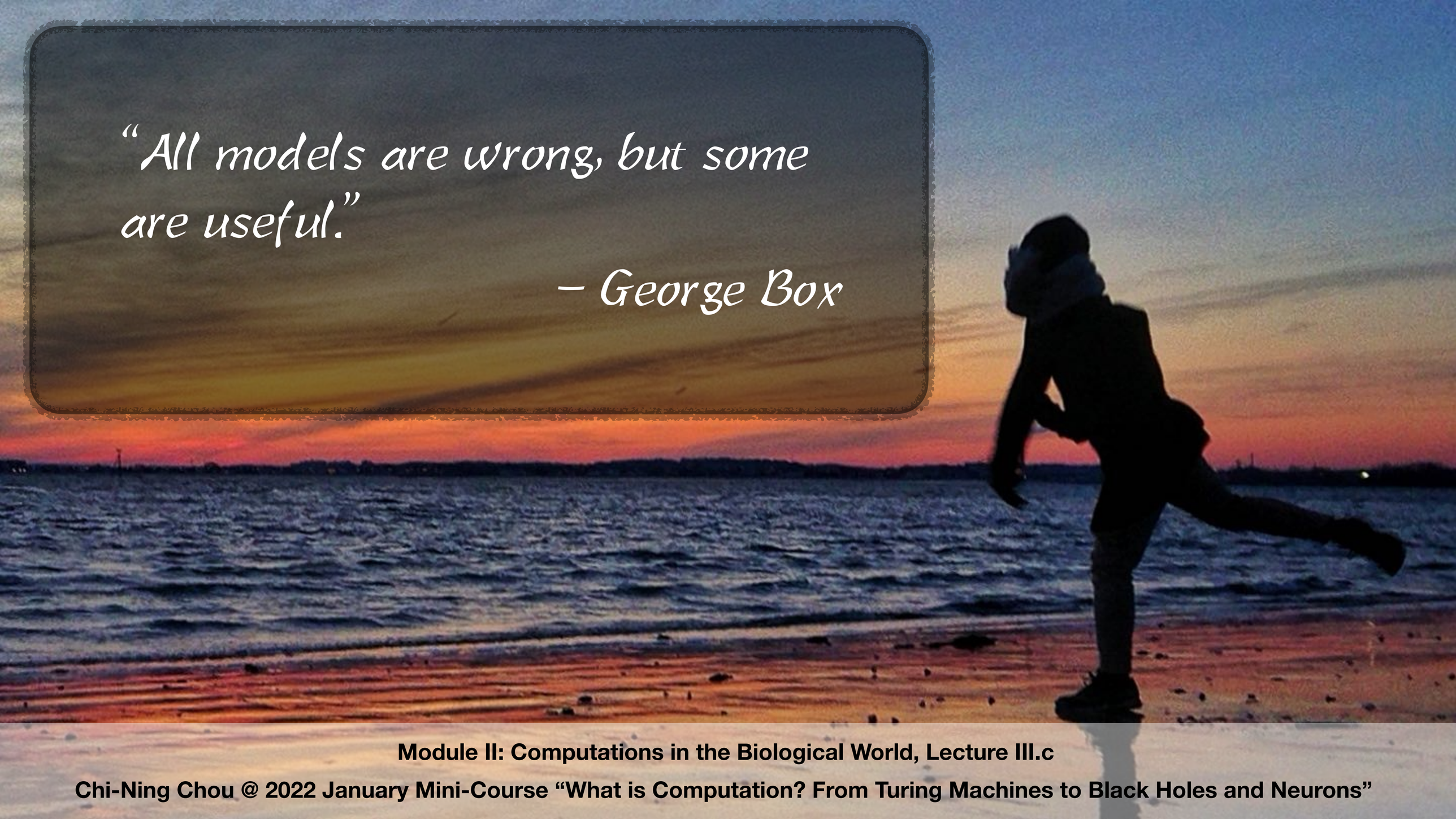


Module II: Computations in the Biological World, Lecture III.c

Chi-Ning Chou @ 2022 January Mini-Course "What is Computation? From Turing Machines to Black Holes and Neurons"

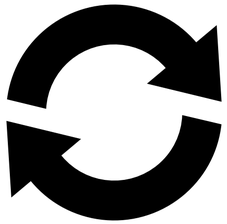
Challenges and Hopes:
A Tango between Biology & Computation

Module III: Computations in the Biological World

"All models are wrong, but some are useful."

– George Box

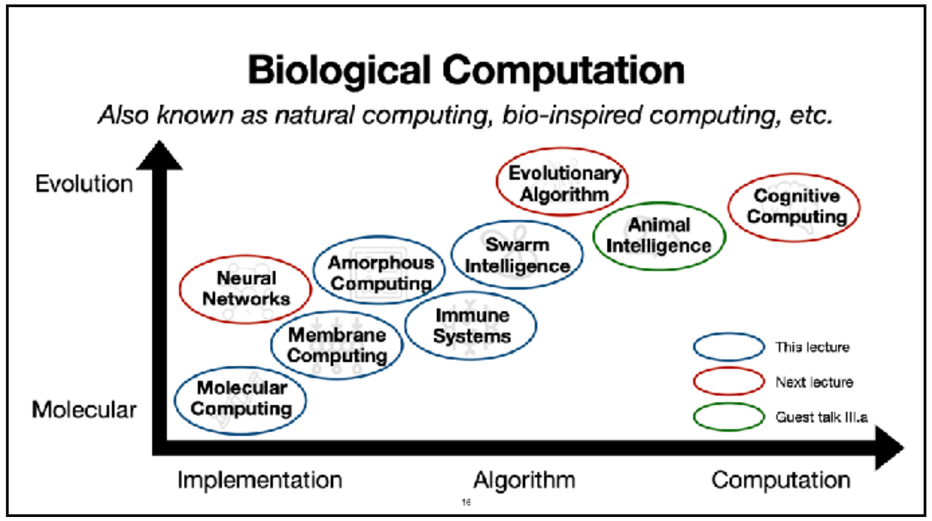
What’s new aspects of computation can be inspired from biology?

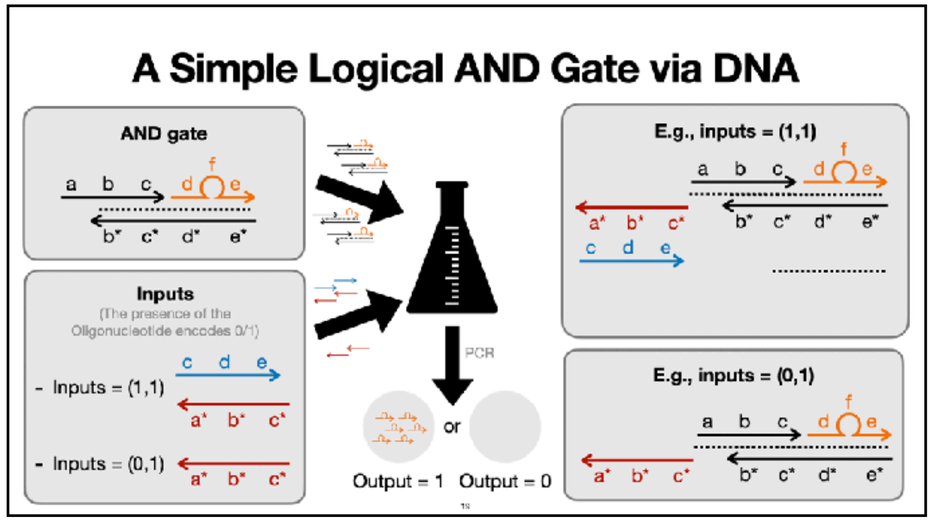
Biology  **Computation**

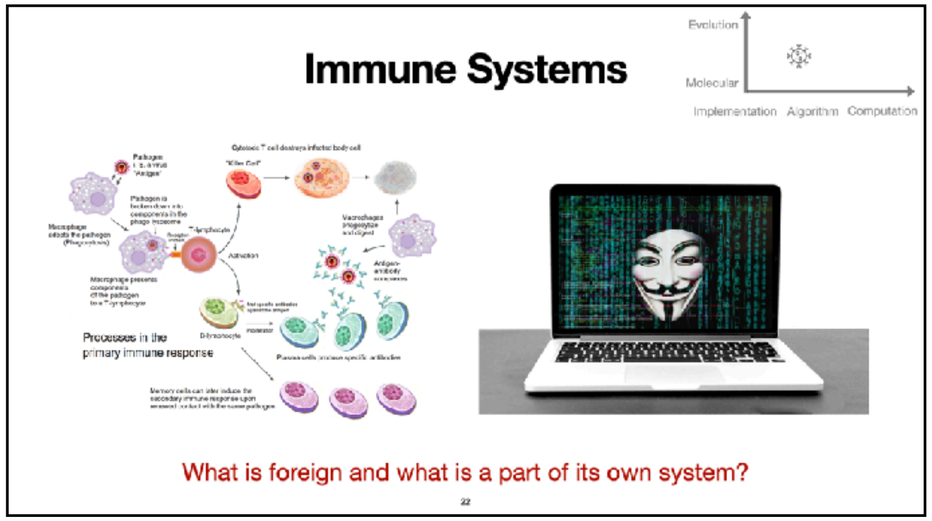
How to study the computation in biology with uncertainties and unknowns?
(With a focus on brain and cognition!)

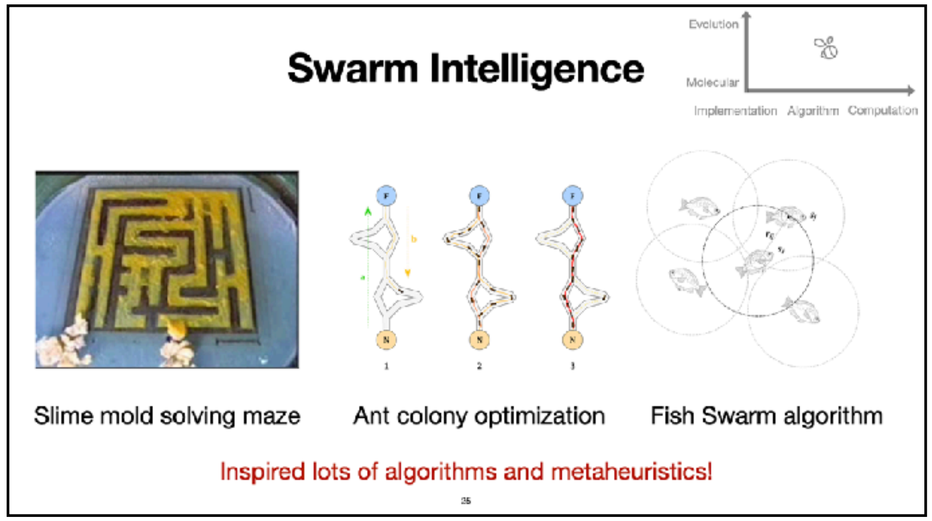
Biological Computations

Many Examples

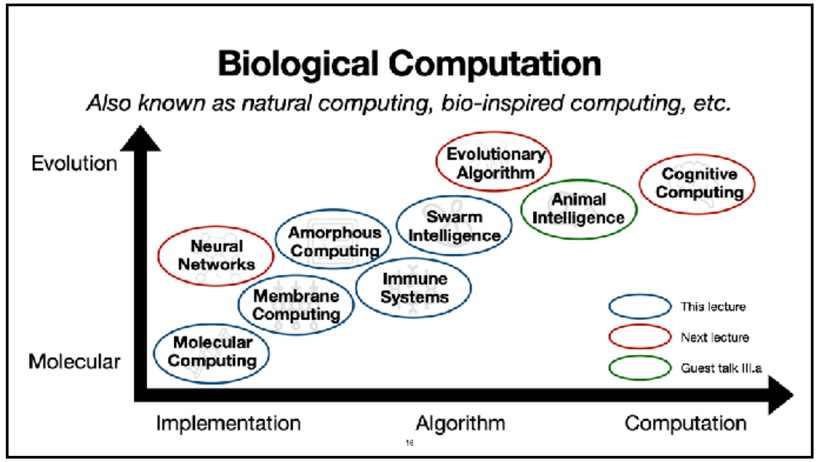


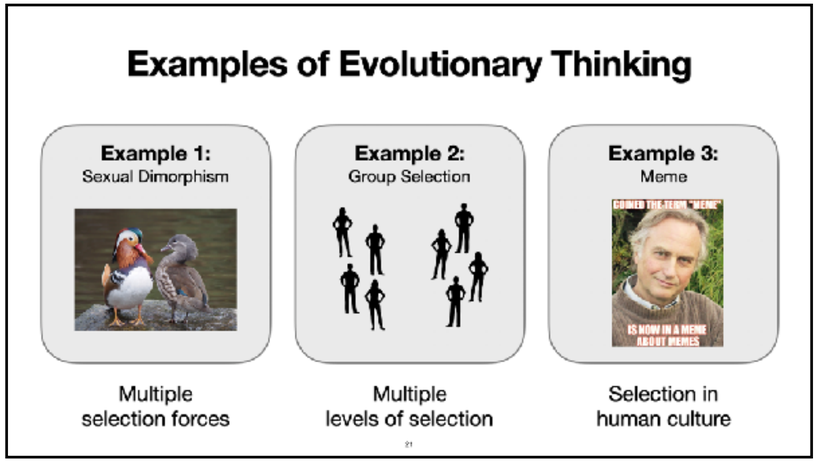


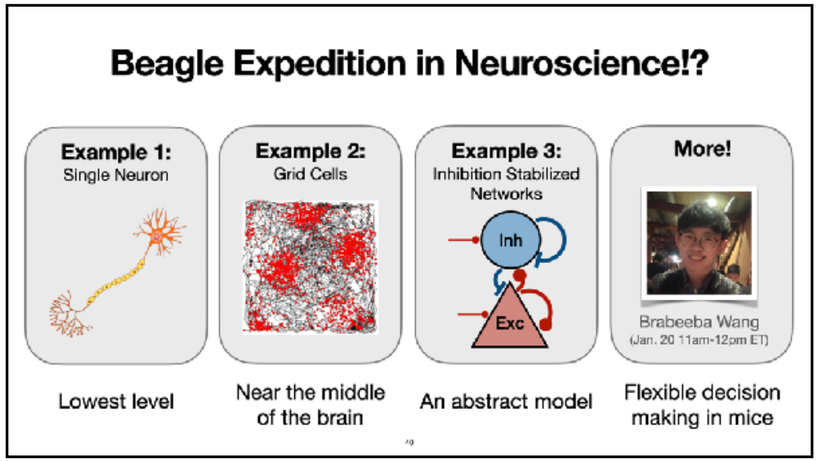




Many Examples







Q1: How do computations in the biological world differ from that in the mathematical and the physical world?

Q2: What would be the difficulties in studying computation in the biological world?

Type your thoughts in zoom chat!

Is There Any Purpose of Life?

Proximate Causes

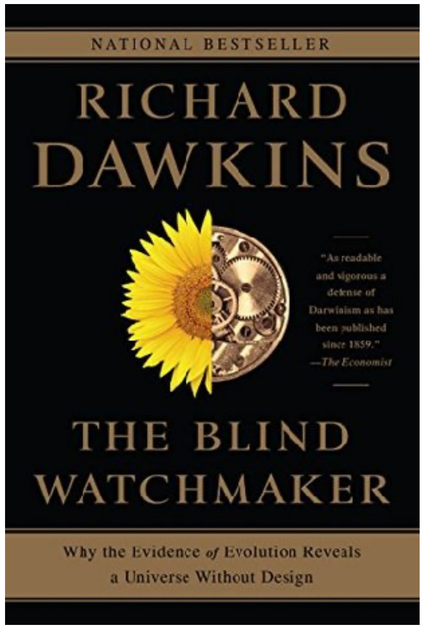
Explanations for the function of an organism and its development. Also, they deal with decoding of genetic and somatic programs.

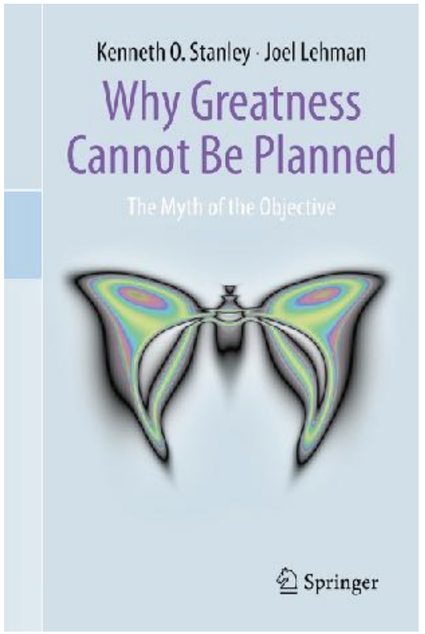
Ultimate Causes

Explanations for why an organism is the way it is. Also, they account for the origin and history of genetic programs.

"Evolution has no long-term goal. There is no long-distance target, no final perfection to serve as a criterion for selection."

– Richard Dawkins





Open-Endedness

Evolution is blind…

And lots of great achievements had not been planned…

But, optimization is still quite useful in daily life and research…

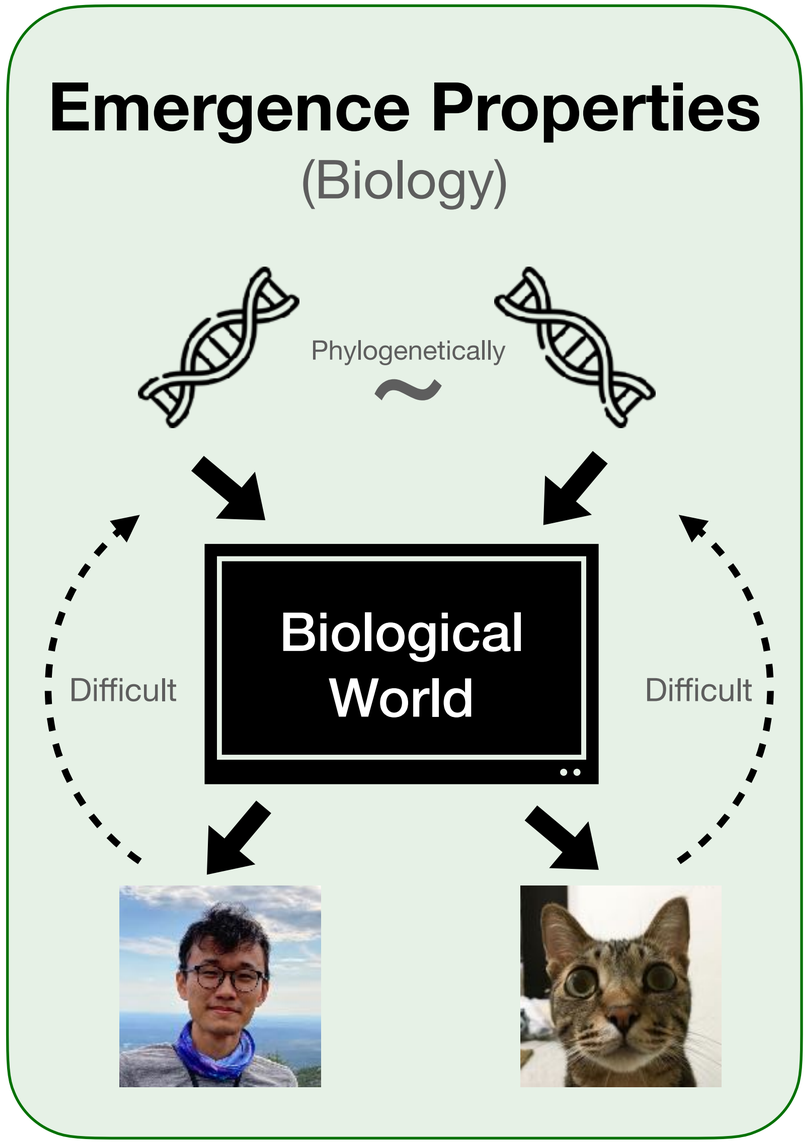
As well as in both the physical and the biological world…

How to study the open-endedness?

While still incorporate with (local) optimization?

Maybe we need a theory for open-endedness!?

Emergence



Q: What kind of understanding are we seeking for?

- Use another black-box (e.g., deep learning) to make prediction?
- Mechanical procedures for certain phenomena?
- Have a complete mathematical characterization?
- Certain kind of computation principles?
- Have an abstract theory and reproduce some interesting phenomena?

All sound quite legitimate to me!

Difficulties in Studying Biology

In my opinion, there are at least five big challenges:

(1) “Noise” is greater than signal in many situations & Special cases.

(2) As opposed to physics, it’s very hard to have first principles in biology.

(3) The lack of top-town framework like “Newton’s laws”.

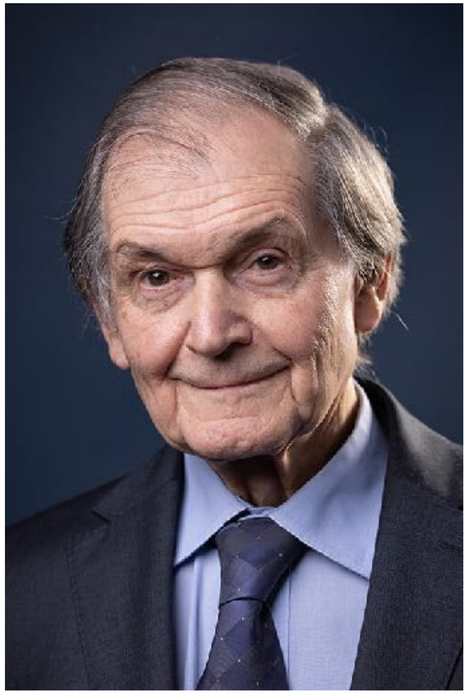
(4) Mechanical understandings sometimes are either vacuous or unanalyzable.

(5) Social challenges: given the above, it is very difficult to convince or “prove” an idea to the community.

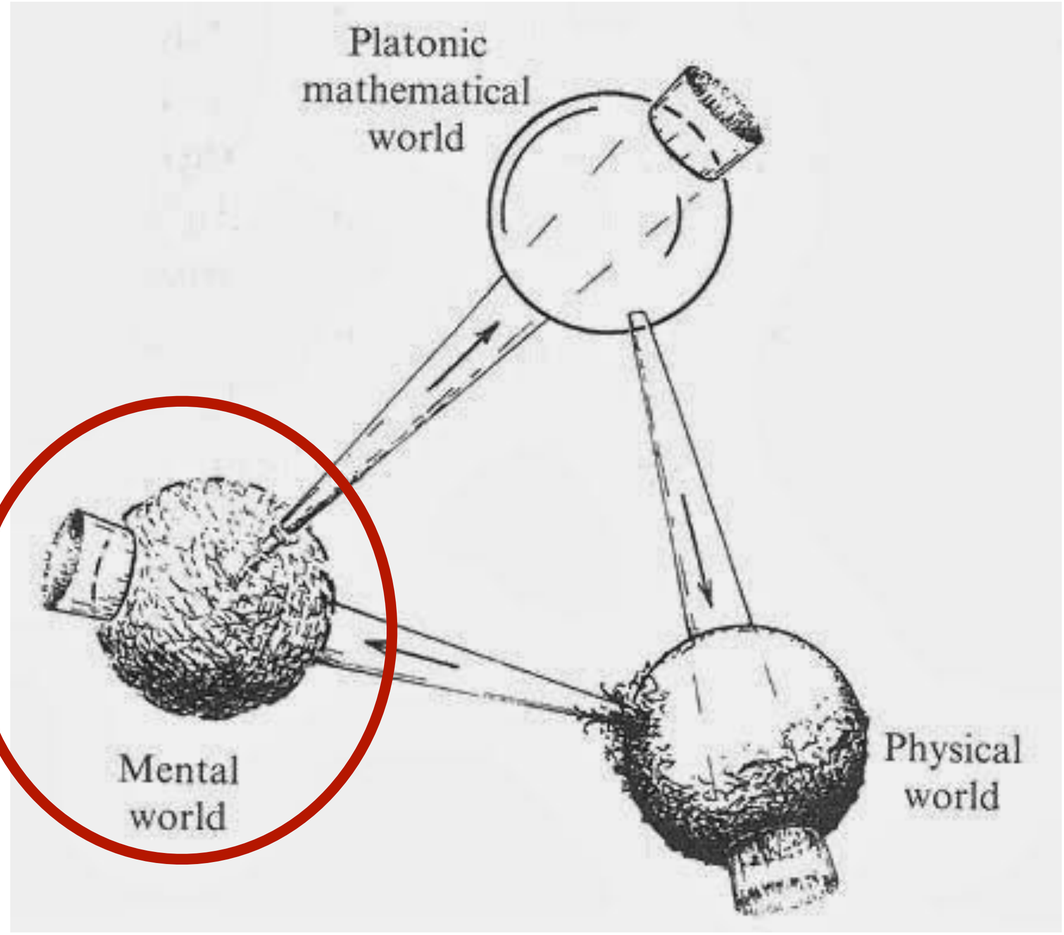
We need a completely different way to study biology!?

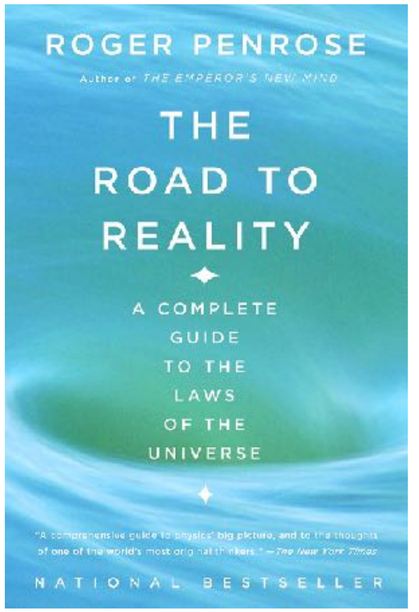
Brain and Cognition

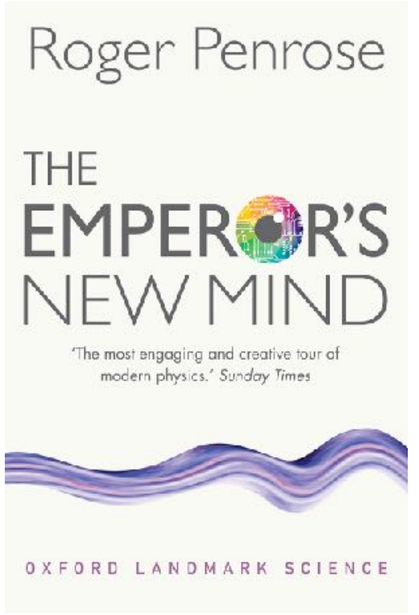
Penrose's Three Worlds



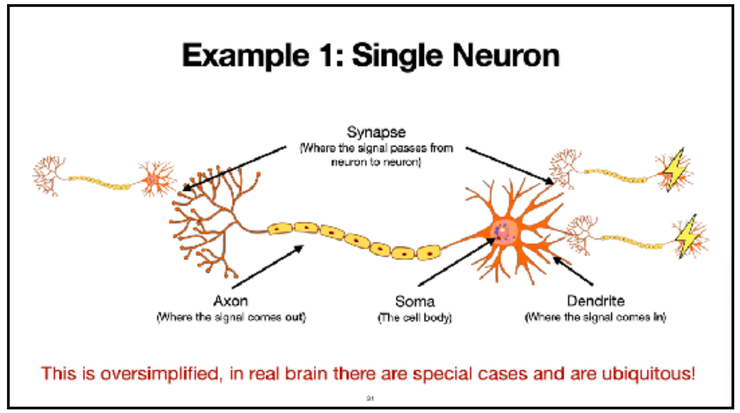
Roger Penrose
1931-present

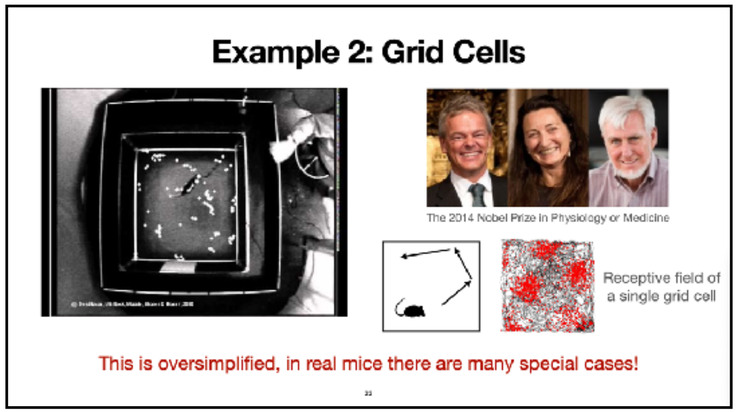


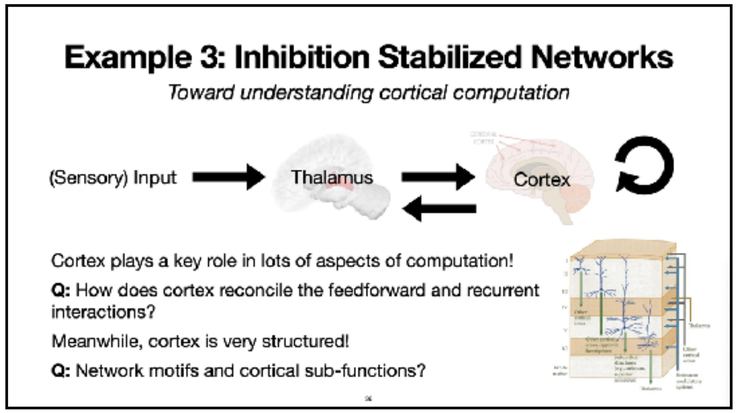




Different Levels of Studies







Cell level

Network level

Math abstraction

"Animal Intelligence: Flexible Computation Under Uncertainty"

Brabeeba Wang
(Jan. 20 11am-12pm ET)

Behavioral level

More…?
(E.g., psychology, consciousness, etc.)

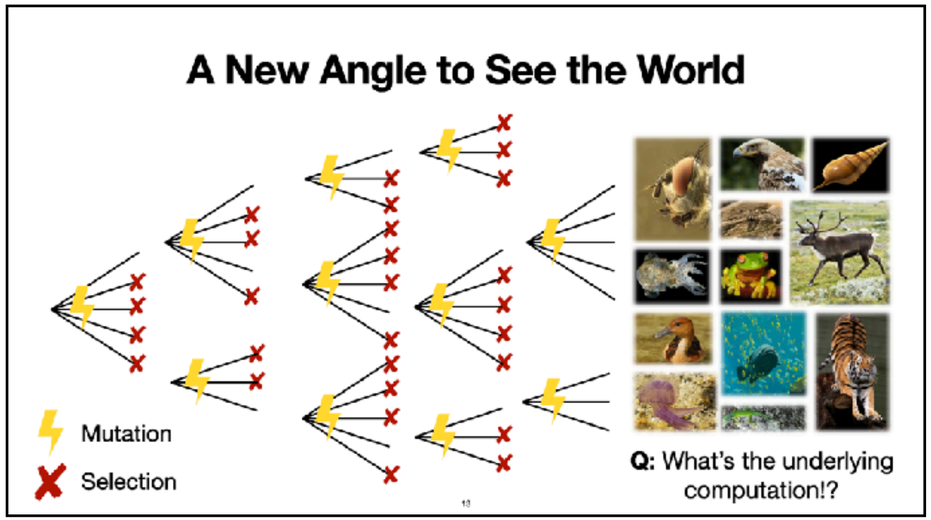
Bridging Bottom-Up & Top-Down Approaches?

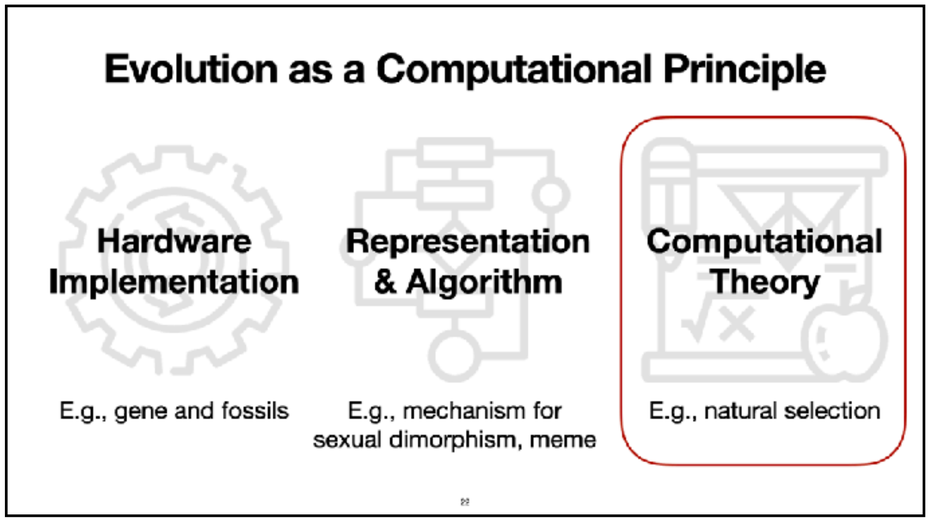
Q3: Any thoughts on how to bridge bottom-up and top-down approaches?

Q4: Meanwhile, what can we infer from abstract theories?

Type your thoughts in zoom chat!

Learning from Evolution Theory!?





- Natural selection provides us a “framework” to see the world.
- It allows different “instantiations” while itself stays abstract and high-level.

Computational principles for the study of brain can be the bridges!?

Computational Explanation for Brain/Cognition?

A glimpse into different branches of computationalism

Classicism

Computational models for cognitive activities. Downplay the connection to neuroscience.

Connectionism

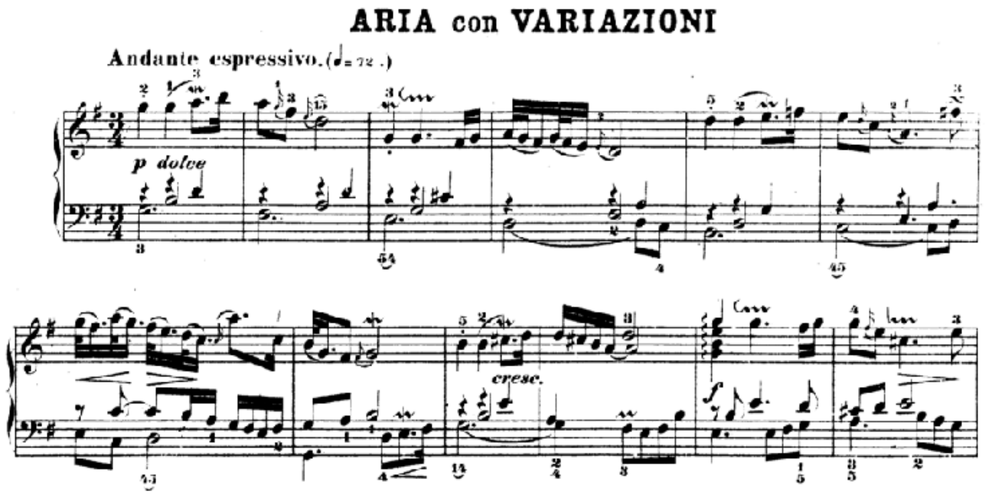
Neural-inspired networks as computational models. And aim to explain higher level computation.

Computational Neuroscience

Computational models for actually neural systems.

All sound quite legitimate to me! The question might be how to integrate them!?

A Lesson from Music Theory?



After the teacher explained what's a sentence and what's a period in music theory, he said…

"You probably won't see any composer literally follows these rules…"

But, why music theory is still very important?

- Extracting useful patterns;
- A language to communicate;
- A framework to lift our appreciation.

Aren't these what we want for biology!?

Summary

Questions of This Lecture

Q1: How do computations in the biological world differ from that in the mathematical and the physical world?

Q2: What would be the difficulties in studying computation in the biological world?

Q3: Any thoughts on how to bridge bottom-up and top-down approaches?

Q4: Meanwhile, what can we infer from abstract theories?

Next

Concluding Lecture
(Jan. 21 10am-10:50am ET)

Panel Discussion
(Jan. 21 11am-12pm ET)

Brabeeba Wang
(Jan. 20 11am-12pm ET)

"Animal Intelligence: Flexible Computation Under Uncertainty"

Salvador
(Jan. 20
1pm-2pm ET)

"DNA Computing, Cellular Automata, and Beyond"

Chi-Ning
(Jan. 21
9am-10am ET)

"When Black Holes Meet Computational Complexity"

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