“The best theory is inspired by practice. The best practice is inspired by theory.”

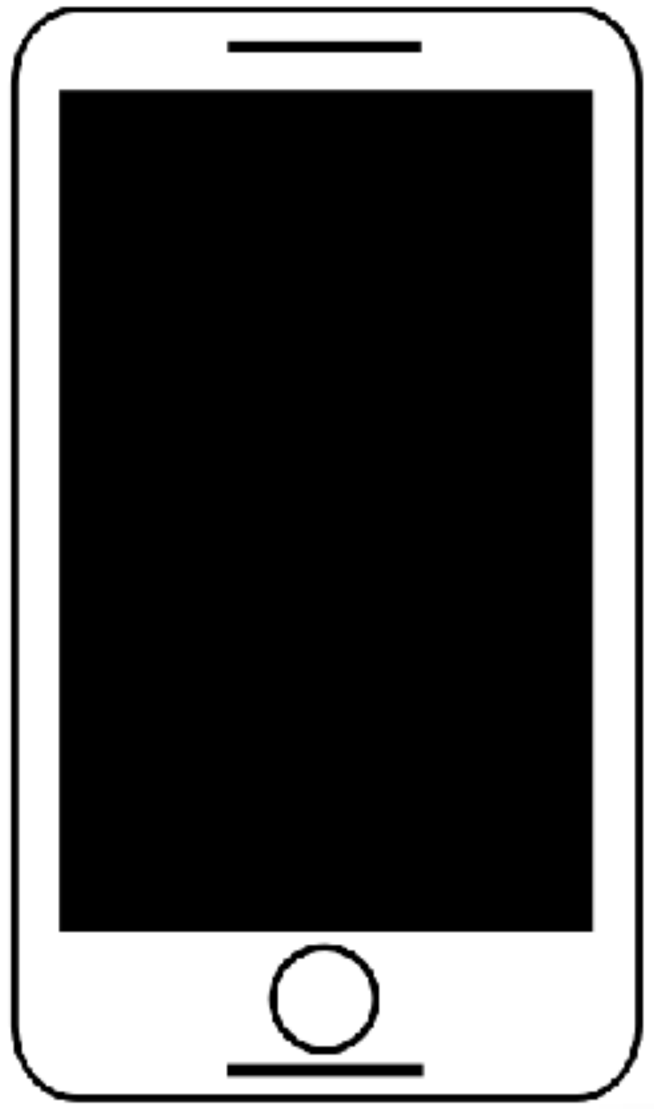
– Donald Knuth

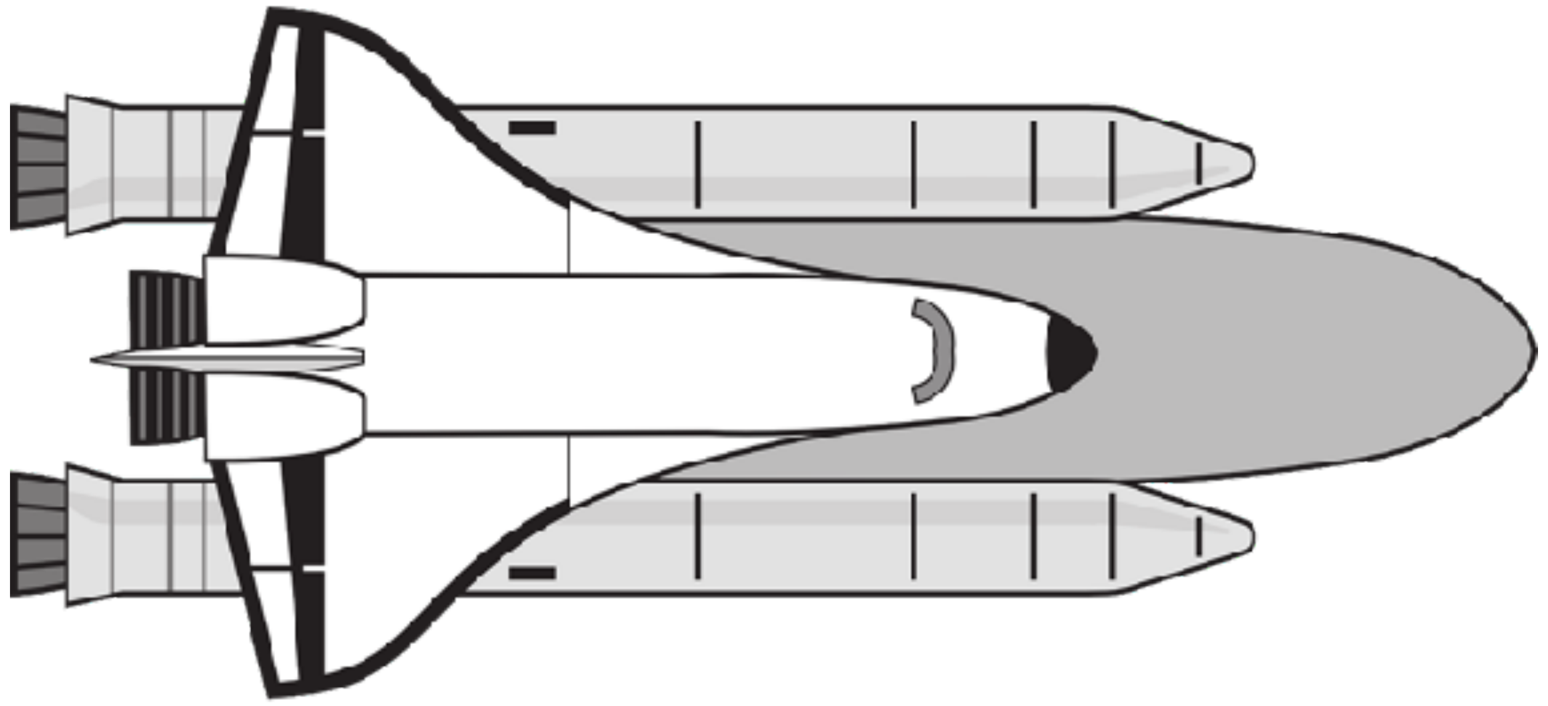
What is Computation?

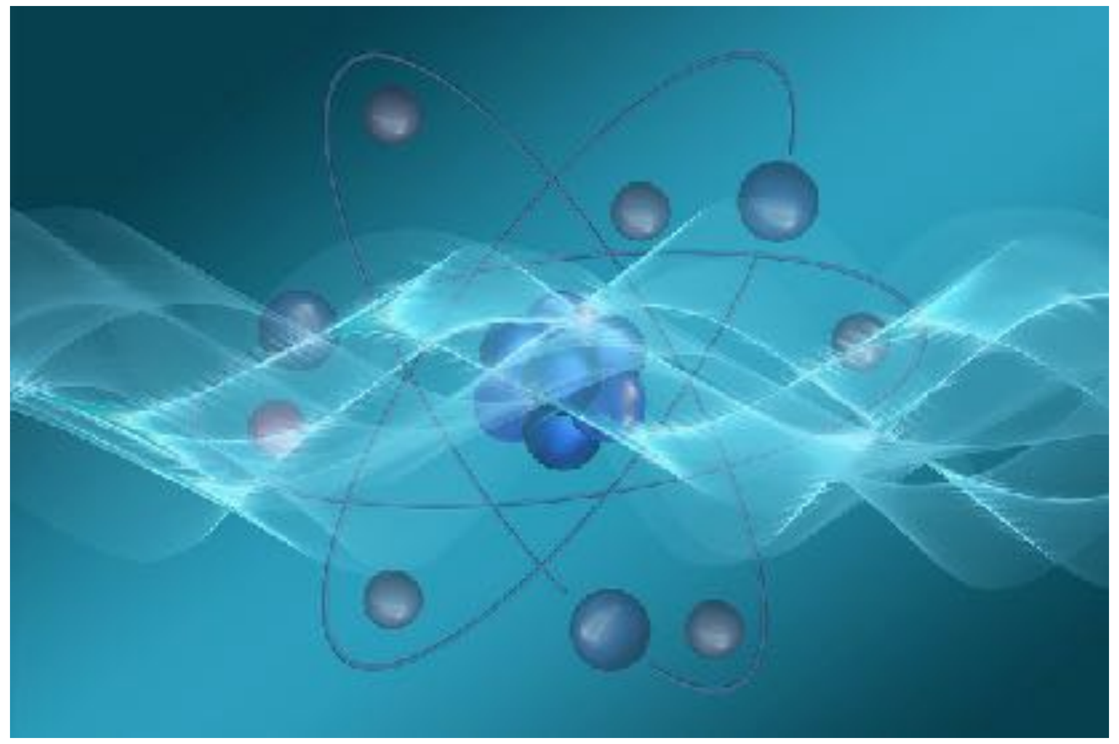
Introductory Lecture

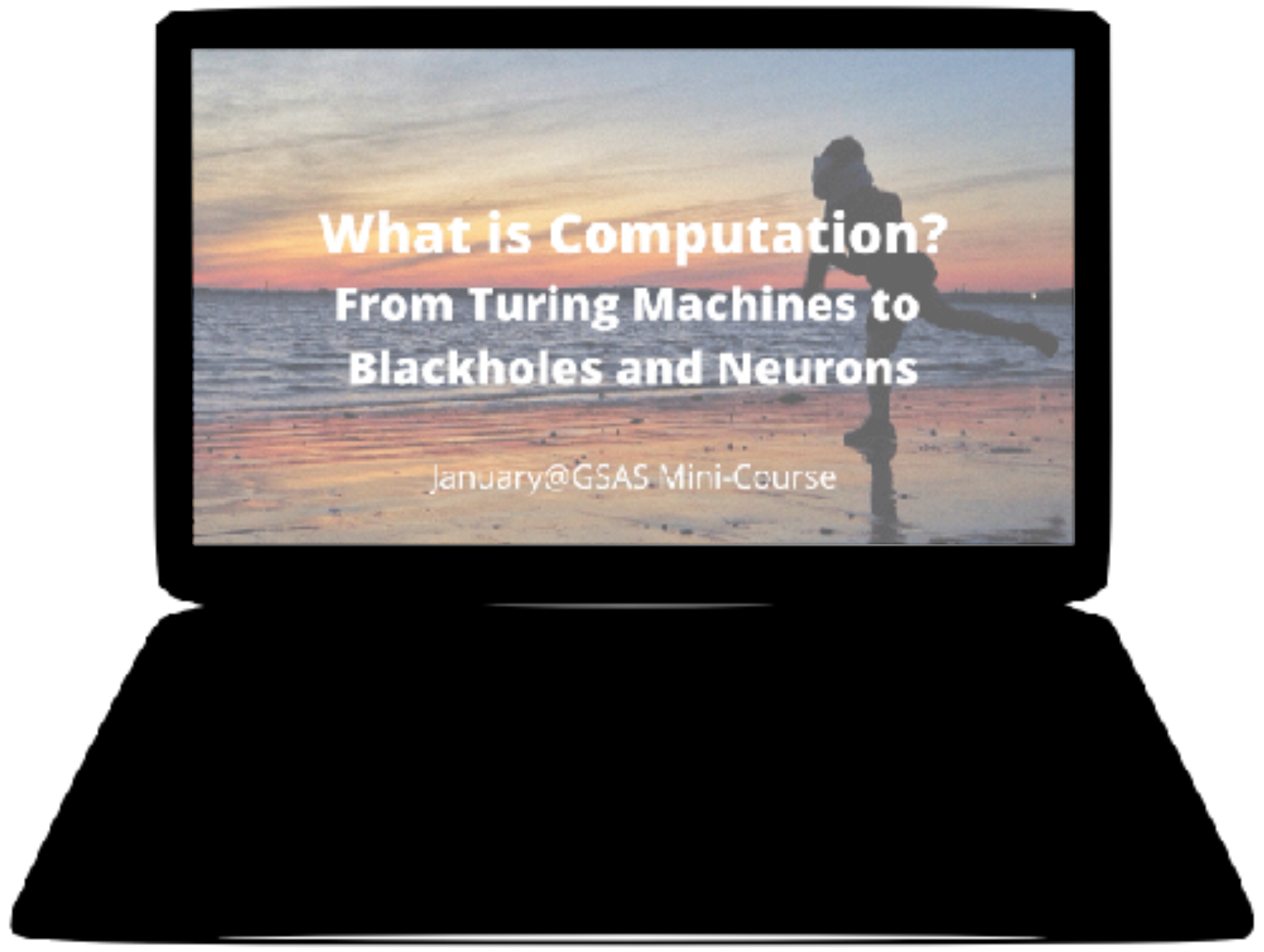
"The best theory is inspired by practice. The best practice is inspired by theory."

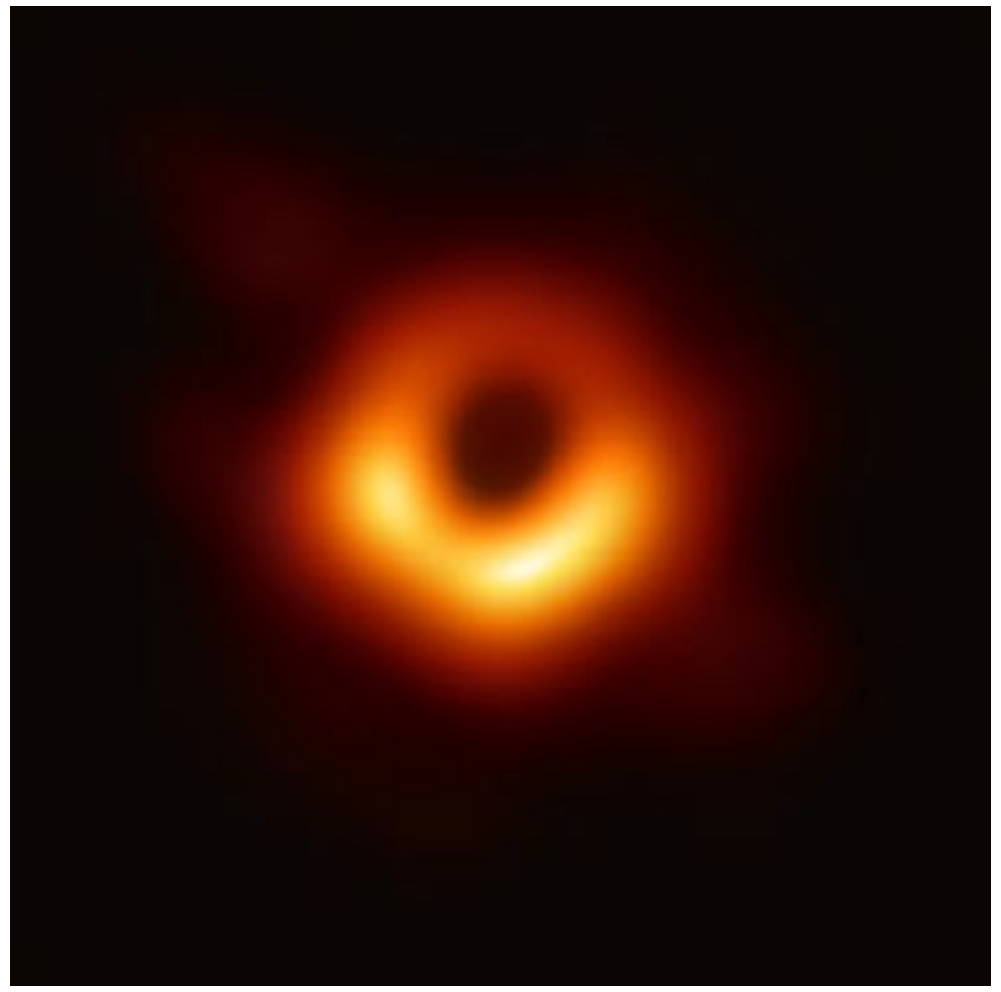
– Donald Knuth

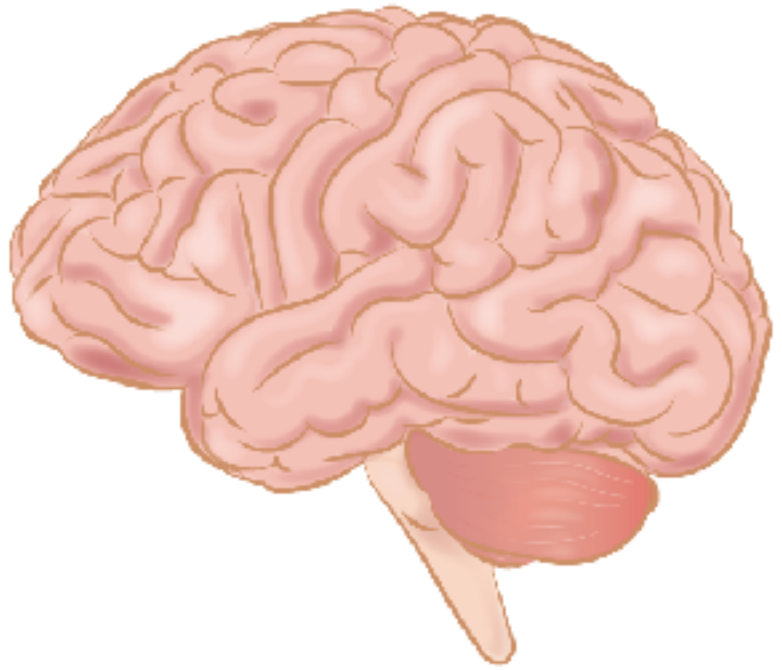


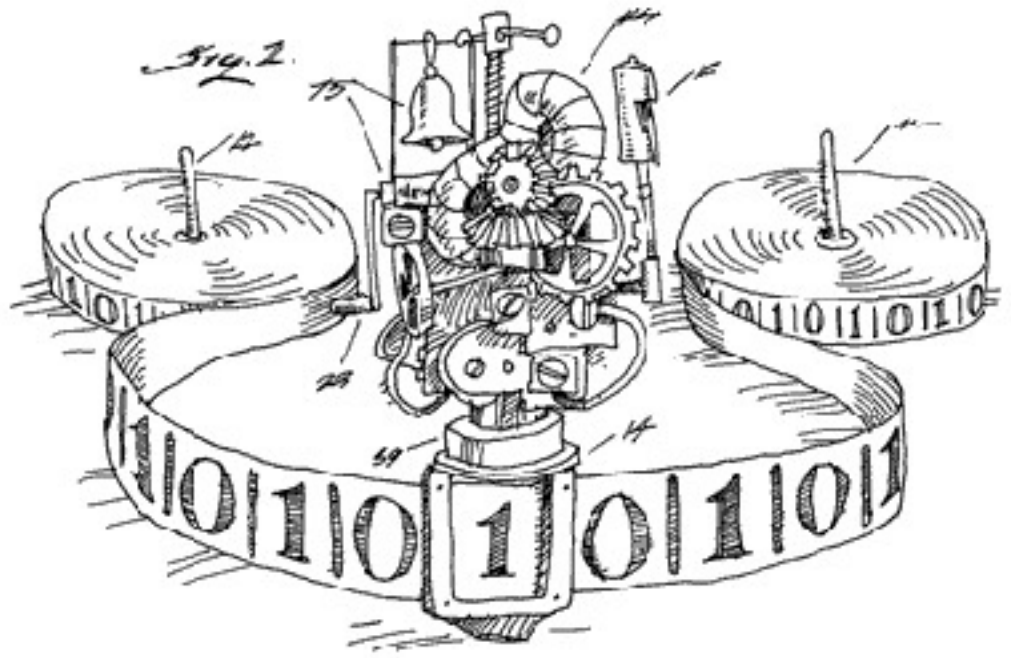


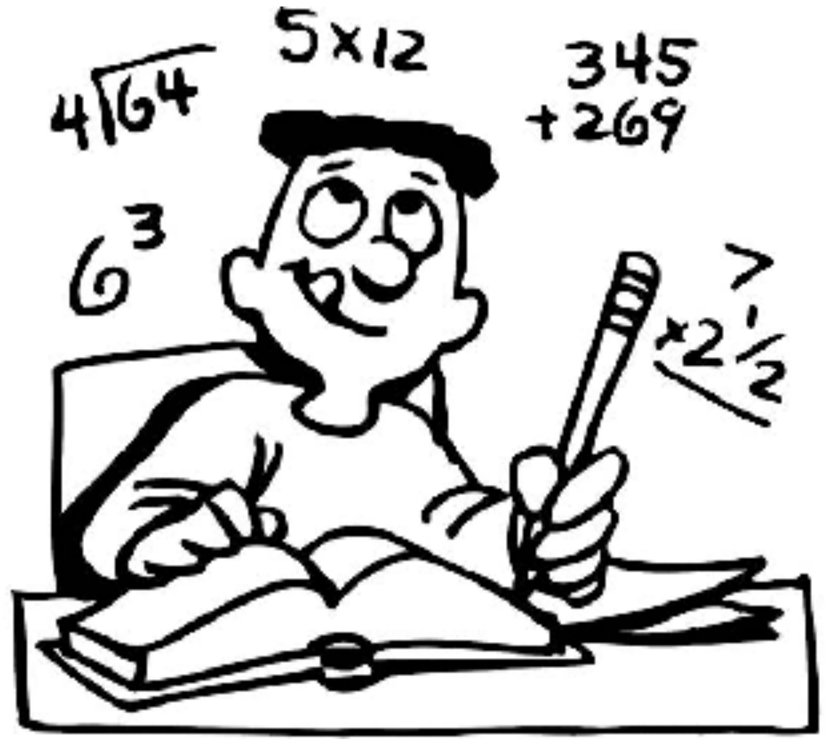



What is Computation?
From Turing Machines to
Blackholes and Neurons
January@GSAS Mini-Course



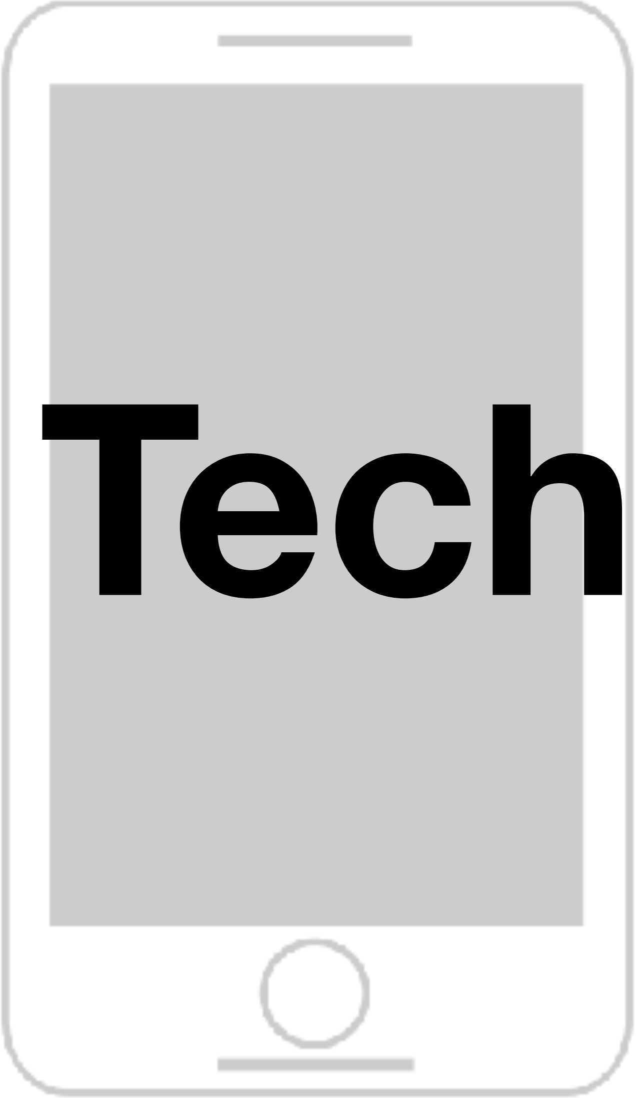




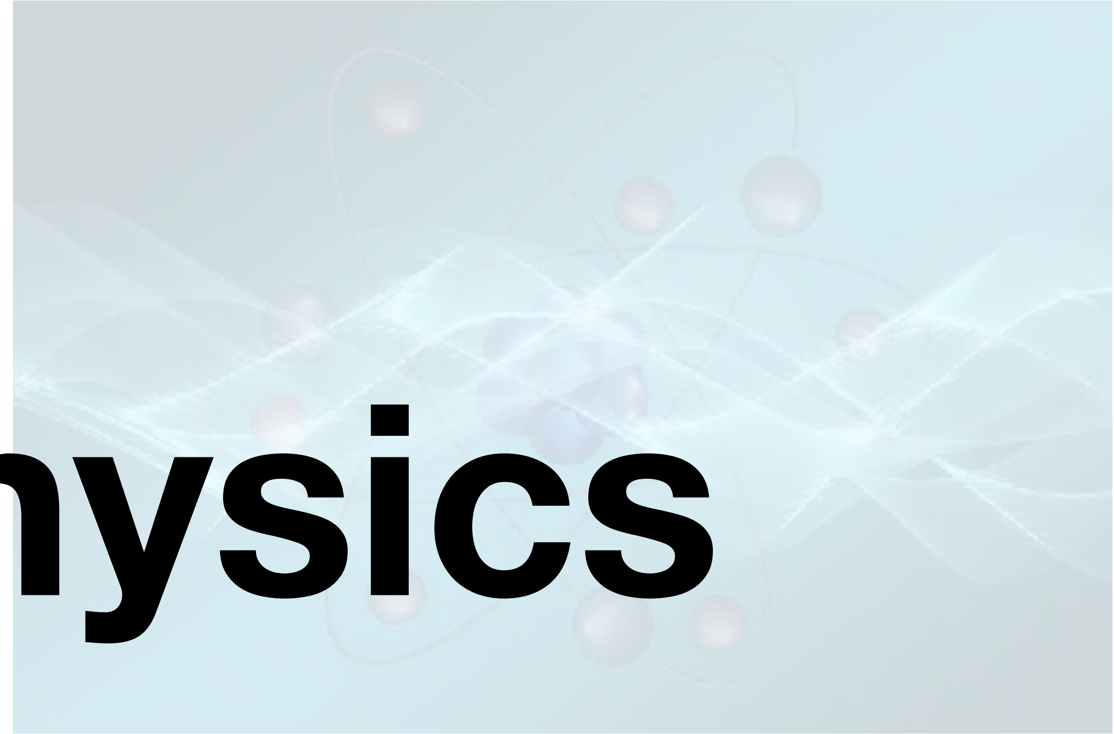

4)64
5x12
345
+269
6³
7
x2½

Wait a Second…

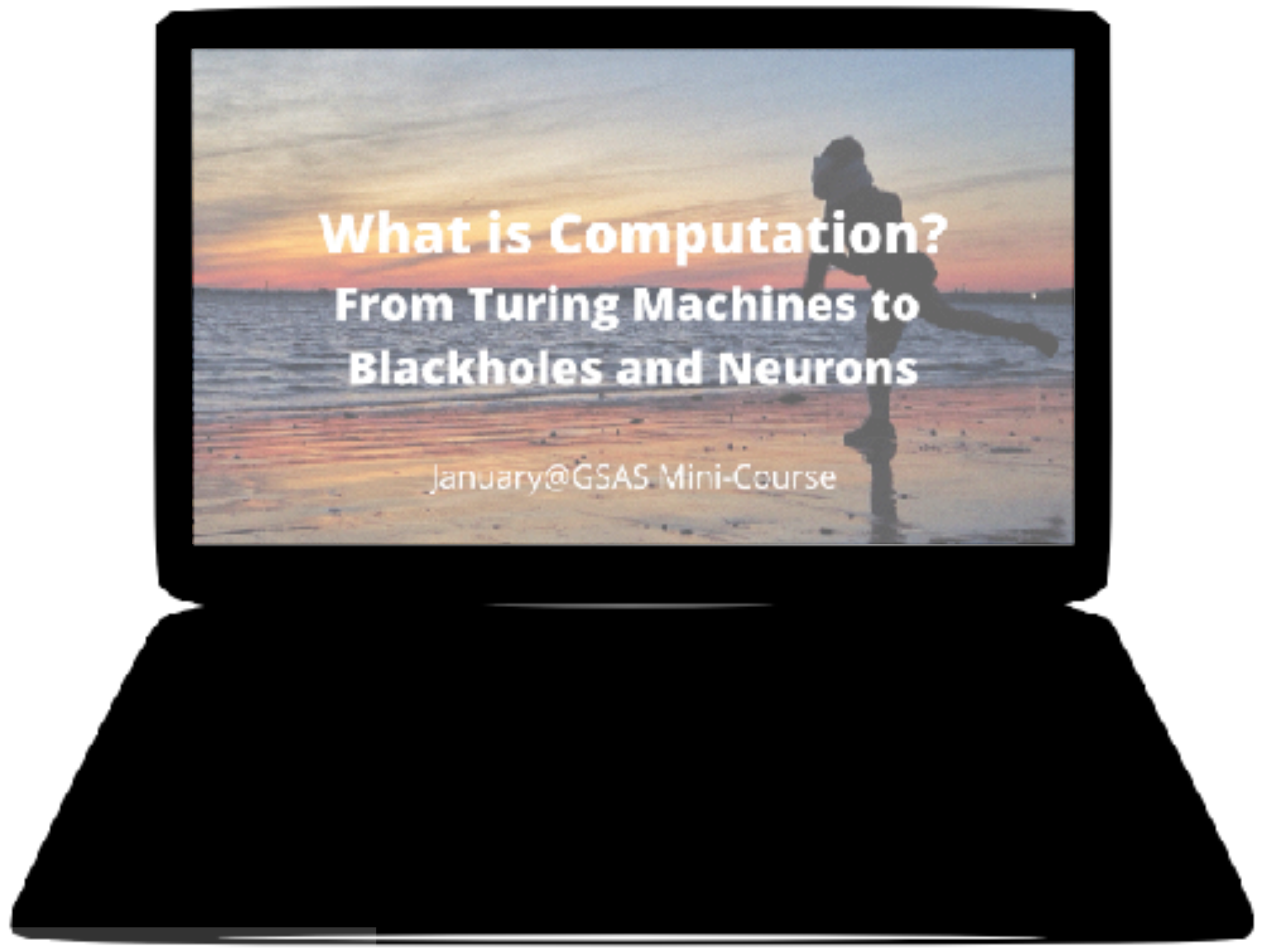
Speaking of Computation,
What Do We Precisely Mean?



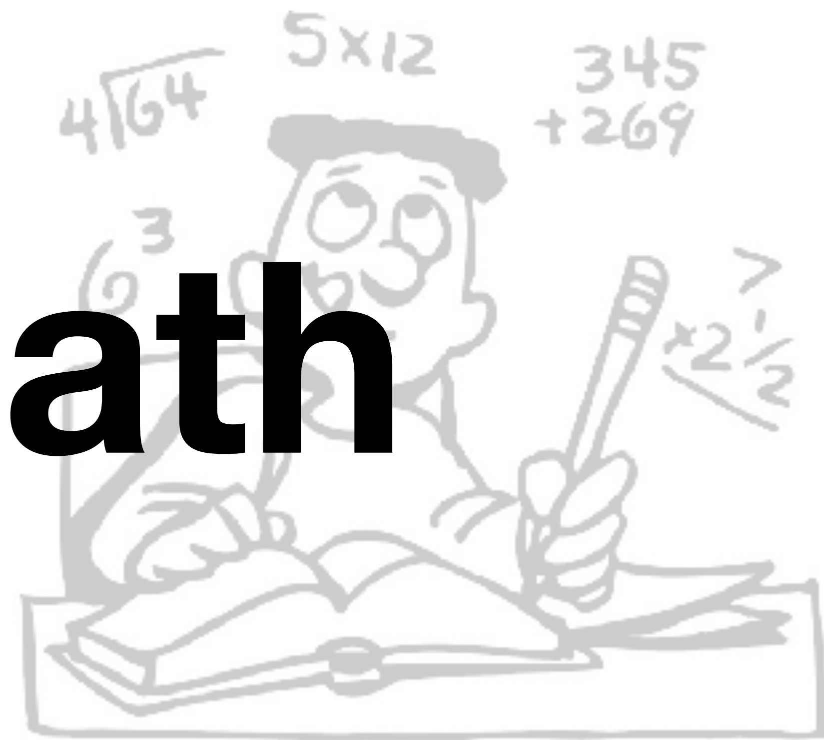

Technology



Physics

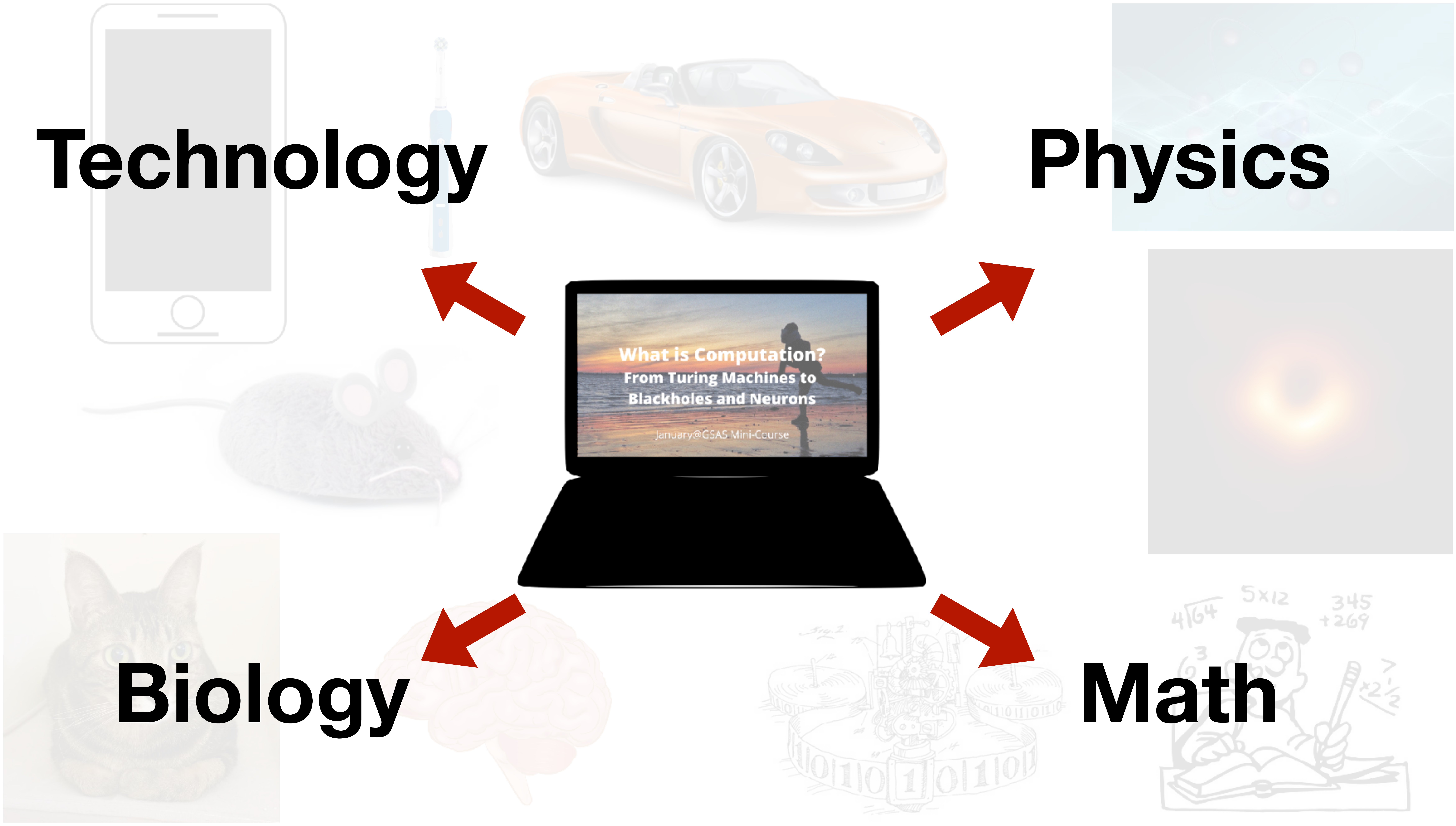


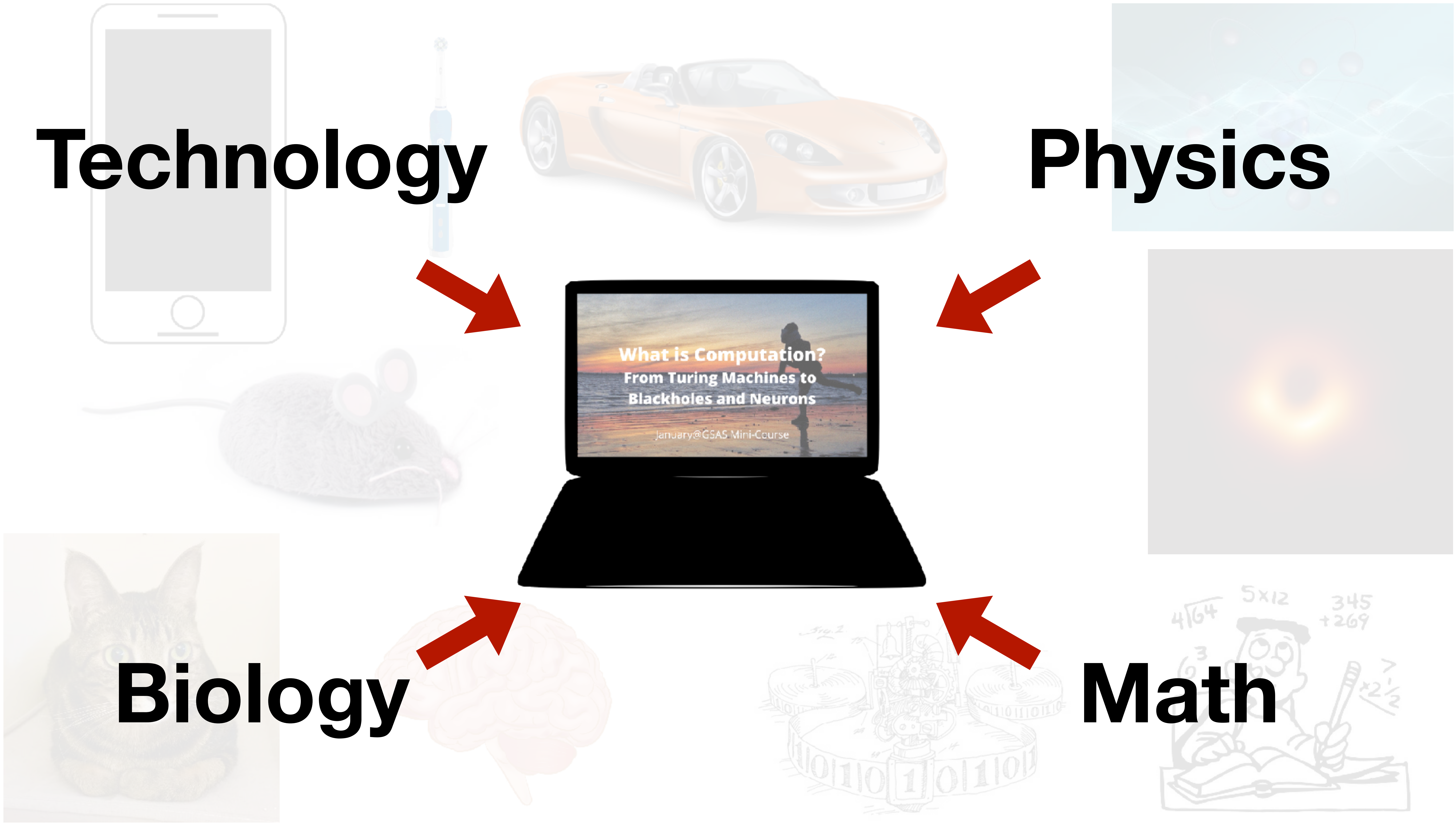

Biology



Math


Technology
Bitcoin
Gambling
Economics
Auction
Game theory
Physics
Painting
Music
Art
Sculpture
Design
What is Computation?
From Turing Machines to
Blackholes and Neurons
January@GSAS Mini-Course
Free will
Ontology
Philosophy
Logic
Computationalism
Biology
Chess
Go
Games
Atari
Minecraft
Math


Technology
Physics
What is Computation?
From Turing Machines to
Blackholes and Neurons
January@GSAS Mini-Course
Biology
Math


Technology
Physics
What is Computation?
From Turing Machines to
Blackholes and Neurons
January@GSAS Mini-Course
Biology
Math

Computation Has Become an Interdisciplinary Notion!

Okay…

But Why Should I Care?

You Don’t Have to Care, But…

If you have one (or more) of the following…

- Curiosity in knowledge
- Passion in learning
- Love in deep and broad thinking
- Wide range of interests

Then I sincerely invite you to reexamine the essence of computation together in this mini-course!

Welcome to a journey of crossdisciplinary exploration 🙂

Overview on this Mini-Course

Please save your questions to the end!

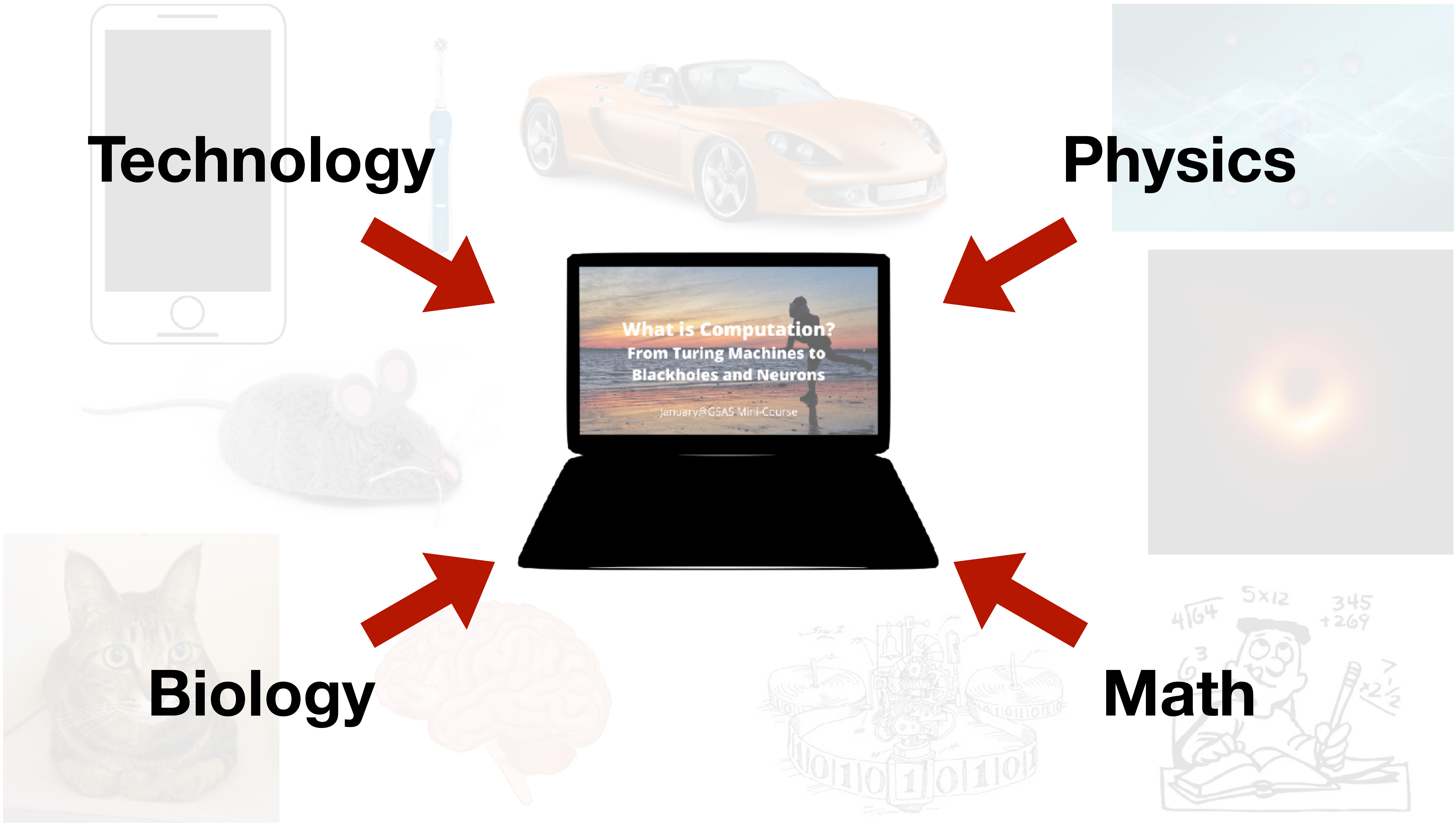
Main Instructor

Name: Chi-Ning Chou

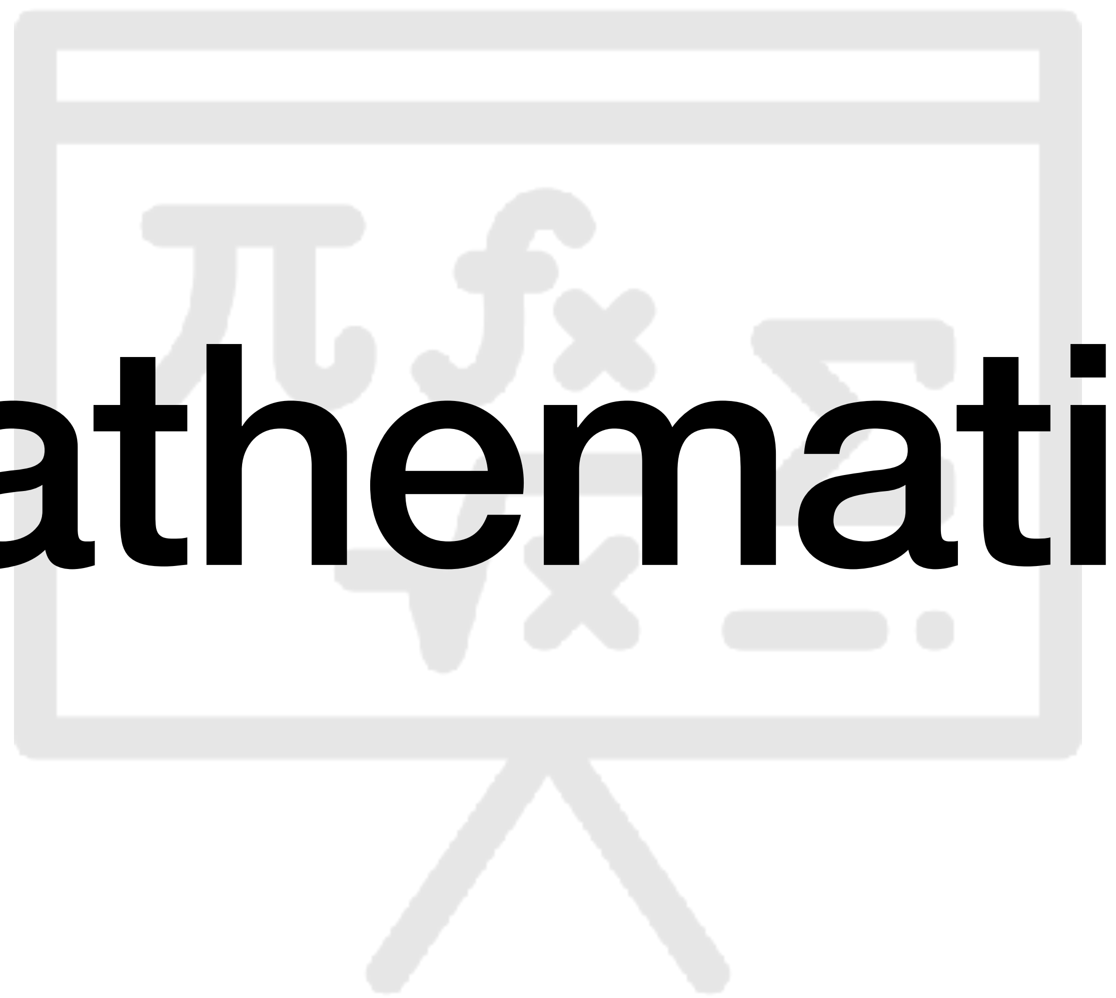
Brief intro: I’m a 5th year Ph.D. student advised by Professor Boaz Barak at Harvard University. My home field is theoretical CS while I’m broadly interested in math, physics, biology, and especially their interconnections. Outside academics, I love sports, classical music, and cooking :)

Introduction to our guest speakers and teaching staff soon!

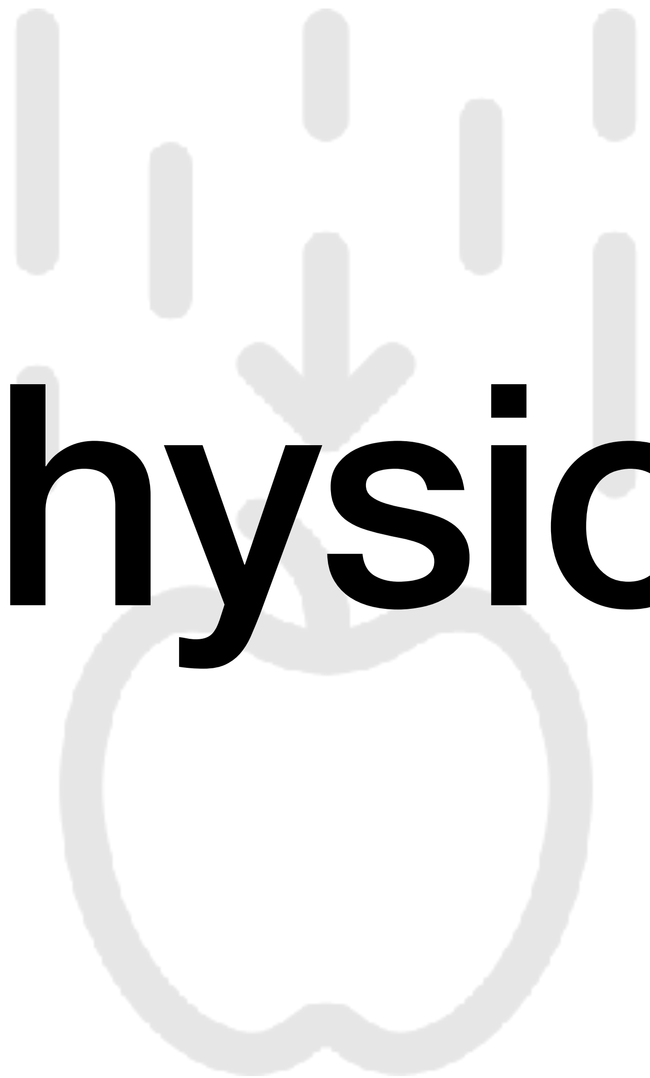
An Abstract Approach



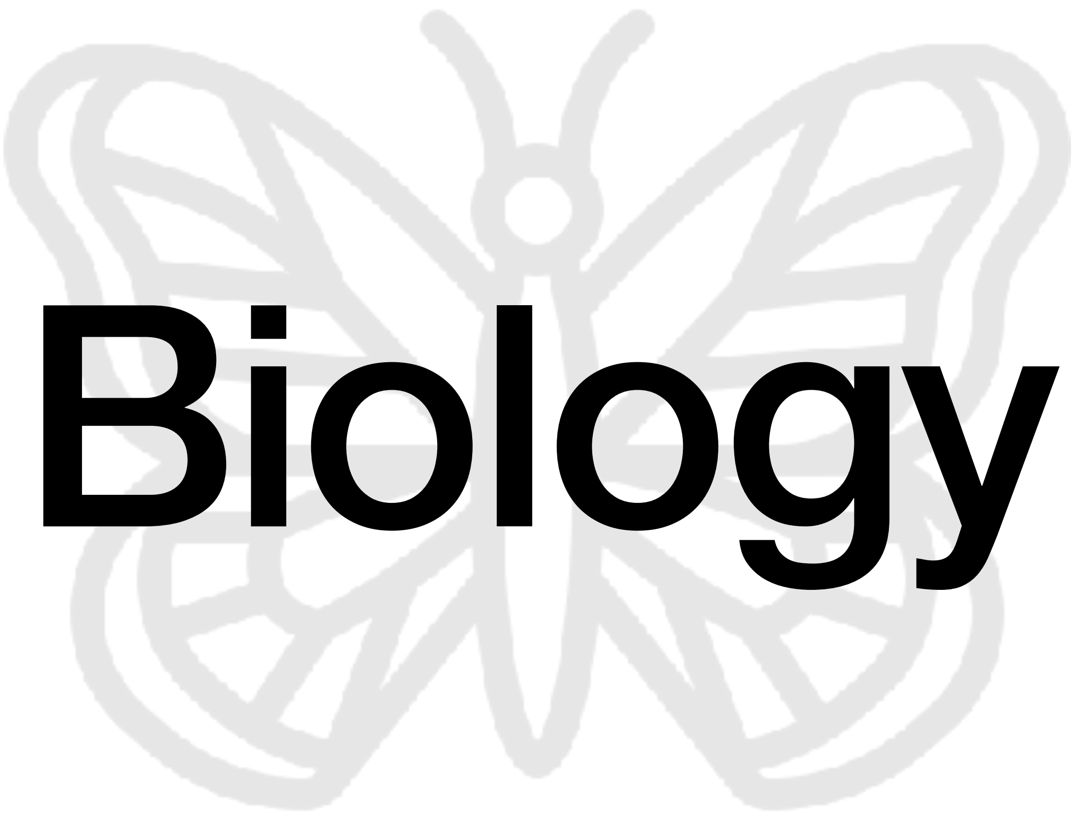
Three Modules



Mathematics



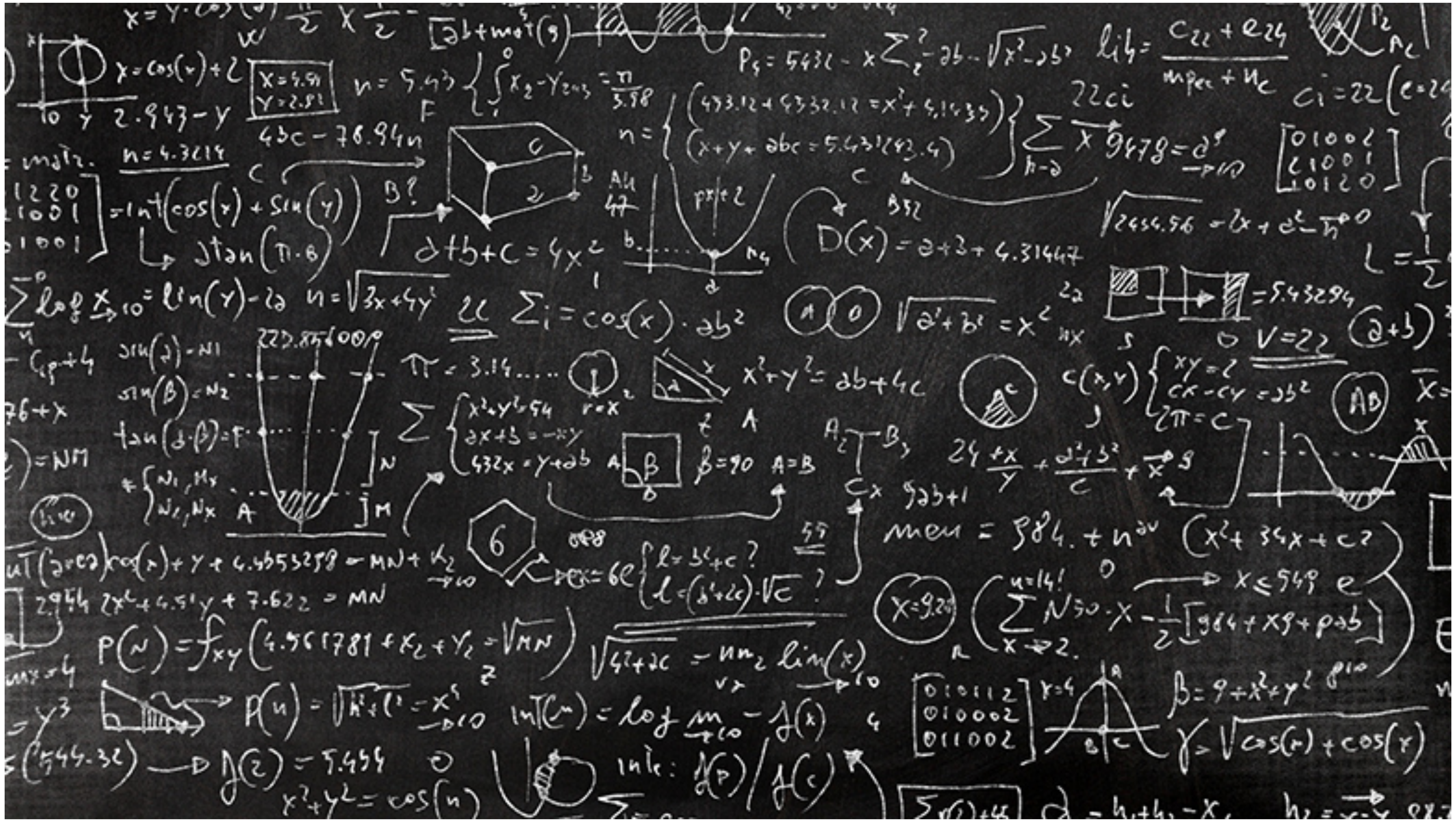
Physics



Biology

Why these three?

Why Math?



Why Math?

Why Math?

Rules **Calculations**

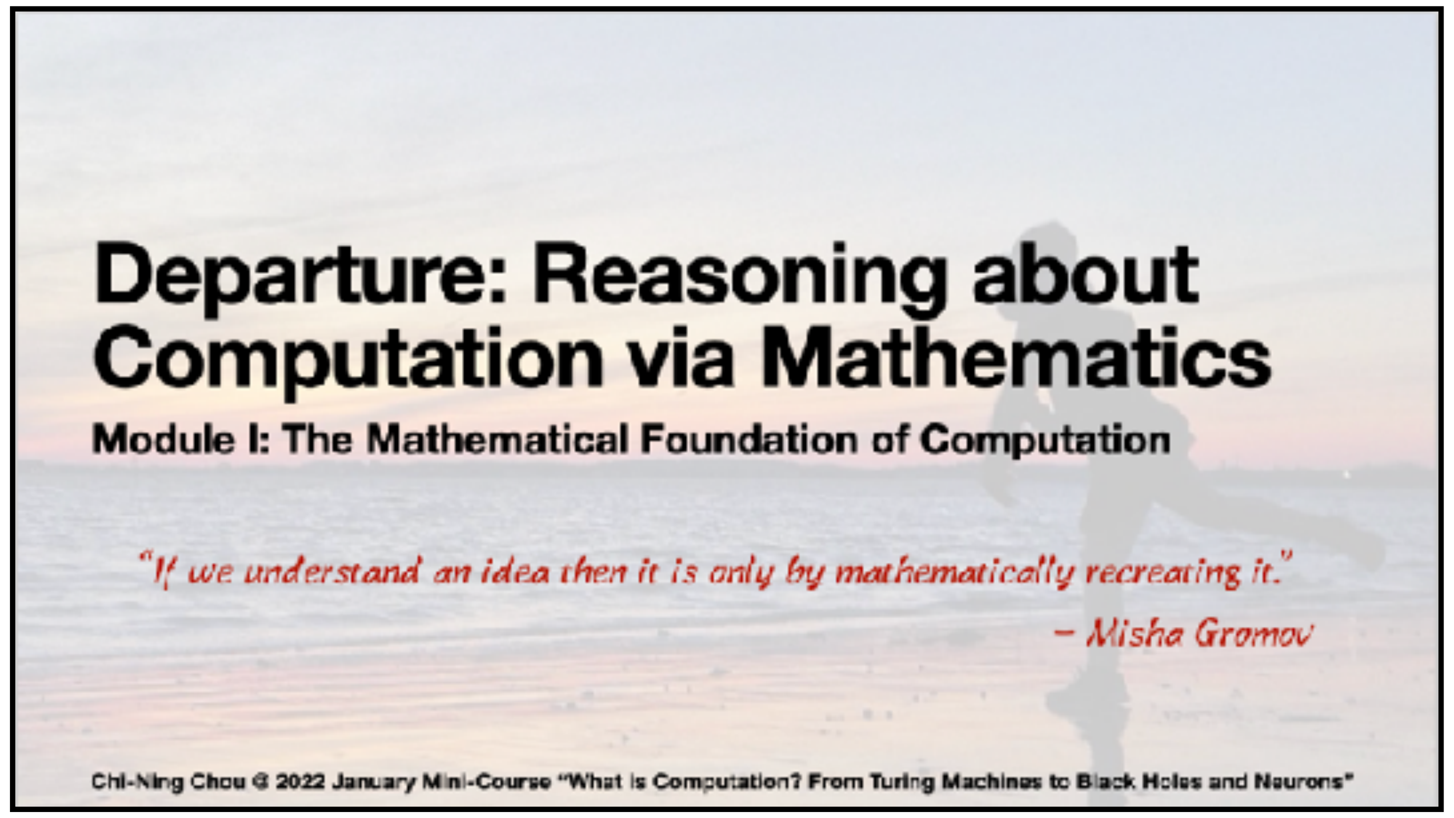
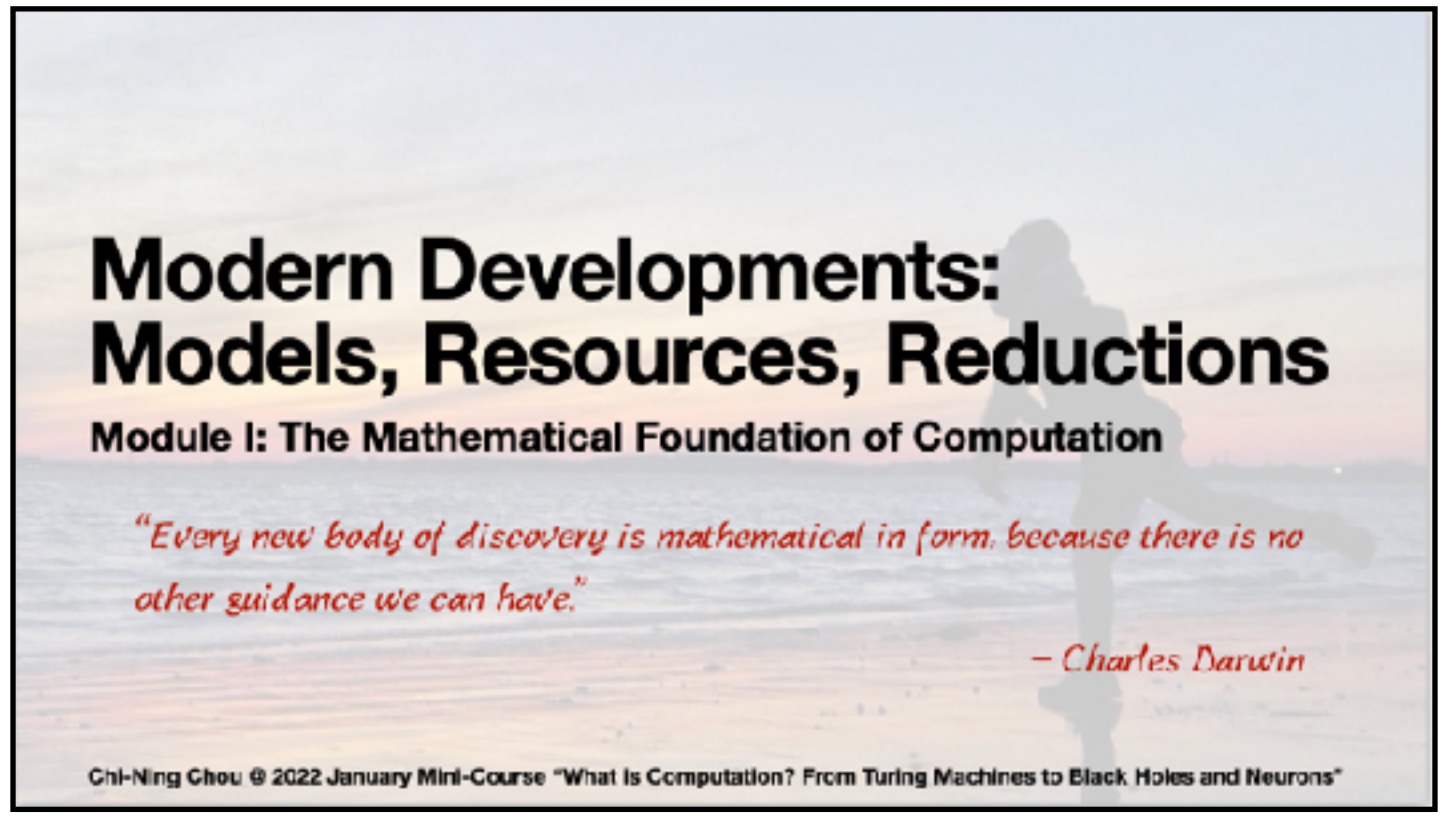
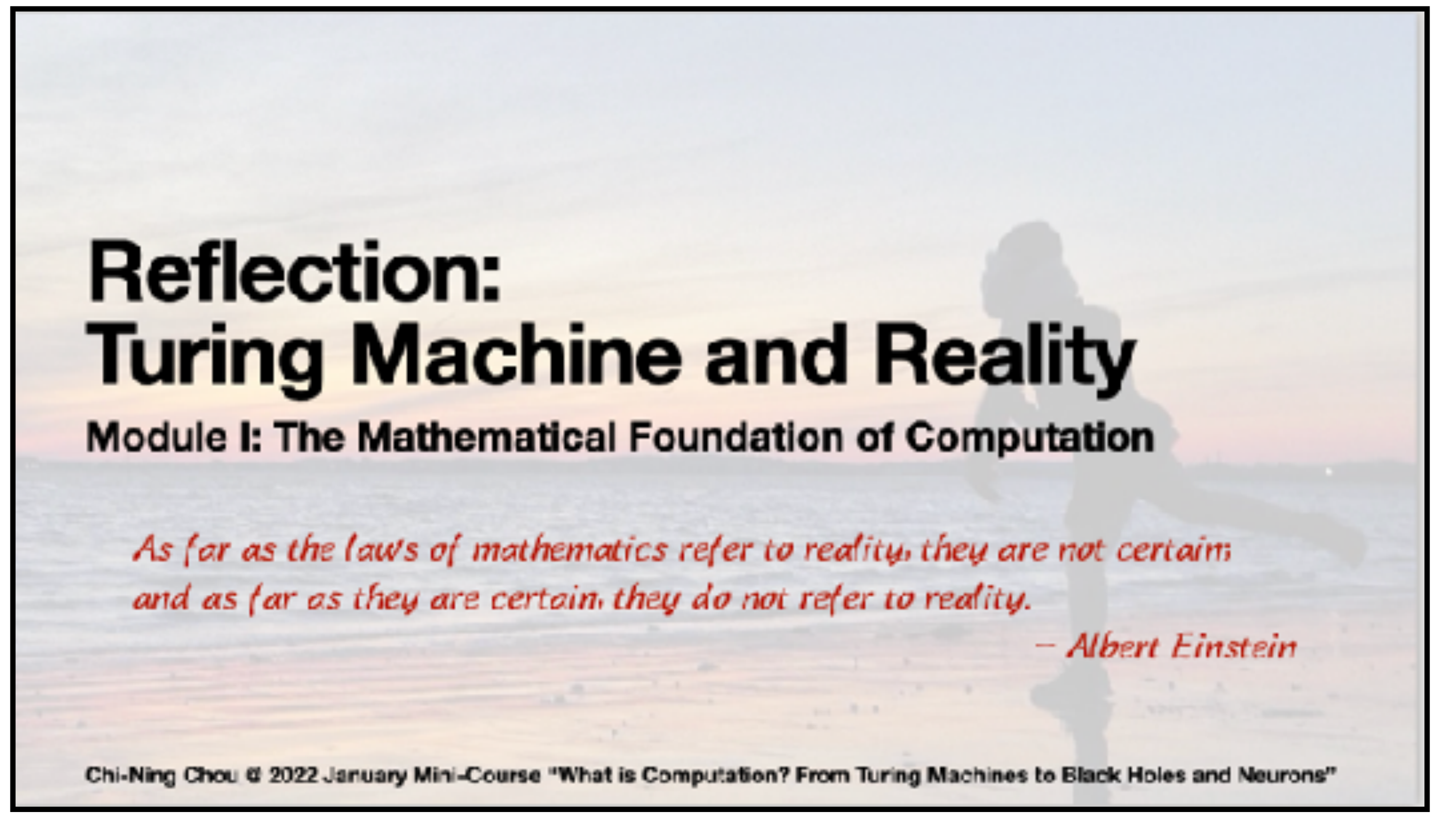
Constructions **Notations**

$$
\begin{aligned}
& (2q^2e^2)^{u/2}(n/u)^{u/2}\cdot\alpha^{(o+\eta)/k}C^u(n/\kappa)^\kappa(u/\sqrt{n\eta})^\eta(u/n)^o\cdot C_2^{h'}(sn/h'^2)^{h'/4}\cdot h\cdot 2^{k\kappa}\cdot(h^2/(sn))^{h/4}\\
\le\ & C_4^uC_5^h\alpha^{(o+\eta)/k}\cdot(n/u)^{u/2}\cdot(n/\kappa)^\kappa\cdot(u/\sqrt{n\eta})^\eta\cdot(u/n)^o\cdot(sn/h'^2)^{h'/4}\cdot(h^2/(sn))^{h/4}\\
& \qquad (\text{Using } h'\le h\le 2^h,\ \kappa\le u,\ C_4\triangleq\sqrt{2}e\cdot q\cdot C\cdot 2^k,\ C_5\triangleq 2C_2)\\
\le\ & C_4^uC_6^h\alpha^{(o+\eta)/k}\cdot(n/u)^{u/2}\cdot(n/\kappa)^\kappa\cdot(u/\sqrt{n\eta})^\eta\cdot(u/n)^o\cdot(sn/h^2)^{-(h-h')/4}\\
& \qquad (\text{Using } (h/h')^{h'/2}\le e^h) \text{ and } C_6=eC_5)\\
=\ & C_4^uC_6^h\alpha^{(o+\eta)/k}\cdot(n/u)^{u/2}\cdot(n/\kappa)^\kappa\cdot(u/\sqrt{n\eta})^\eta\cdot(u/n)^o\cdot(sn/h^2)^{-(u+\kappa-(\eta+o))/4}\\
=\ & C_4^uC_6^h\alpha^{(o+\eta)/k}\cdot(nh^2/(su^2))^{u/4}\cdot(h^2n^3/(s\kappa^4))^{\kappa/4}\cdot(su^4/(n\eta^2h^2))^{\eta/4}\cdot(su^4/n^3h^2)^{o/4}\\
=\ & C_4^uC_6^h\alpha^{(o+\eta)/k}\cdot(h^2/(\varepsilon u^2))^{u/4}\cdot(h^2n^2/(\varepsilon\kappa^4))^{\kappa/4}\cdot(\varepsilon u^4/(\eta^2h^2))^{\eta/4}\cdot(\varepsilon u^4/(n^2h^2))^{o/4}\\
\le\ & C_4^uC_6^h\alpha^{(o+\eta)/k}\cdot(h^2/u^2)^{u/4}\cdot(h^2n^2/(\kappa^4))^{\kappa/4}\cdot(u^4/(\eta^2h^2))^{\eta/4}\cdot(u^4/(n^2h^2))^{o/4}\\
& \qquad (\text{Collecting terms } u+\kappa-(\eta+o)\le 0 \text{ and } \ldots)\\
\le\ & (e^2C_4)^uC_6^h\alpha^{(o+\eta)/k}\cdot(h/u)^{u/2}\cdot(hn/(u^2))^{\kappa/2}\cdot(u/h)^{\eta/2}\cdot(u^2/(nh))^{o/2}\\
& \qquad (\text{Using } (u/\kappa)^\kappa\le e^u \text{ and } (u/\eta)^\eta\le e^u)\\
=\ & (e^2C_4)^uC_6^h\alpha^{(o+\eta)/k}\cdot(h/u)^{u/2}\cdot(u/h)^{\eta/2}\cdot(u^2/(nh))^{(o-\kappa)/2}\\
\le\ & (e^2C_4)^uC_6^h\alpha^{(o+\eta)/k}\cdot(h/u)^{u/2}\cdot(u/h)^{\eta/2}\cdot(u/h)^{(o-\kappa)/2}\\
\le\ & (e^2C_4)^uC_6^h\alpha^{(u-h)/k}\cdot(h/u)^{u/2}\cdot(u/h)^{\eta/2}\cdot(u/h)^{(o-\kappa)/2}\\
& \qquad (\text{Using } \alpha\le 1 \text{ and } u-h\le\eta+o)\\
=\ & (\alpha^{1/k}e^2C_4)^u(C_6/\alpha^{1/k})^h(h/u)^{u/2}\cdot(u/h)^{\eta/2}\cdot(u/h)^{(o-\kappa)/2}
\end{aligned}
$$

Why Math?

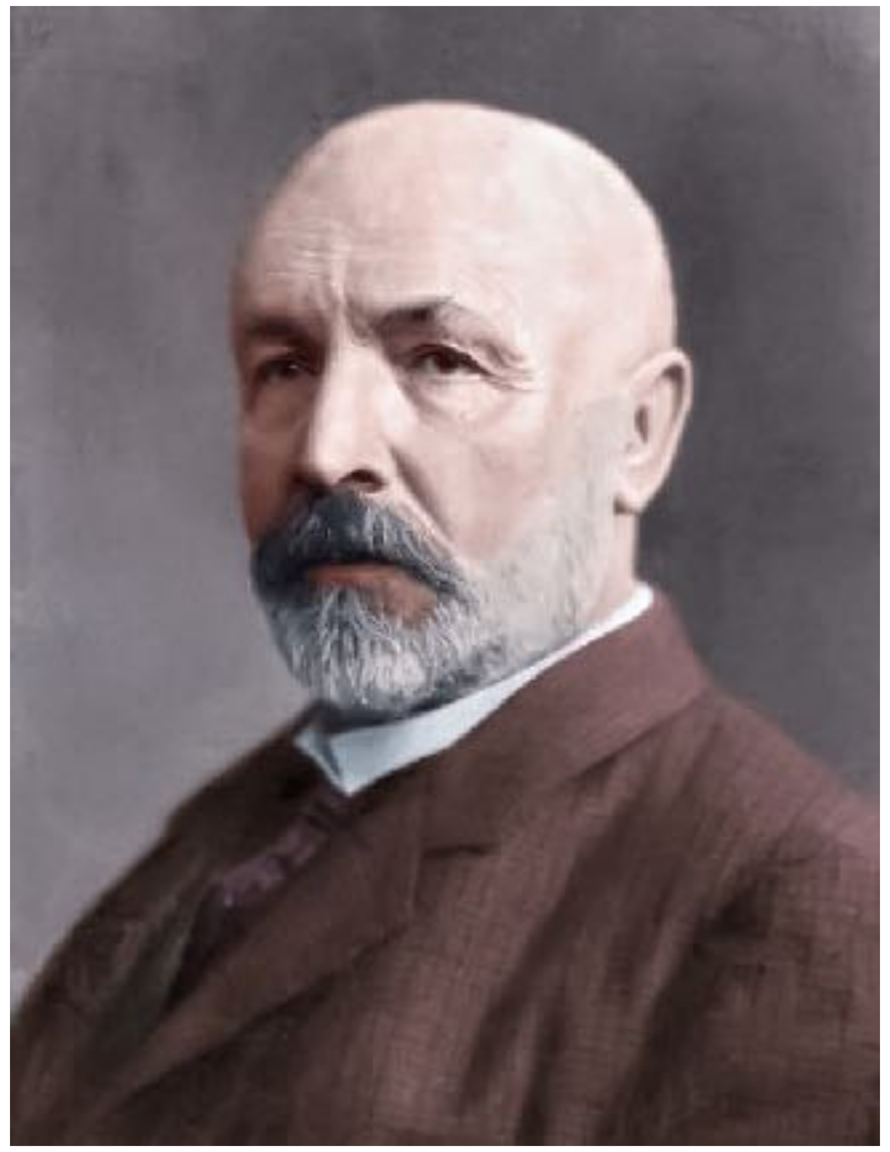
I encourage you to follow your instinct and feel the underlying story like watching an art movie!

Module I: The mathematical foundation of computation

Fundamentals	Modern approach	Philosophy
		
Lecture I.a	Lecture I.b	Lecture I.c
(Jan. 10 11am-11:50am ET)	(Jan. 11 10am-10:50am ET)	(Jan. 17 10am-10:50am ET)

Why Physics?

Module II: Computations in the physical world

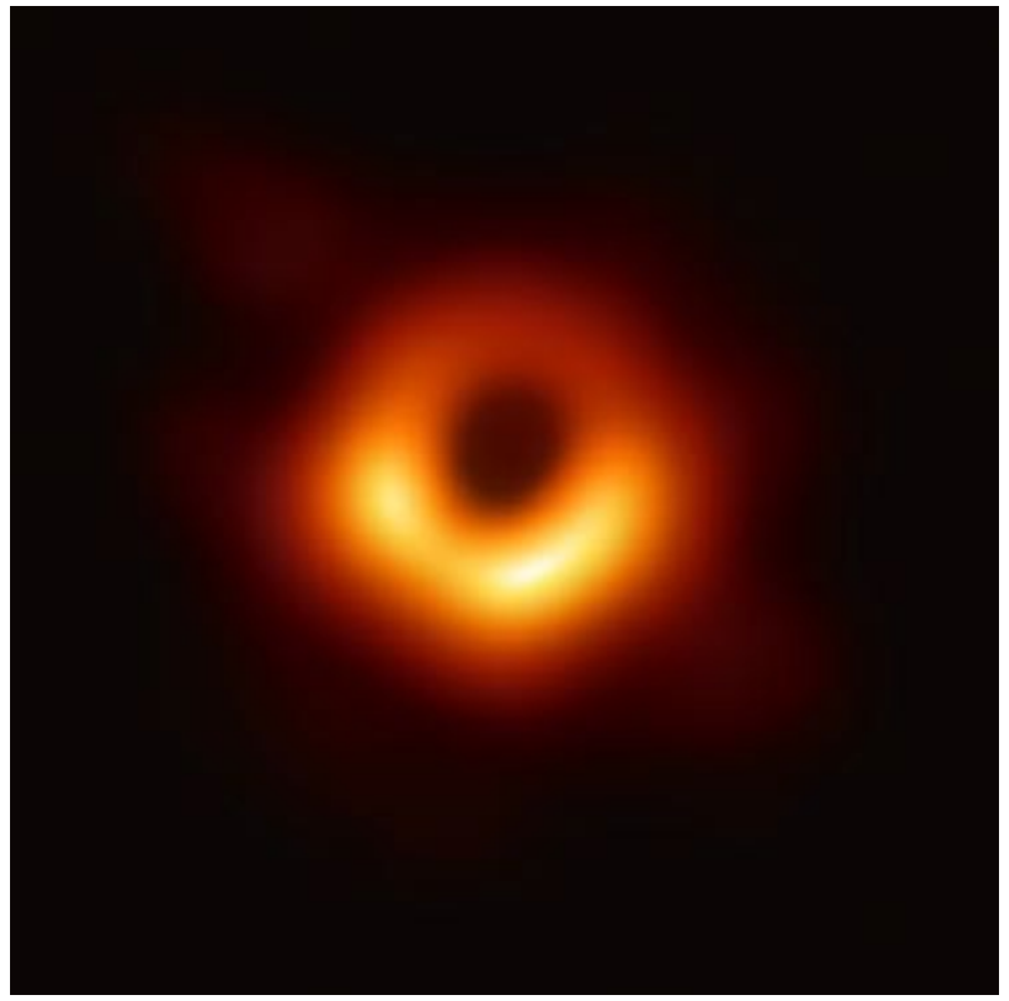


"The essence of math lies in its freedom."

– Georg Cantor

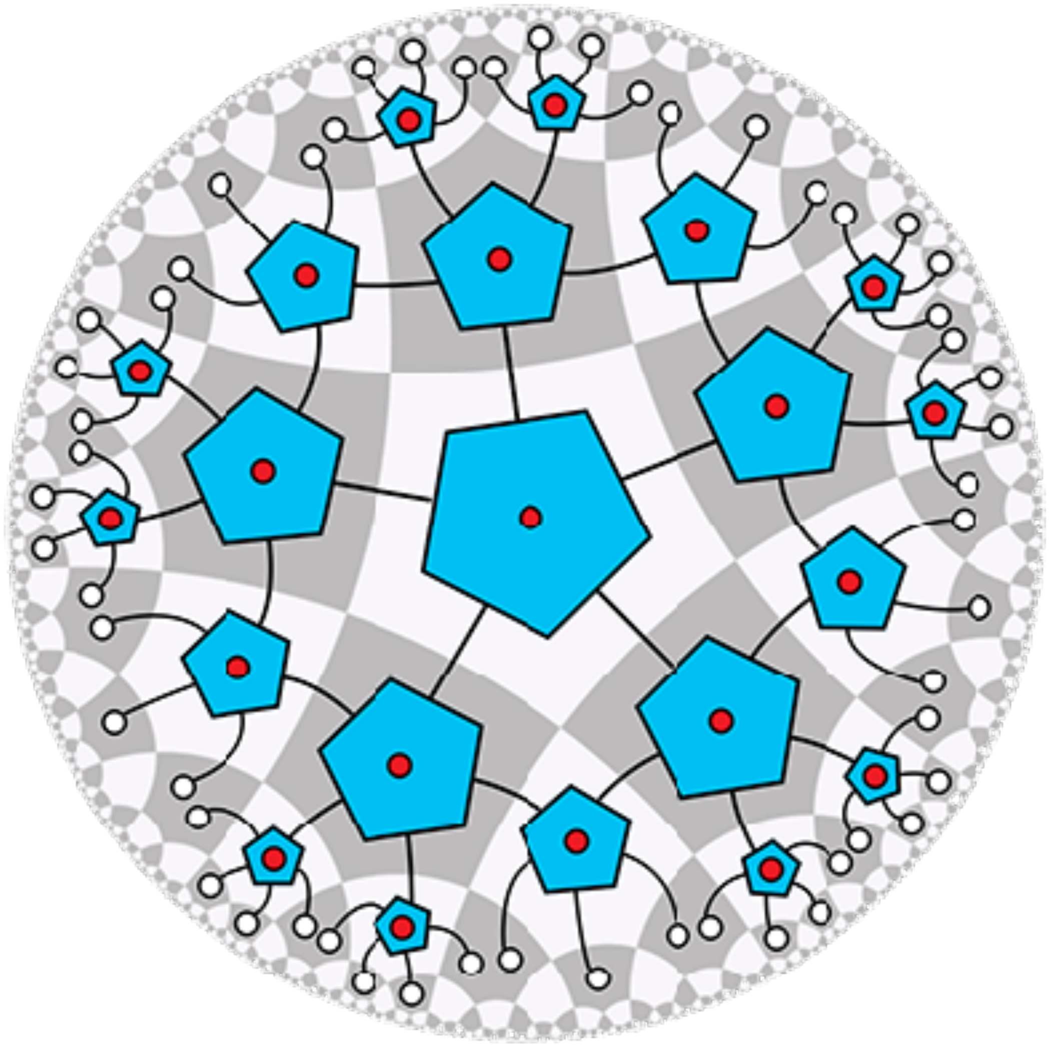
Why Physics?

Module II: Computations in the physical world



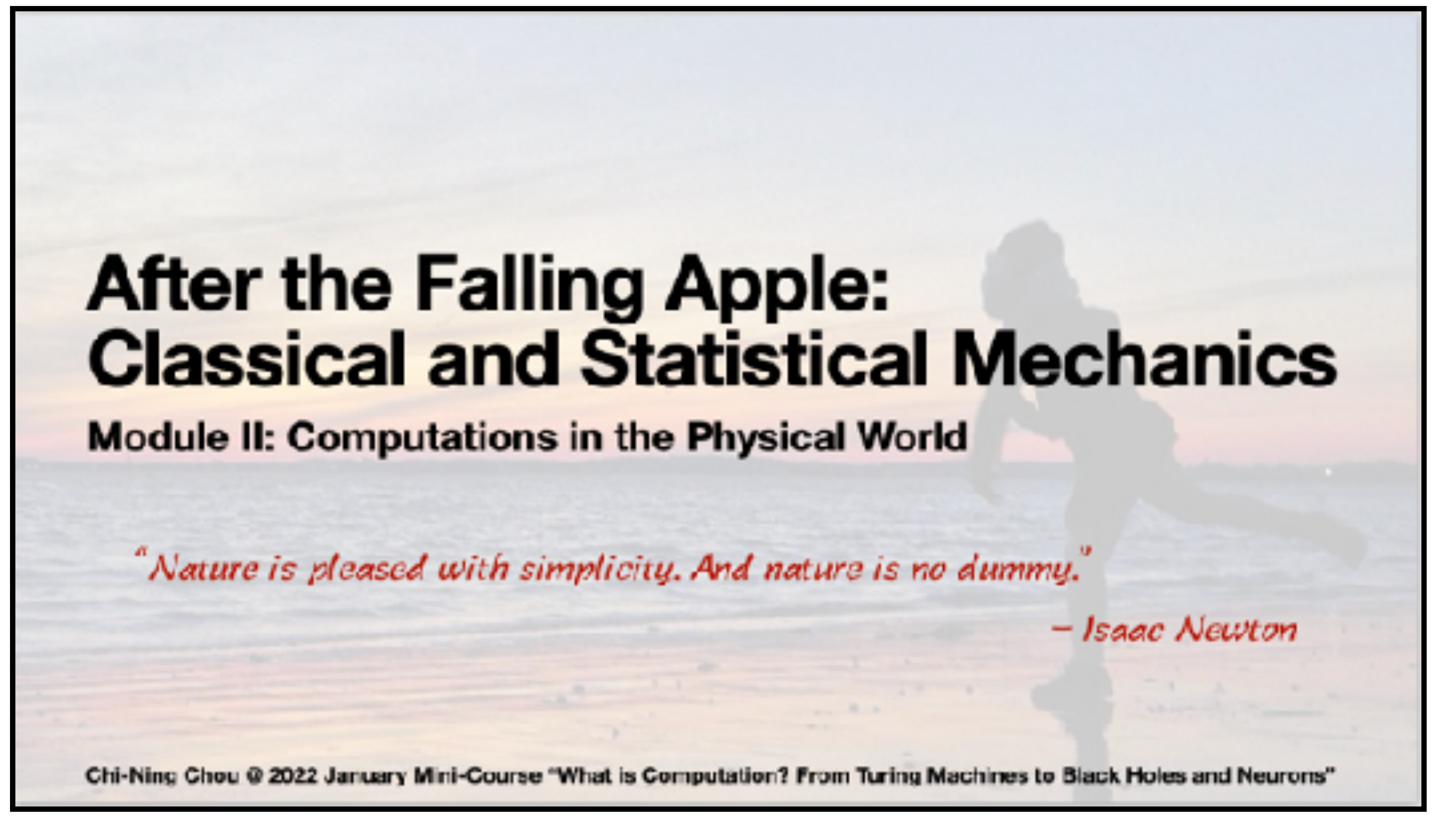
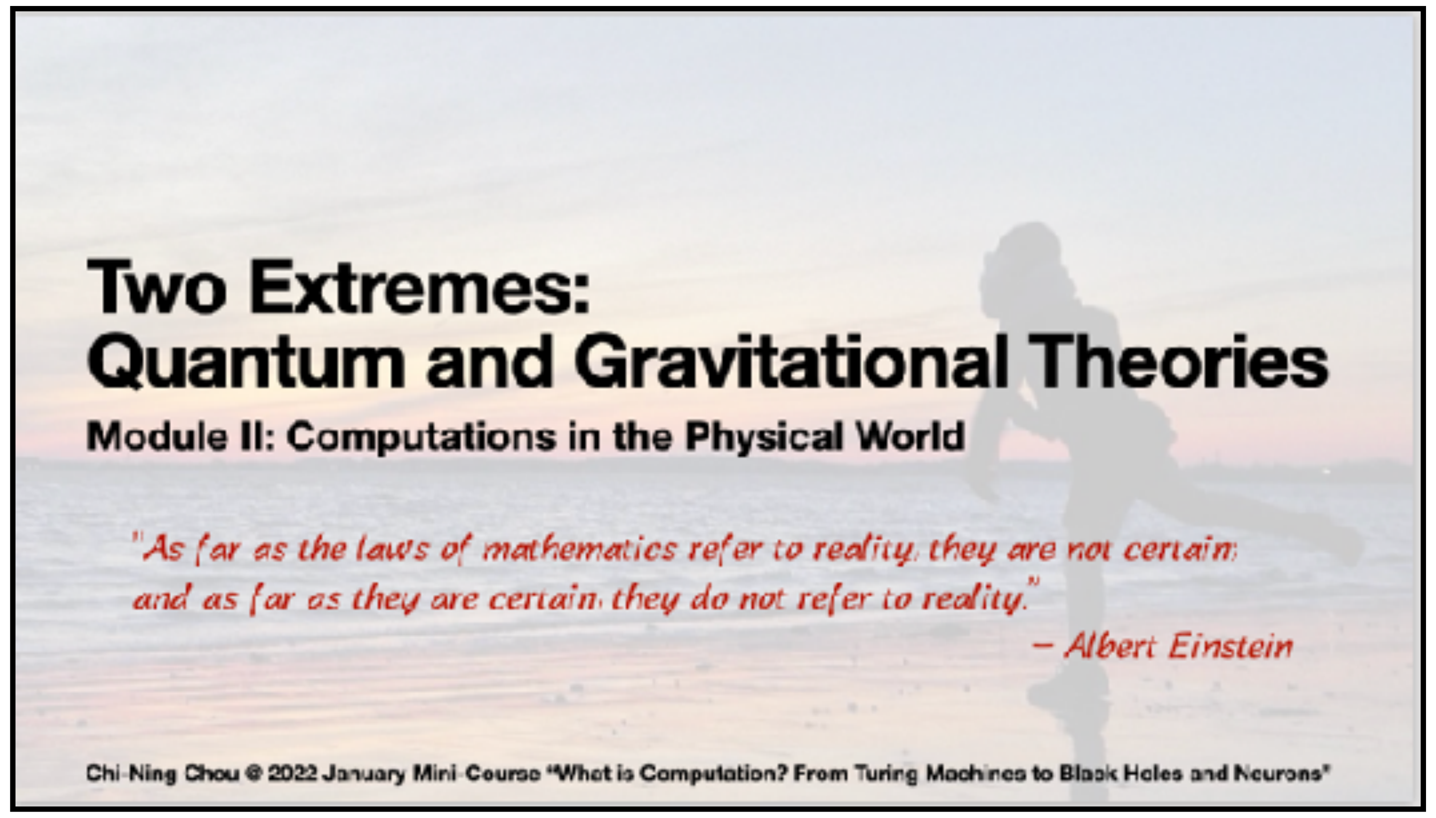
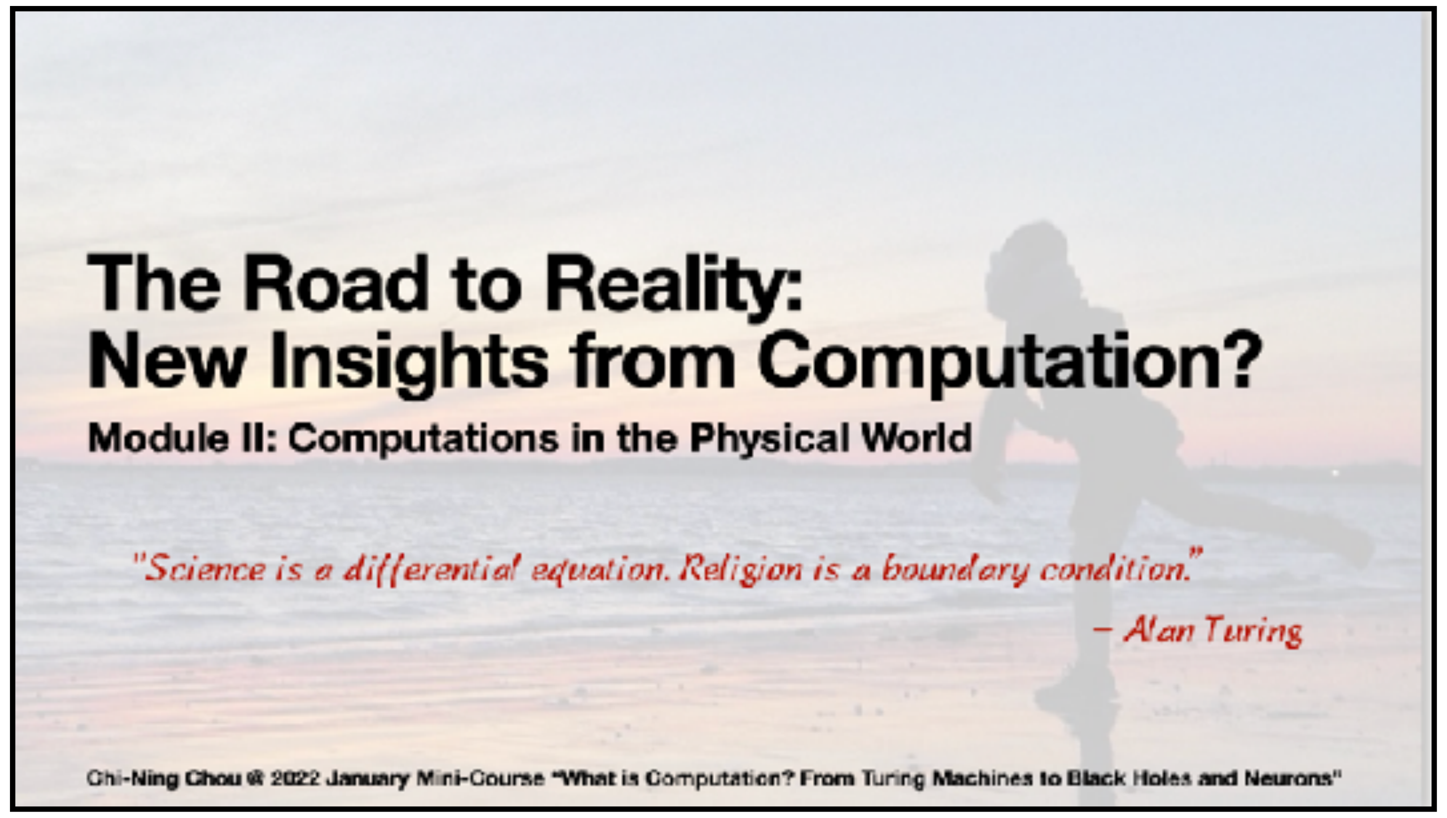
Constraints & Structures

Abstraction & Symmetry



I encourage you to focus on the different world views and postulates physicists used for studying reality!

Module II: Computations in the Physical World

Classical approach	Modern approach	Philosophy
		
Lecture II.a	Lecture II.b	Lecture II.c
(Jan. 12 10am-10:50am ET)	(Jan. 13 10am-10:50am ET)	(Jan. 19 10am-10:50am ET)

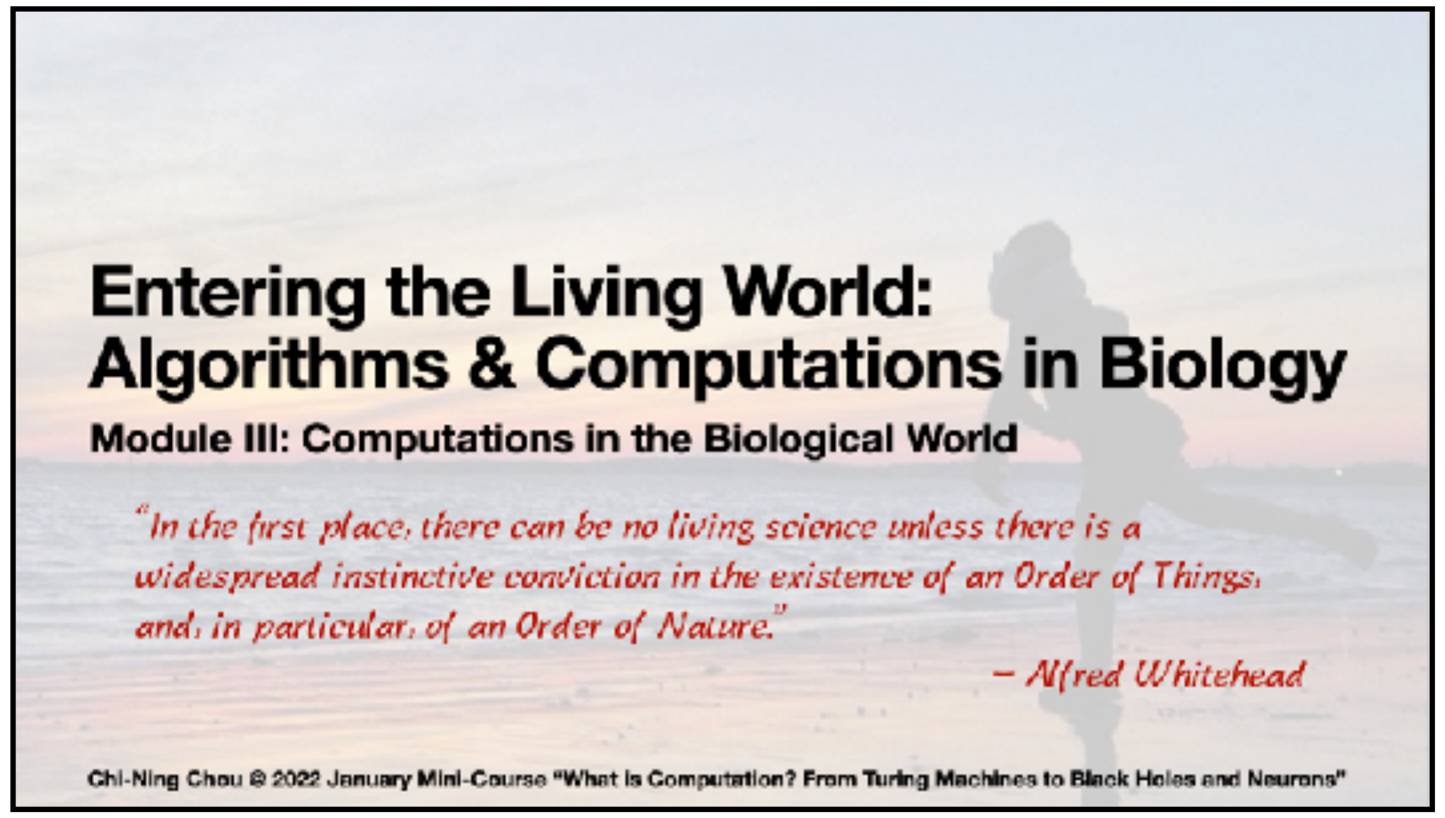
Why Biology?

Module III: Computations in the biological world

I encourage you to enjoy the many examples we are going to see throughout the lectures and build up your own story!

Module III: Computations in the Biological World

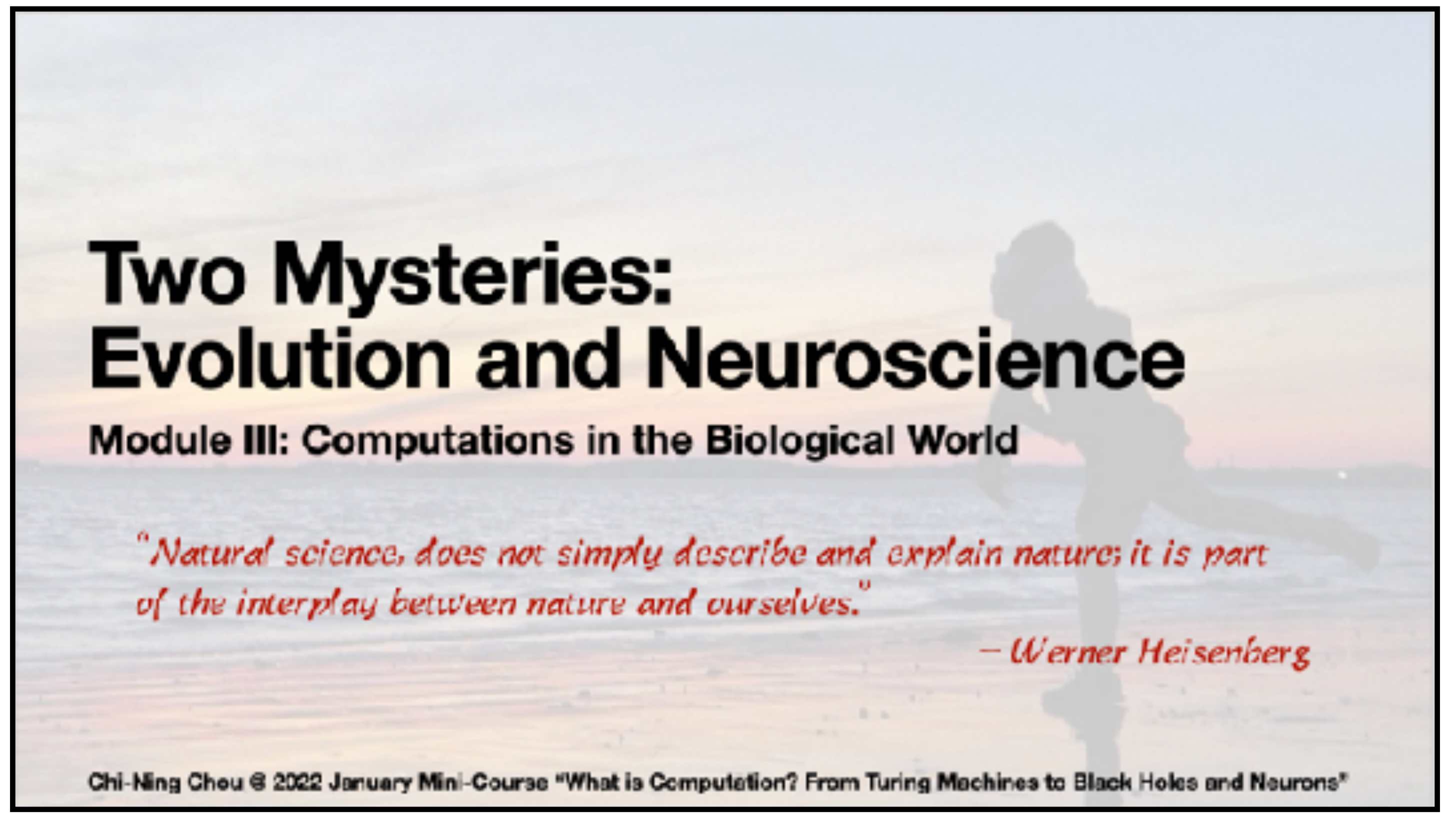
Many Examples



Lecture III.a

(Jan. 12 11am-11:50am ET)

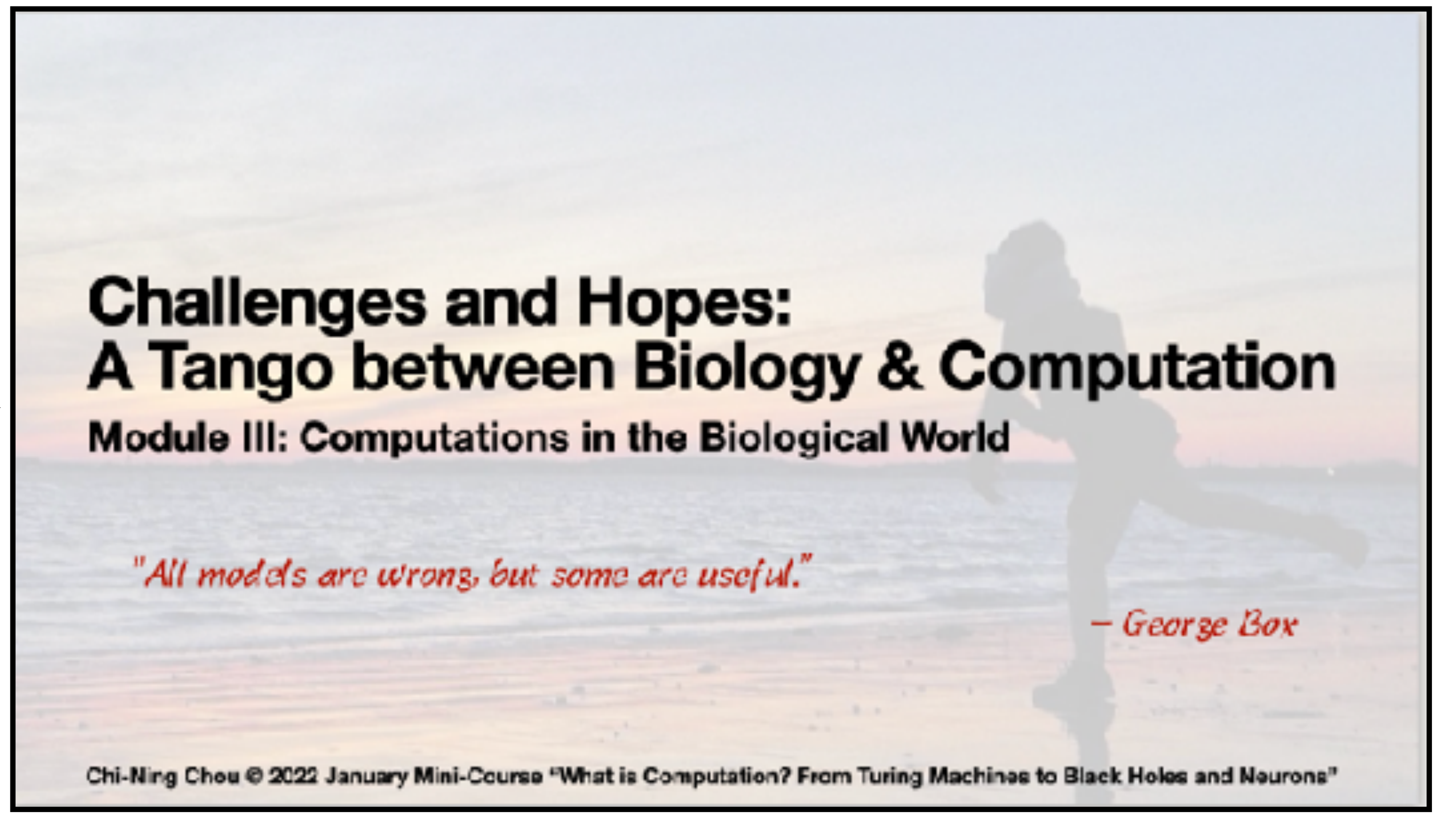
Evolution & Brain



Lecture III.b

(Jan. 14 10am-10:50am ET)

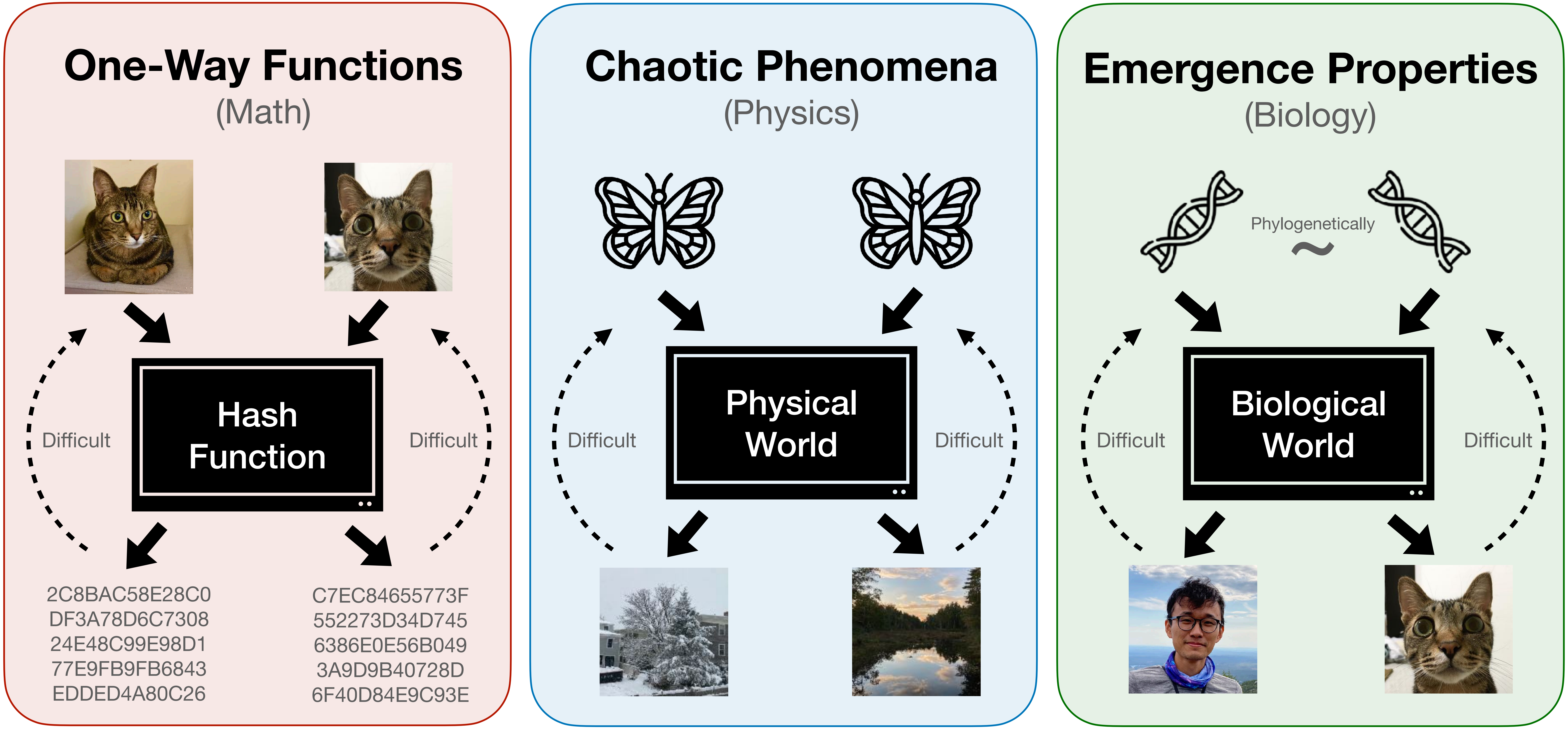
Philosophy



Lecture III.c

(Jan. 20 10am-10:50am ET)

An Example of the Intersection of the Three



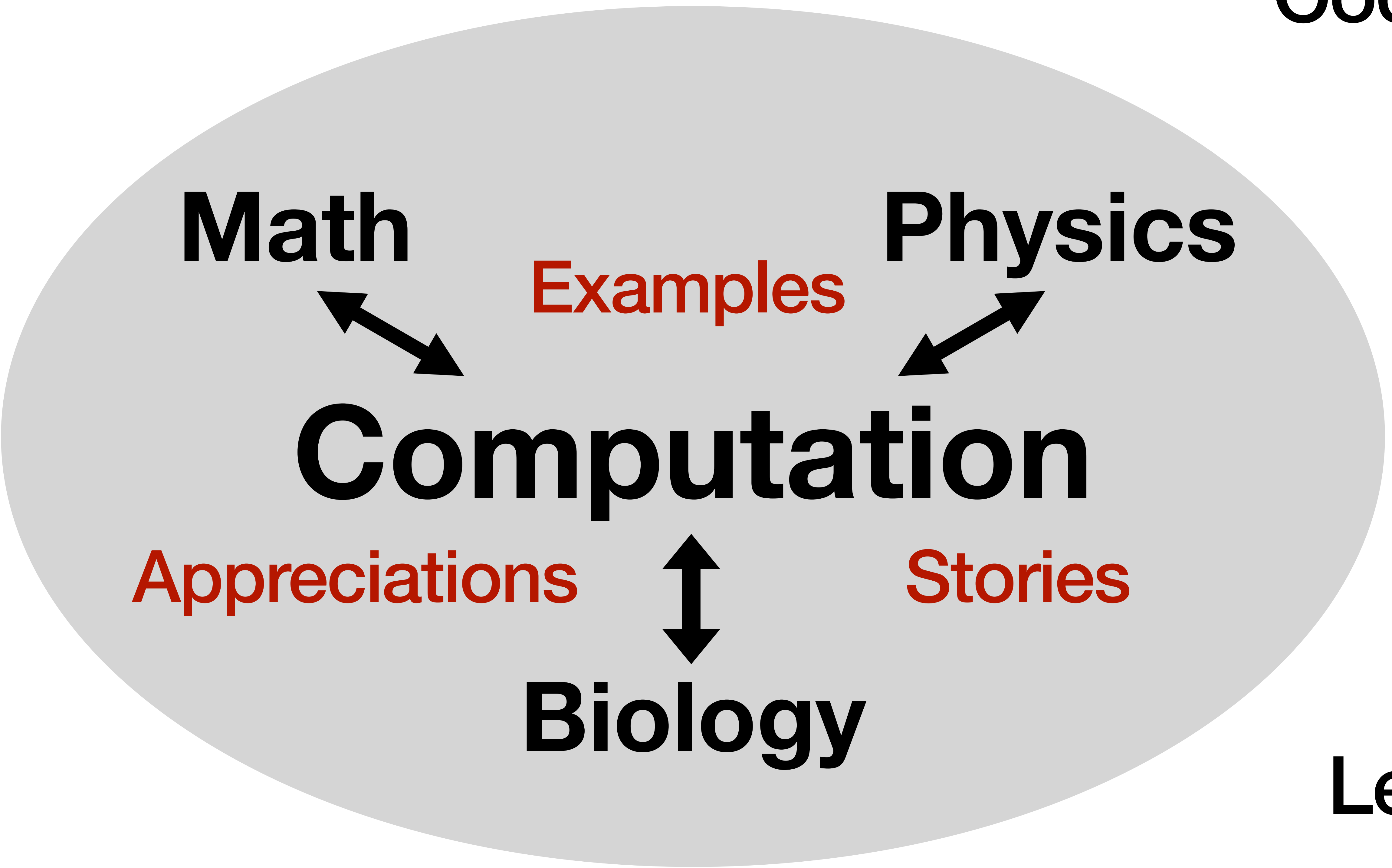
What’s Covered and What’s Not?

Consciousness

Creativity

Art

Intelligence



Coding theory

Game theory

Information

Cryptography

Learning

“Our knowledge can only be finite, while our ignorance must necessarily be infinite.”

– Karl Popper

If you are familiar with the materials

I encourage you to…

- Focus on how the high-level big pictures connect to each other.
- Be critical to the narrative I give.
- Think about how to explain the same materials to non-professionals.

If you are unfamiliar with the materials

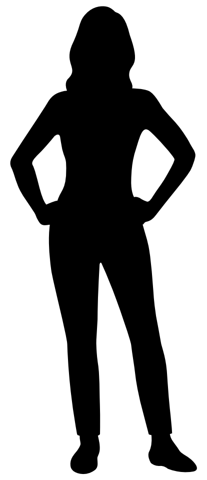
I encourage you to…

- Grasp the high-level stories before understanding all details.
- Build up “feeling” and “intuition” on the topics you find interesting.
- Come up with some takeaways for each lecture you attend.

In either case, feel comfortable to share your thoughts!

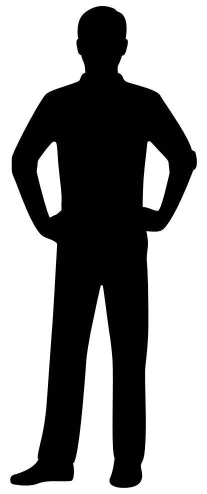
Goals

Goals



“Shiba is so cute!”

“Hmmm, Shiba is dumb,
I like Schrödinger’s cat
better”



“Shiba is so smart!”

“Can you axiomatize a
cat? If so maybe I’ll
consider to take care of
Shiba when you are on
vacation”

Goals

Mathematics

Physics

Biology

This is just the beginning of a lifelong journey!

Quick Logistics

- **Zoom:**
    - Would be great to see your beautiful faces :)
    - For technical support or clarification questions, send a zoom message to the teaching staff (marked as co-host). I **won't** frequently check zoom message.
- **Online Q&A:**
    - Due to the large attendance, please **don't interrupt the lecture** in the middle. Instead, ask questions through vevox (will introduce it shortly). The teaching staff will answer some urgent clarification questions for you through zoom chat.
    - There will be several question break during each lecture and I'll answer some top-rated questions on vevox.
- **Scribe notes:**
    - Scribe notes are "shared notes" among students for the lectures and talks.
    - I encourage people to sign up and you will be credited in the final report!

Meanwhile, let us know how to improve your learning experience!

Guest Speakers for Module I

"Efficiency of Algorithms and the Sorites Paradox"

Lijie Chen

(Jan. 11 11am-12pm ET)

Guest Speakers for Module II

Xun Gao
(Jan. 13 11am-12pm ET)

"Quantum Correlation: the Resource to Make Quantum Machine More Powerful"

"Quantum Machine Learning from Algorithms to Reality"

Khadijeh Sona Najafi
(Jan. 14 11am-12pm ET)

Guest Speakers for Module III

"Into the Unknown: (De)constructing Creativity in the Age of Human-Machine Partnership"

Angel Hsing-Chi Hwang
(Jan. 17 11am-12pm ET)

"A Road to Totality: Between Art and Computation"

Zhiqian Wang
(Jan. 19 11am-12pm ET)

"Animal Intelligence: Flexible Computation Under Uncertainty"

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

Teaching Staff

Thank you all for volunteering!


Aman


Pawan


Mostafa


Aaron


Reijo
(Jan. 11
2pm-3pm ET)

"Undecidability of the Halting Problem and Gödel's incompleteness Theorem"


Prahlad
(Jan. 12
9am-10am ET)

"The Four Color Theorem"


Erick
(Jan. 13
2pm-3pm ET)

"Information Geometry"


Simone
(Jan. 14
2pm-3pm ET)

"Simulated Annealing"


Sowmya
(Jan. 18
10am-11am ET)

"Basic of Quantum Computing and Future Direction"


Avantika
(Jan. 18
11am-12pm ET)

"Quantum Complexity Theory"

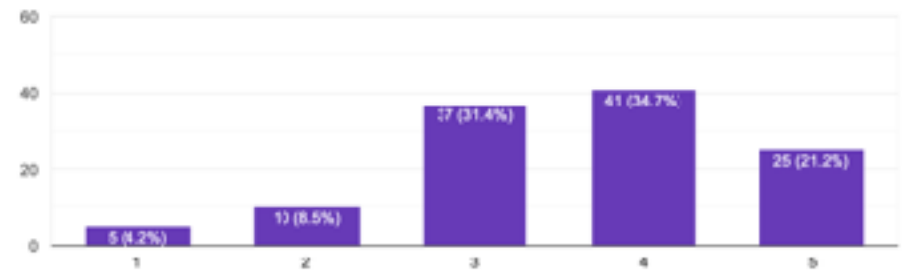

Salvador
(Jan. 19
2pm-3pm ET)

"DNA Computing, Cellular Automata, and Beyond"

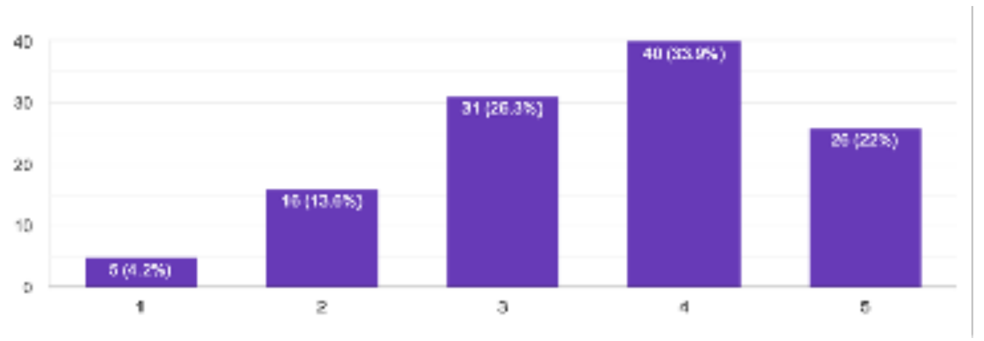

Kartikeya
(Jan. 20
9am-10am ET)

"Quantum Computing from a Condensed Matter Perspective"

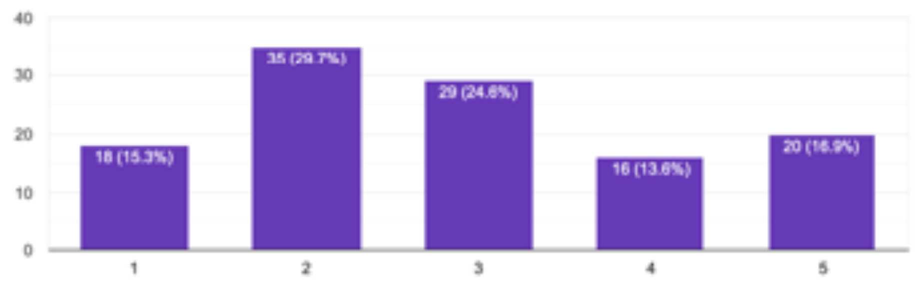
Math



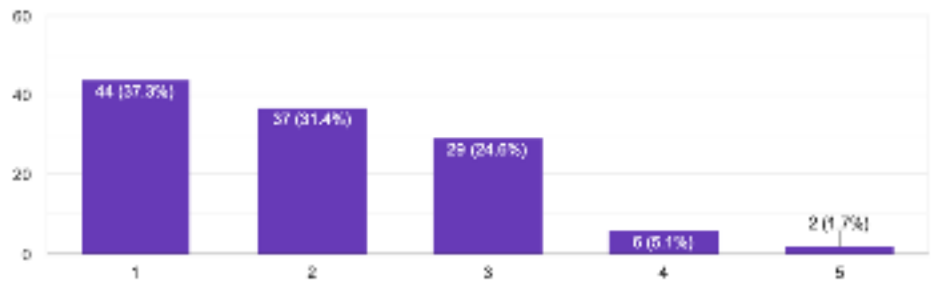
CS

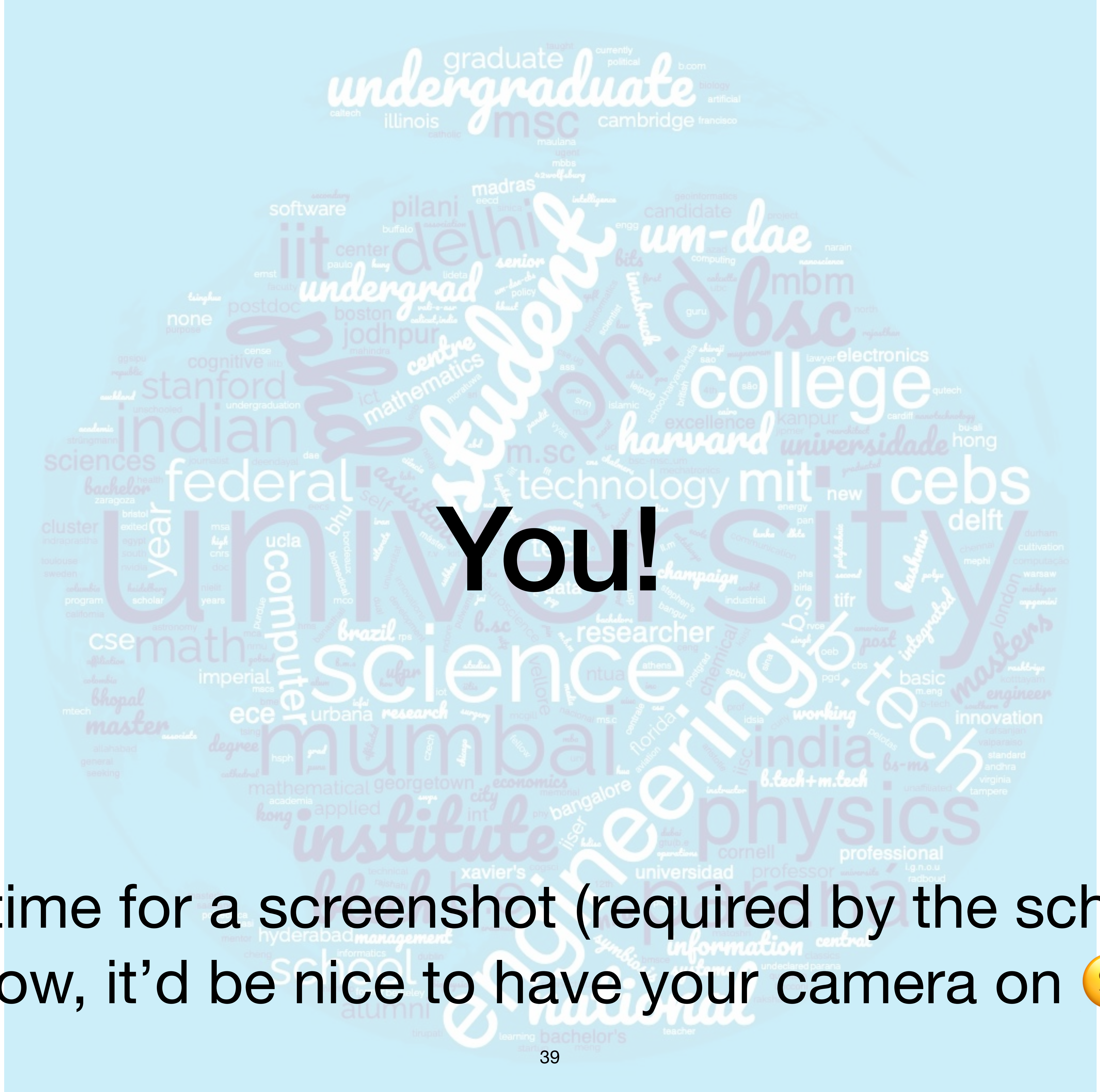


Physics



Biology





You!

It’s time for a screenshot (required by the school) now, it’d be nice to have your camera on 🙂

Online Q & A Platform

Type this in your browser

Or scan the QR code with your phone

(1) If you want to show your name, feel free to attach it to the end of your question.

(2) In future lecture, teaching staff will regularly post the link in zoom chat.

(3) Try to ask a question or like a question there!

Brief Q & A

Feel free to take a break and see you at 11am ET!

Brief Q & A

Q: Will all the lectures be recorded?

A: Yes, the recording link will be sent out once available and in long term will be posted somewhere publicly.

Q: Is there any homework?

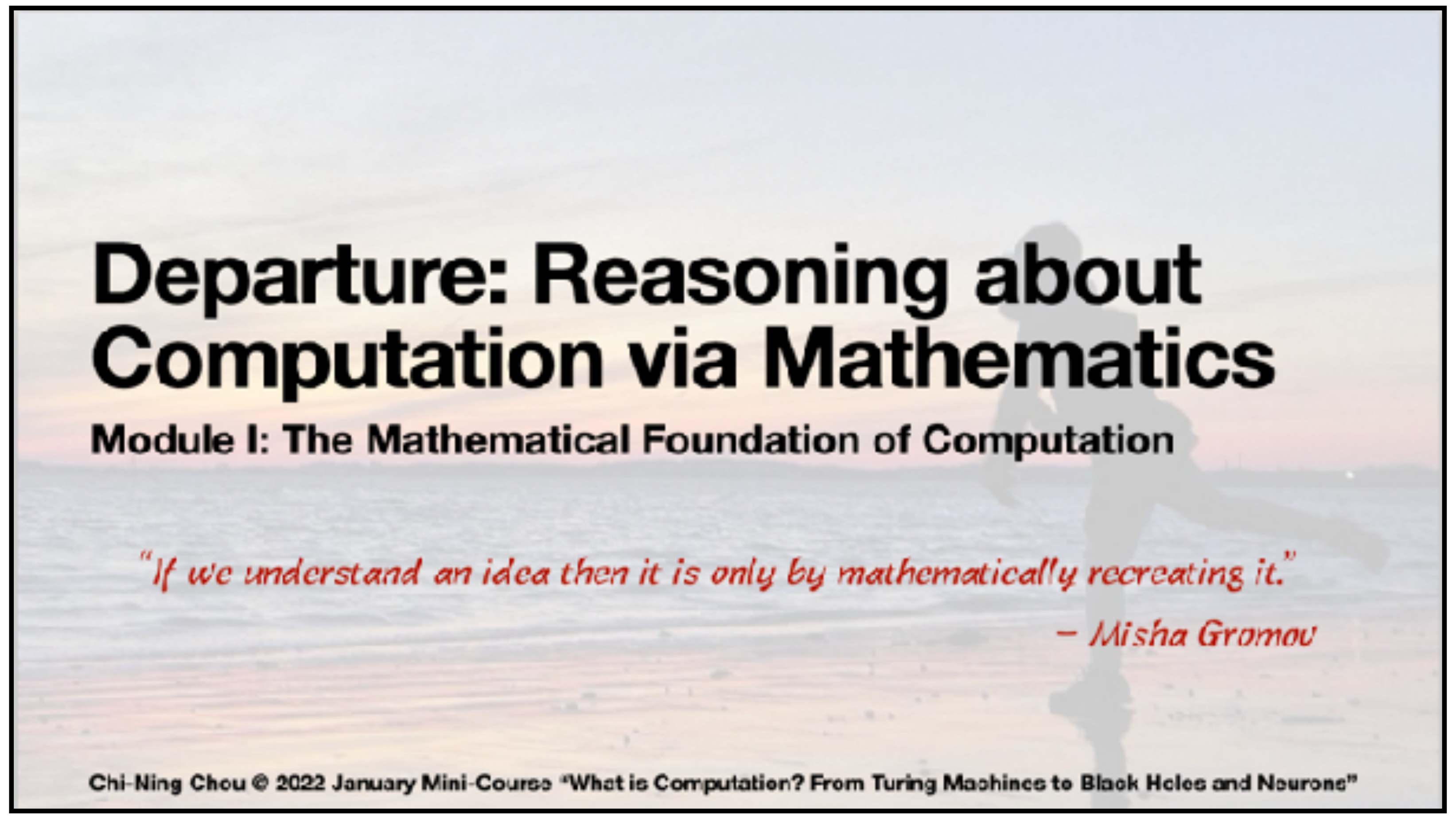
A: No, but there will be food for thought questions at the end of each lecture.

Q: When will the slides be posted?

A: Slides will be posted on the course website after the lecture.

Q: How advanced is the advanced section?

A: Each advanced section will focus on a more specific topic and dive into certain level of details. The target audience is advanced undergraduate students and early-year graduate students (not necessarily in relevant area).



Lecture I.a happens at 11am ET!

Coffee chat happens at 2pm ET!