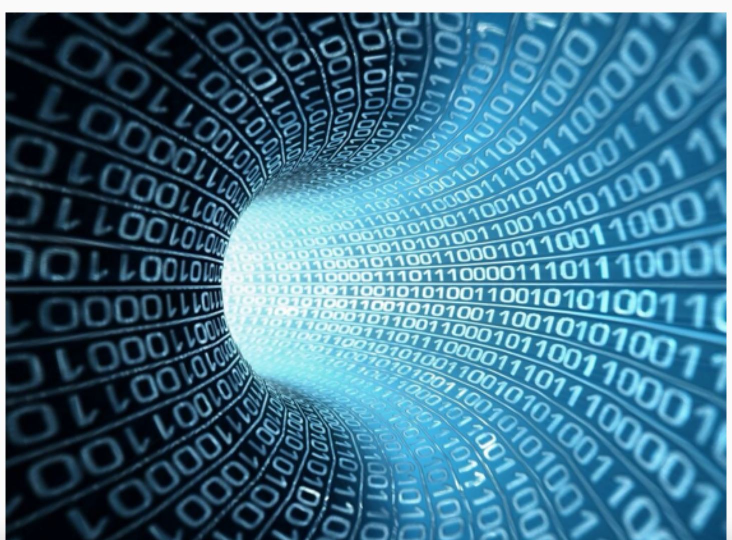
Cool Applications:
CS + Biology
(and friends)



Dave Abel

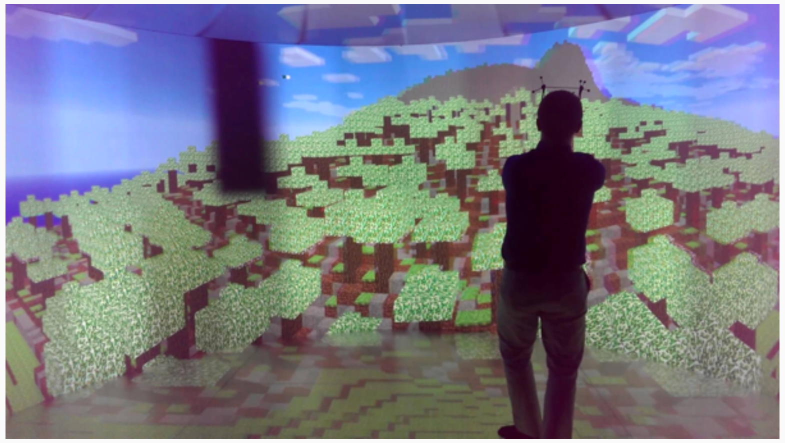
April 20th, 2016

Schedule

- Wednesday (Today): Randomness, CS + Bio!
- Friday (4/22): What CS to take next? Graphics!
- Monday (4/25): Dave's Research
- Wednesday (4/27): Last Day! Whole Term Recap + Final Review
- March 10th: Writing Assignment Due
- March 15th: Python Project Due
- March 19th: Final Exam, 2pm in LIST 120.

Yurt, Round Two

- If you want to go, email me with subject "Yurt"
- Specify which time you'd like to go:
  - **5 slots left:** Monday, May 9th from 2pm-3pm
  - **1 slots left:** Tuesday, May 10th from 11am-noon



Writing Assignment

- Writing Assignment Rubric Released
  - Find a few academic articles or papers that discuss how CS has affected a different **topic** of interest to you.
  - Write a short reflection paper summarizing and analyzing the topic, focusing on the technical explanation and on how computer science concepts are relevant to it.
  - Due May 10th.
  - 800-1200 words (~2 pages)

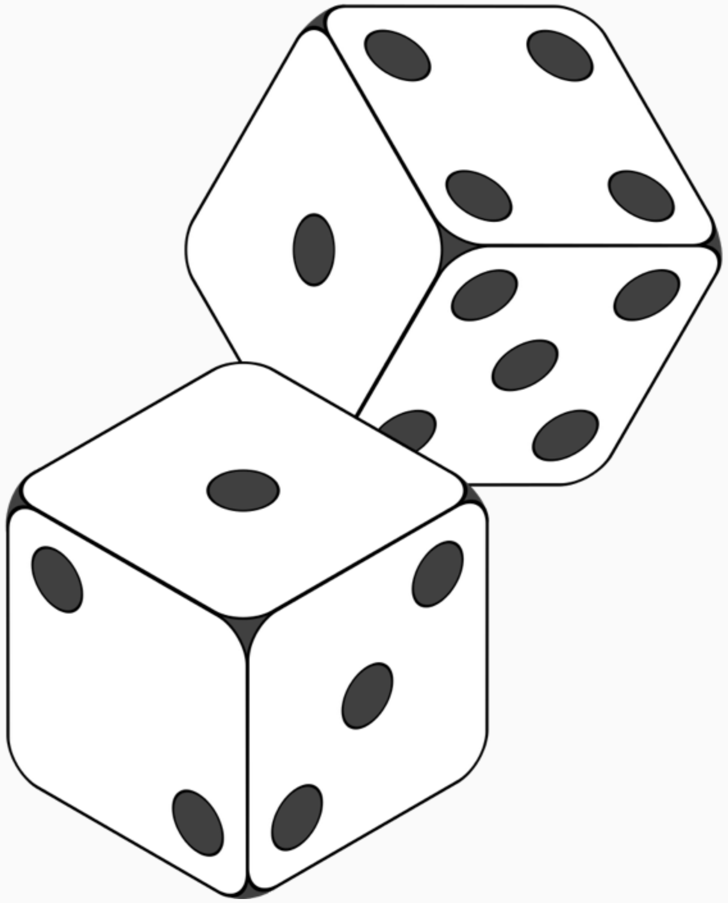
Python Project

- Python Project Rubric Released
  - Due May 15th.
  - Stencil Code Released.
  - More than happy to help in office hours, over email.

Other Notes

- No more labs! Don’t go to your lab tomorrow.
- No more regular homework (writing assignment is the last homework).
- Final Exam review session will be held closer to reading period.
- My office hours will be changing during reading period.

Randomness



Randomness

- Earlier notion of randomness from Theory!
- The higher the Kolmogorov complexity, the more random an object is.

Randomness

- But how about *events*? Really, we want this:

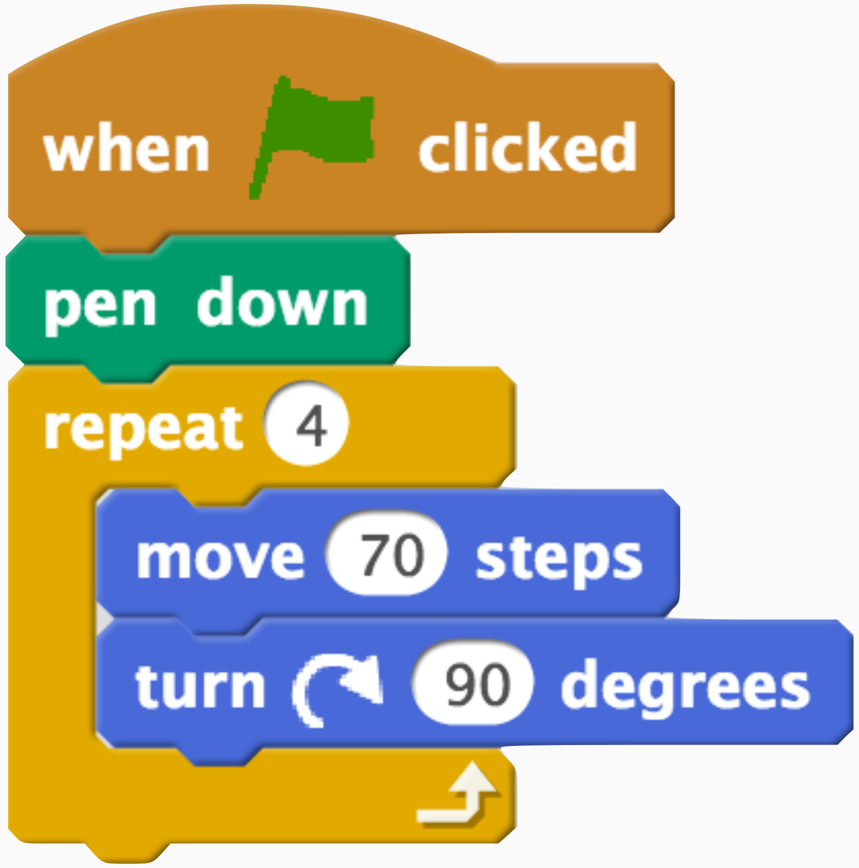
Randomness

- But how about *events*? Really, we want this:

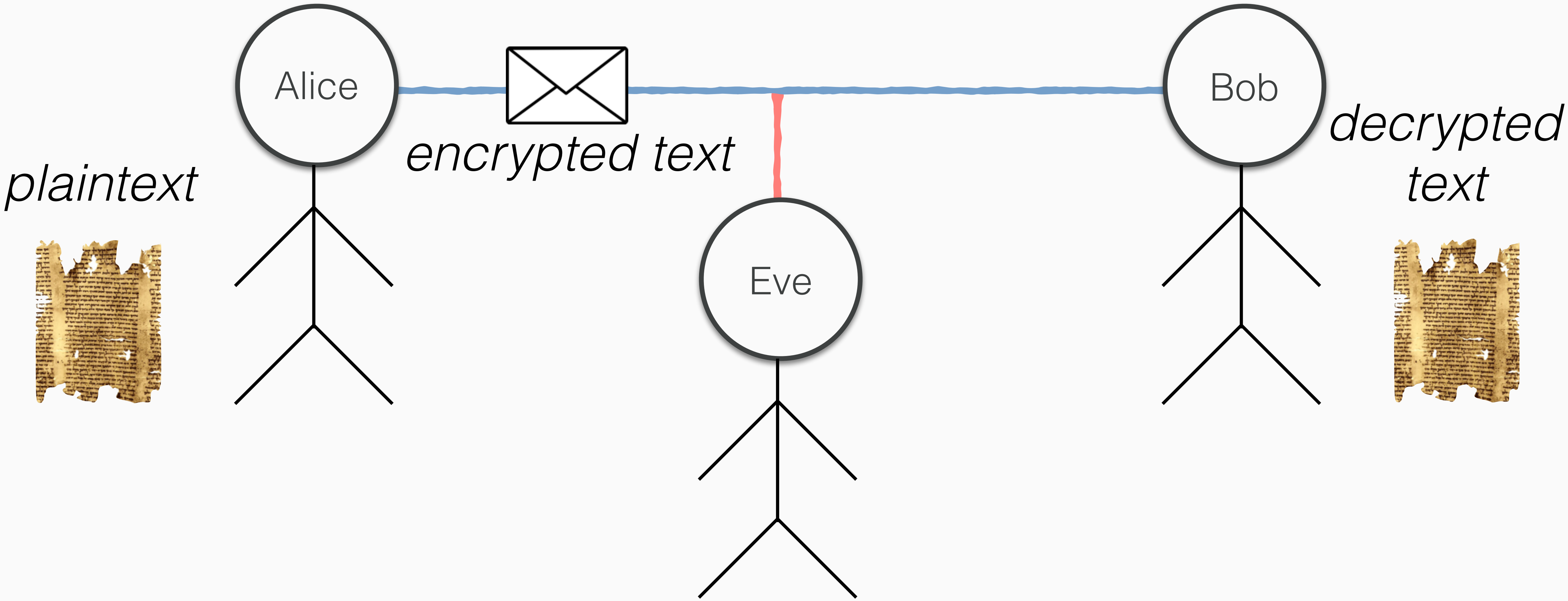
- But suppose we didn't have this block. How could we write a block to carry out random operations?

Randomness

- Everything has been so *deterministic*:



Randomness & Crypto



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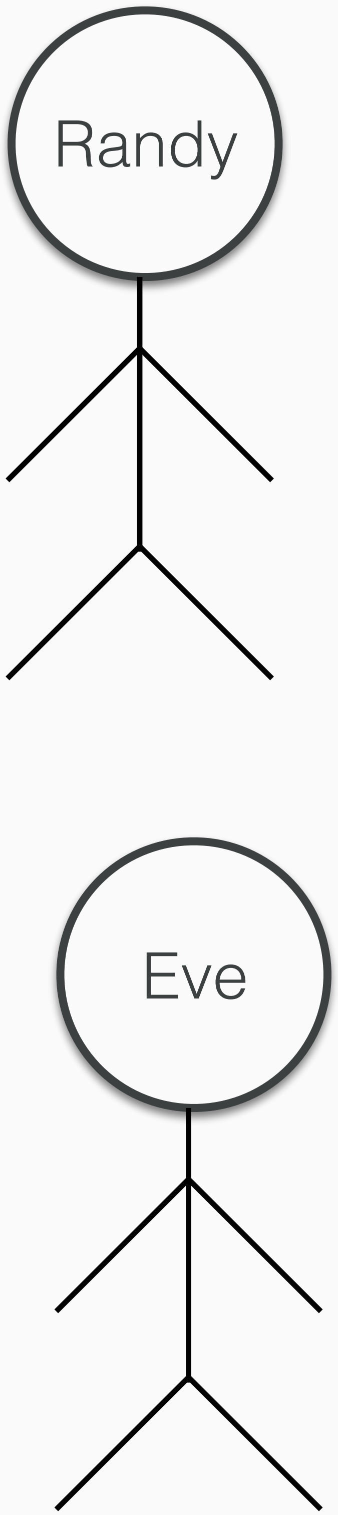

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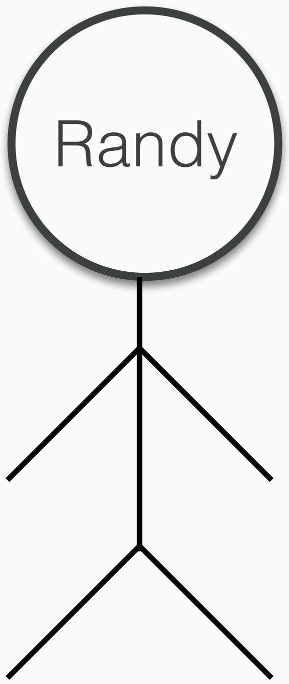
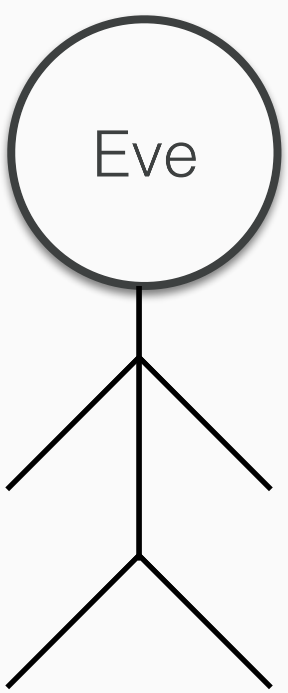


"I have figured out a way to simulate random coins!"



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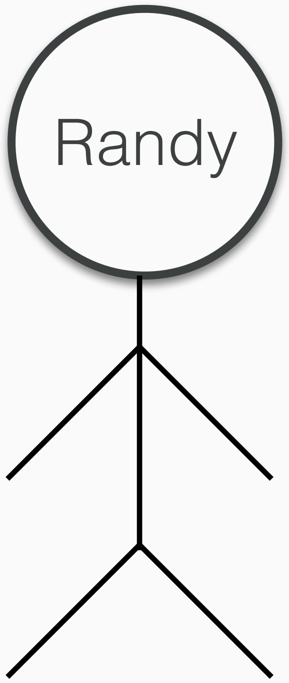

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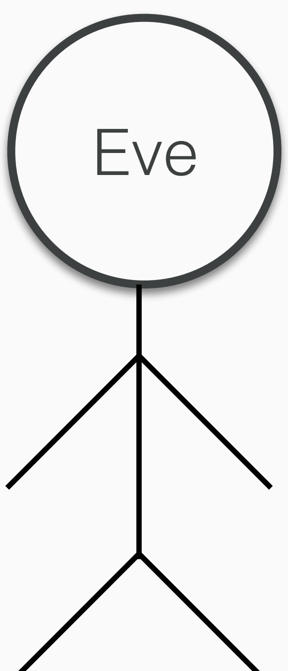
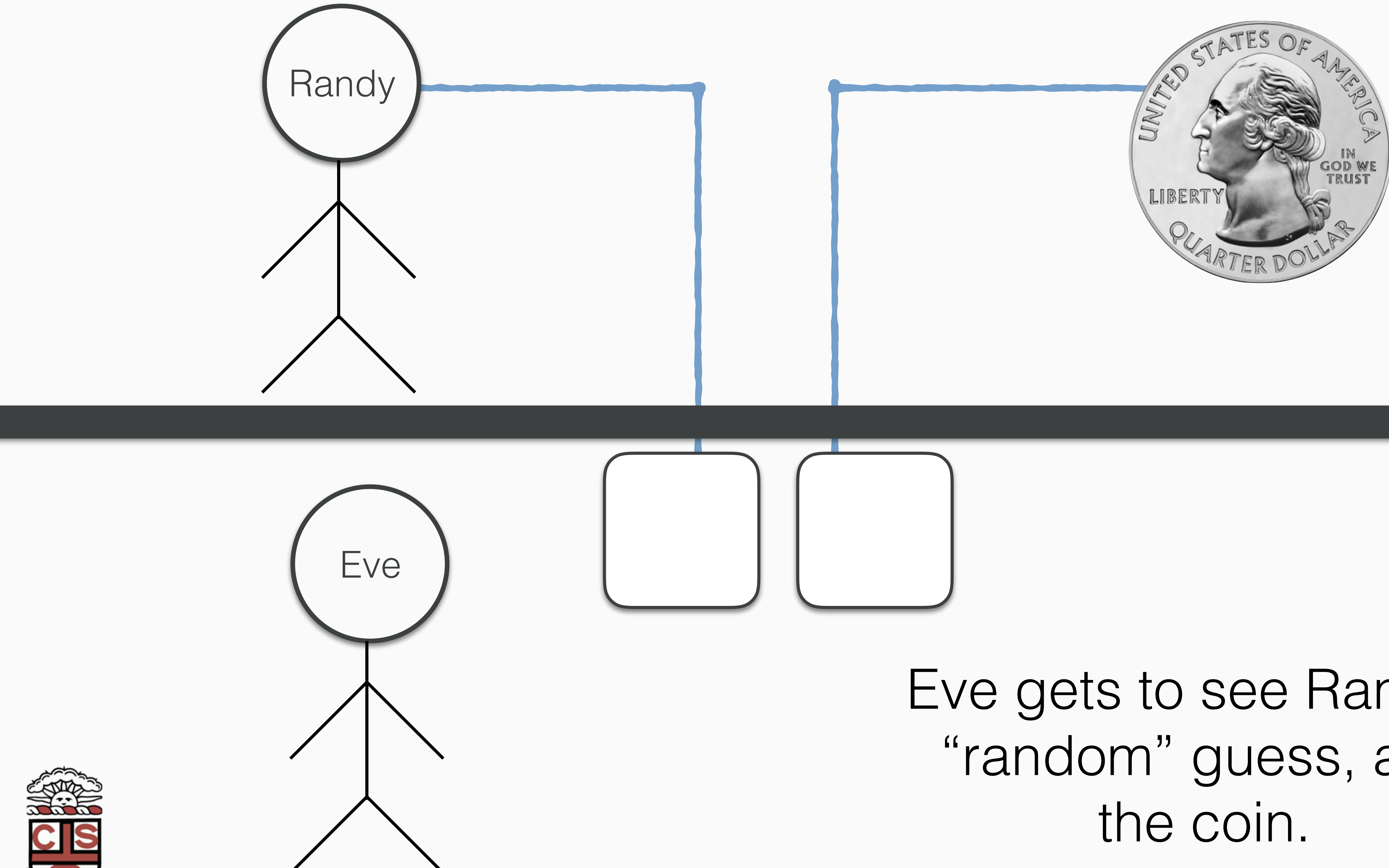


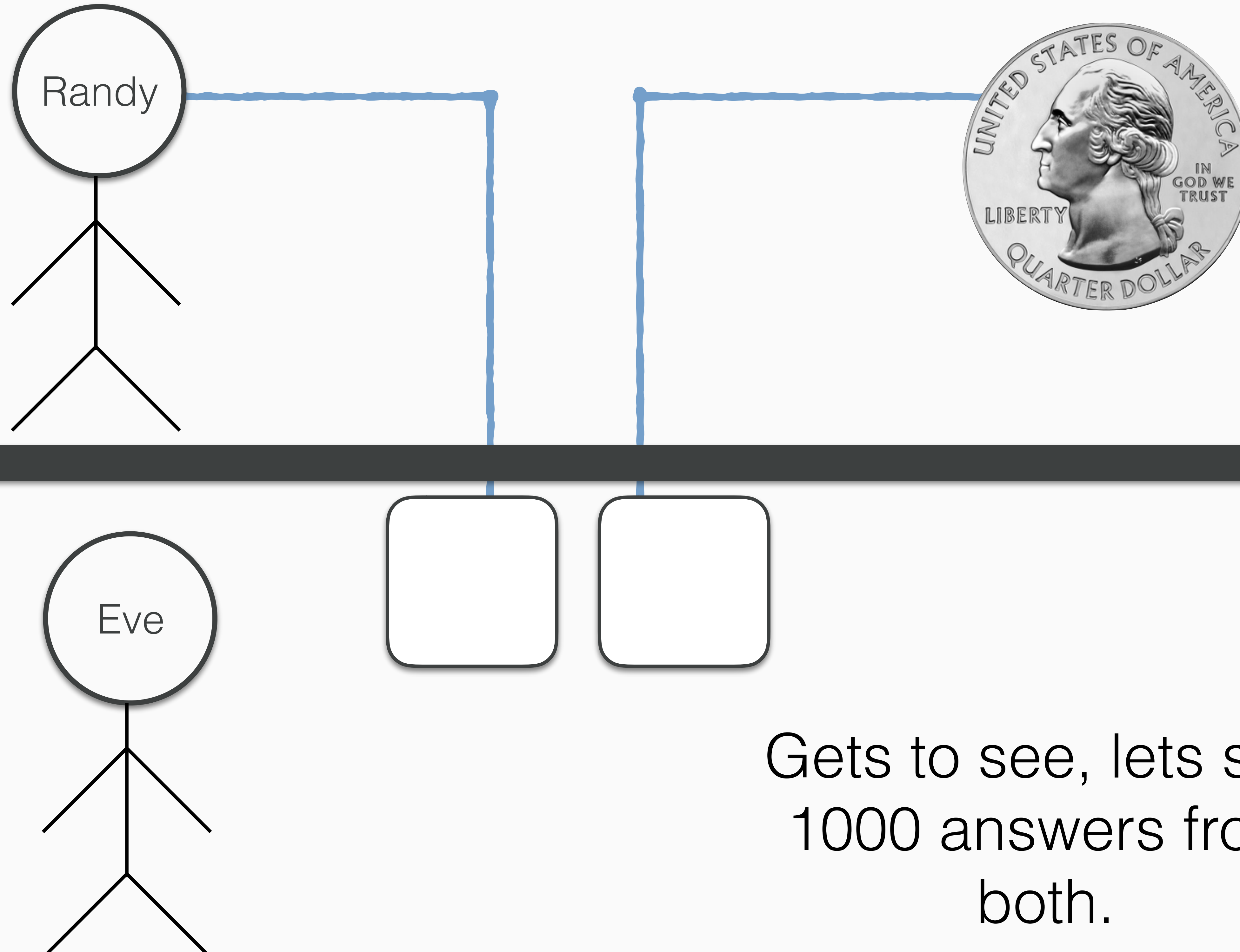
“No way…”

Randomness & Crypto



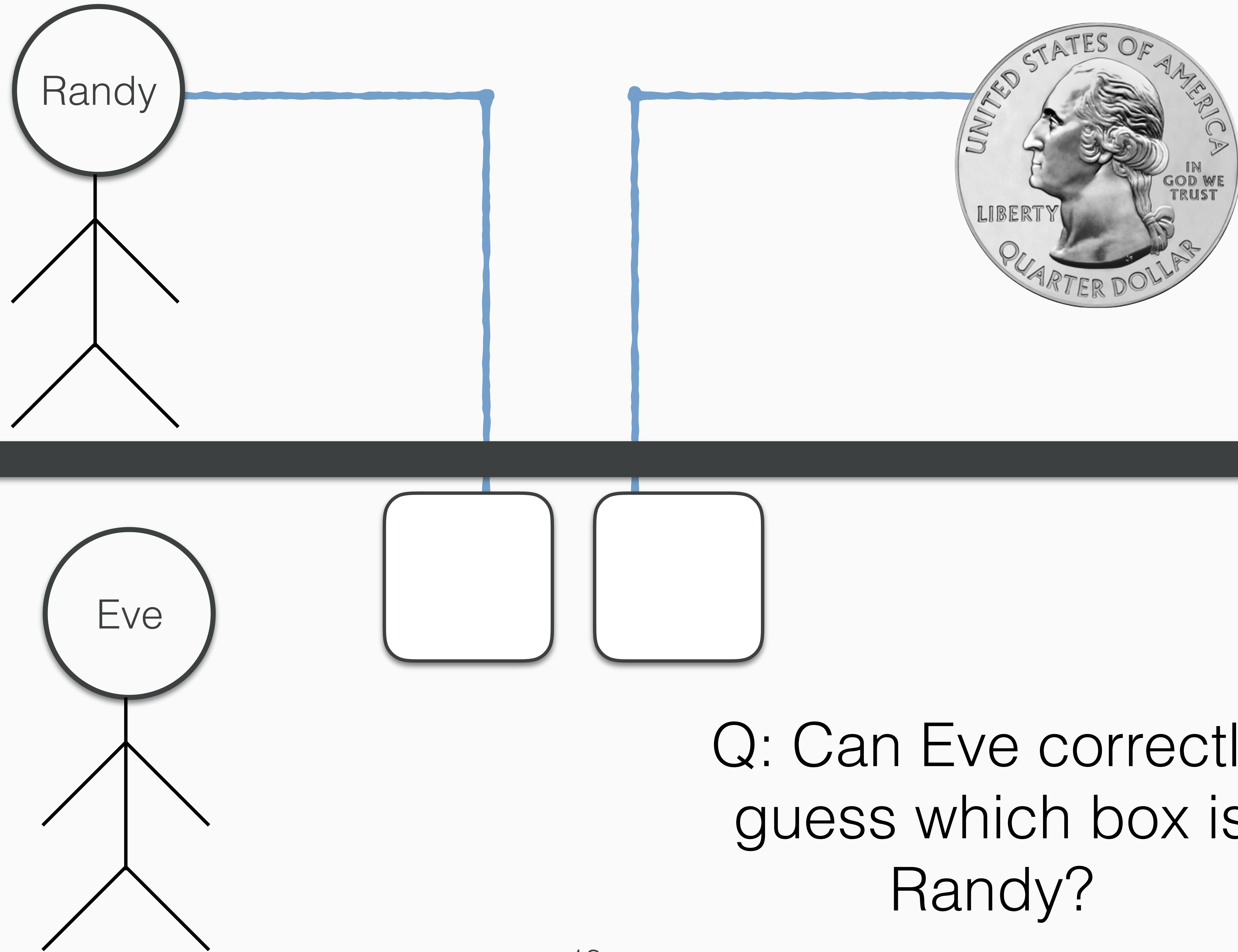
Eve gets to see Randy’s “random” guess, and the coin.

Randomness & Crypto



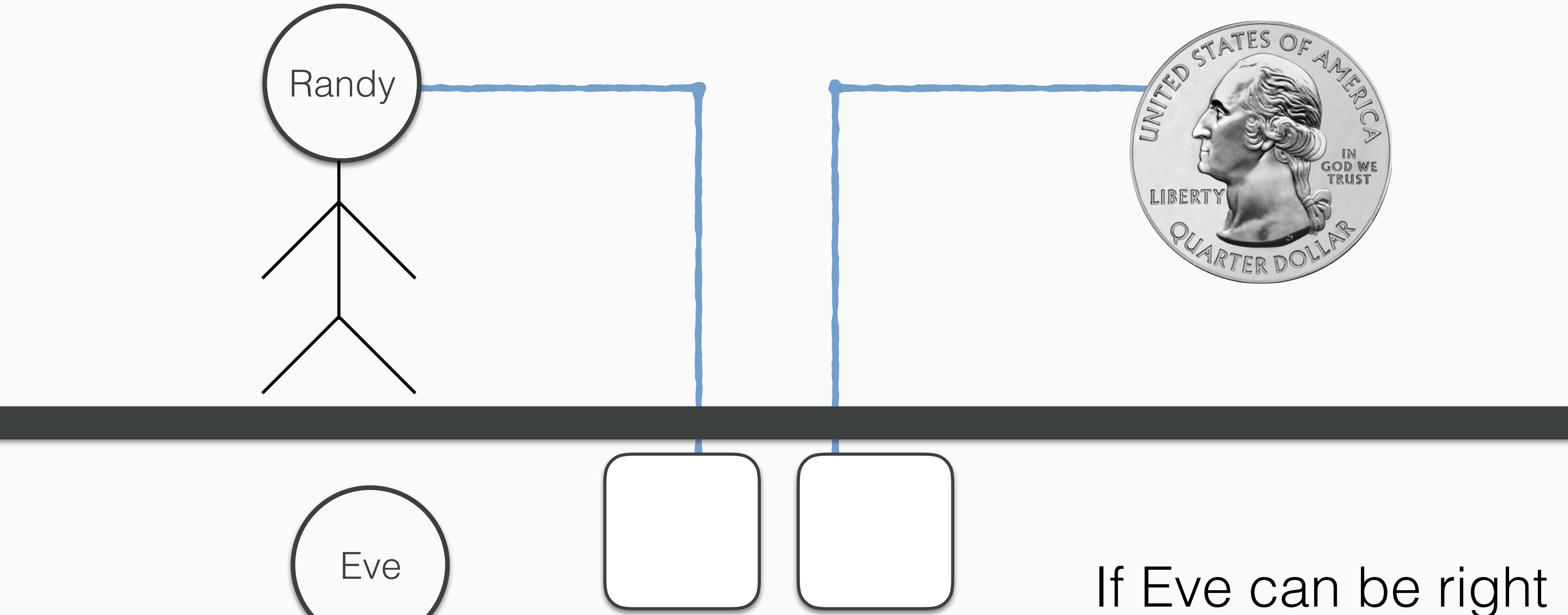
Gets to see, lets say, 1000 answers from both.

Randomness & Crypto



Q: Can Eve correctly guess which box is Randy?

Randomness & Crypto



Q: Can Eve correctly guess which box is Randy?

If Eve can be right more than 1/2 the time, Randy isn't Random

(Psuedo)-Randomness

- **Definition:** A process is *pseudorandom* if an adversary, Eve, cannot distinguish the process from a truly random process!

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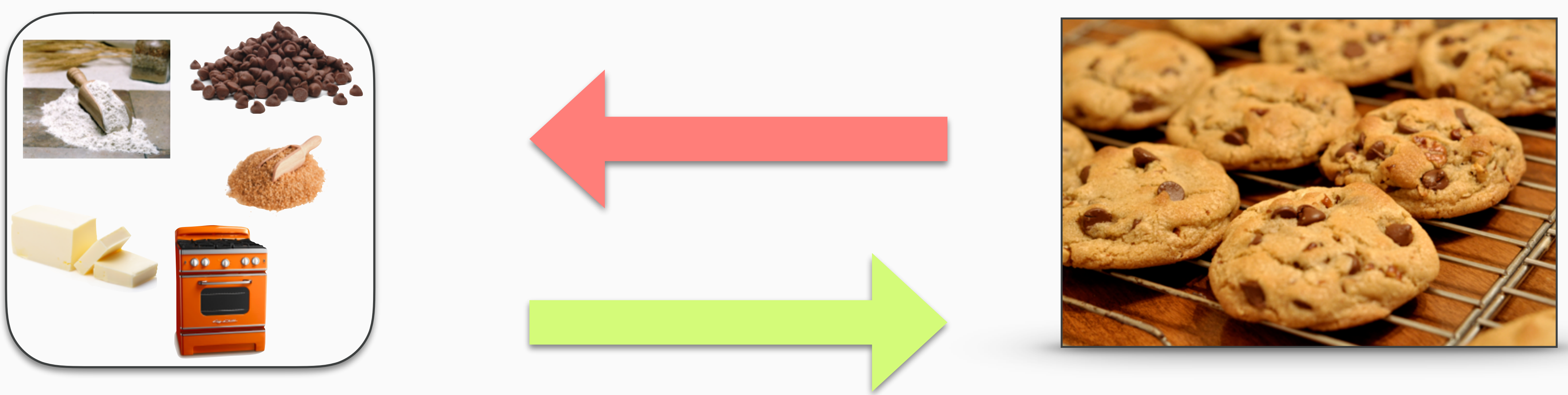
- **Q: Can humans do this?**

Psuedorandomness

- **Definition:** A process is *pseudorandom* if an adversary, Eve, cannot distinguish the process from a truly random process!
- Q: So how do we achieve this?
- A: One Way Functions!

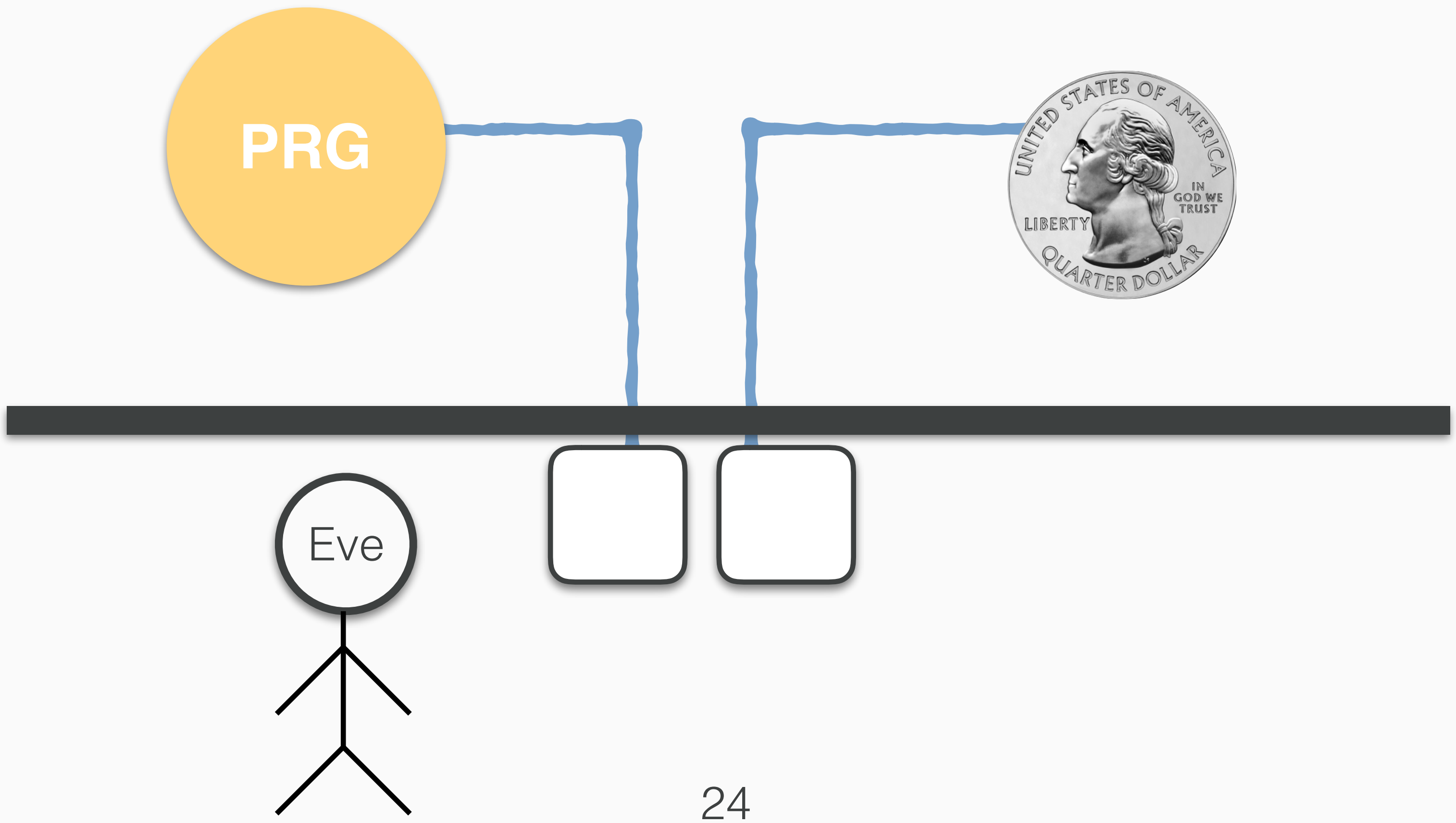


OWFs as Pseudorandom Generators

- Intuition: If it's easy for you to figure out why something happened, then it's not really random.
- One Way Function: It's hard to figure out the input, given the output.

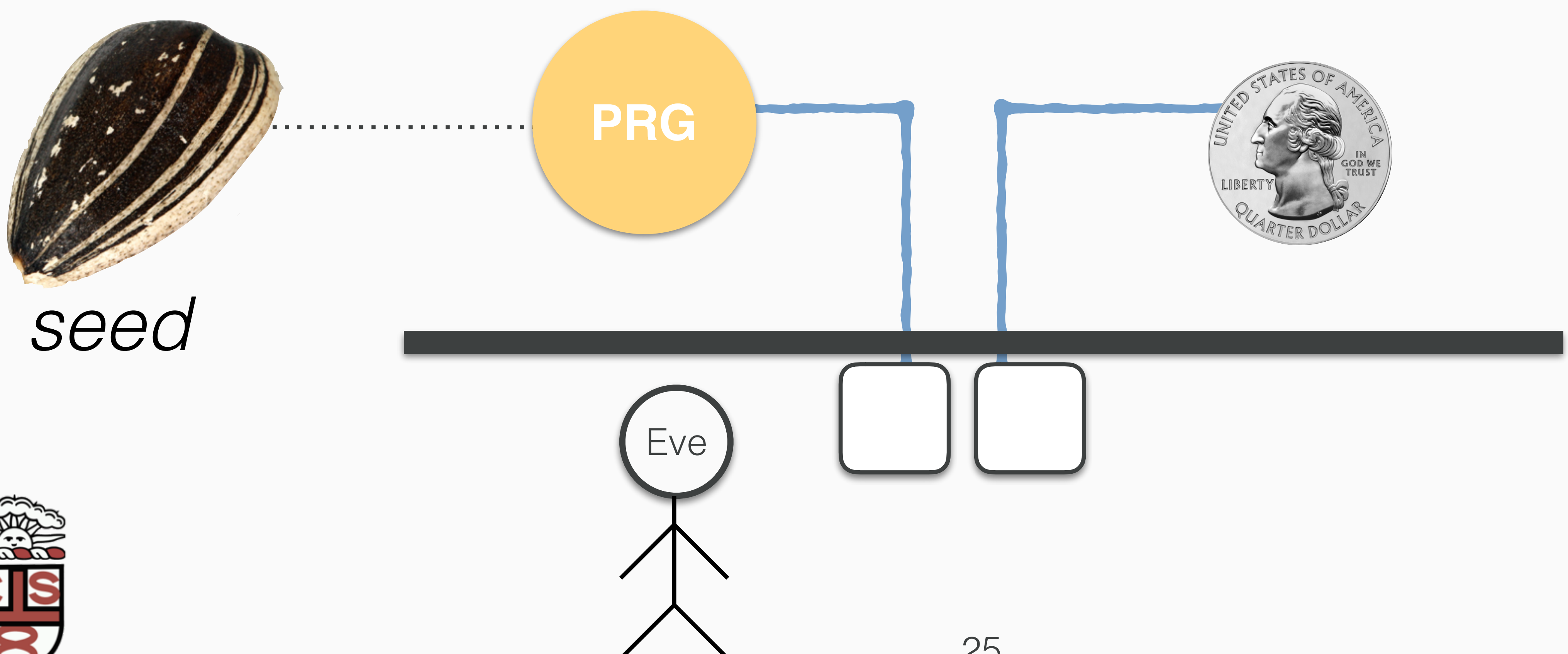
Why Did I Cheat Before?

- An object that generates pseudorandom numbers is called a PseudoRandom Generator, or PRG



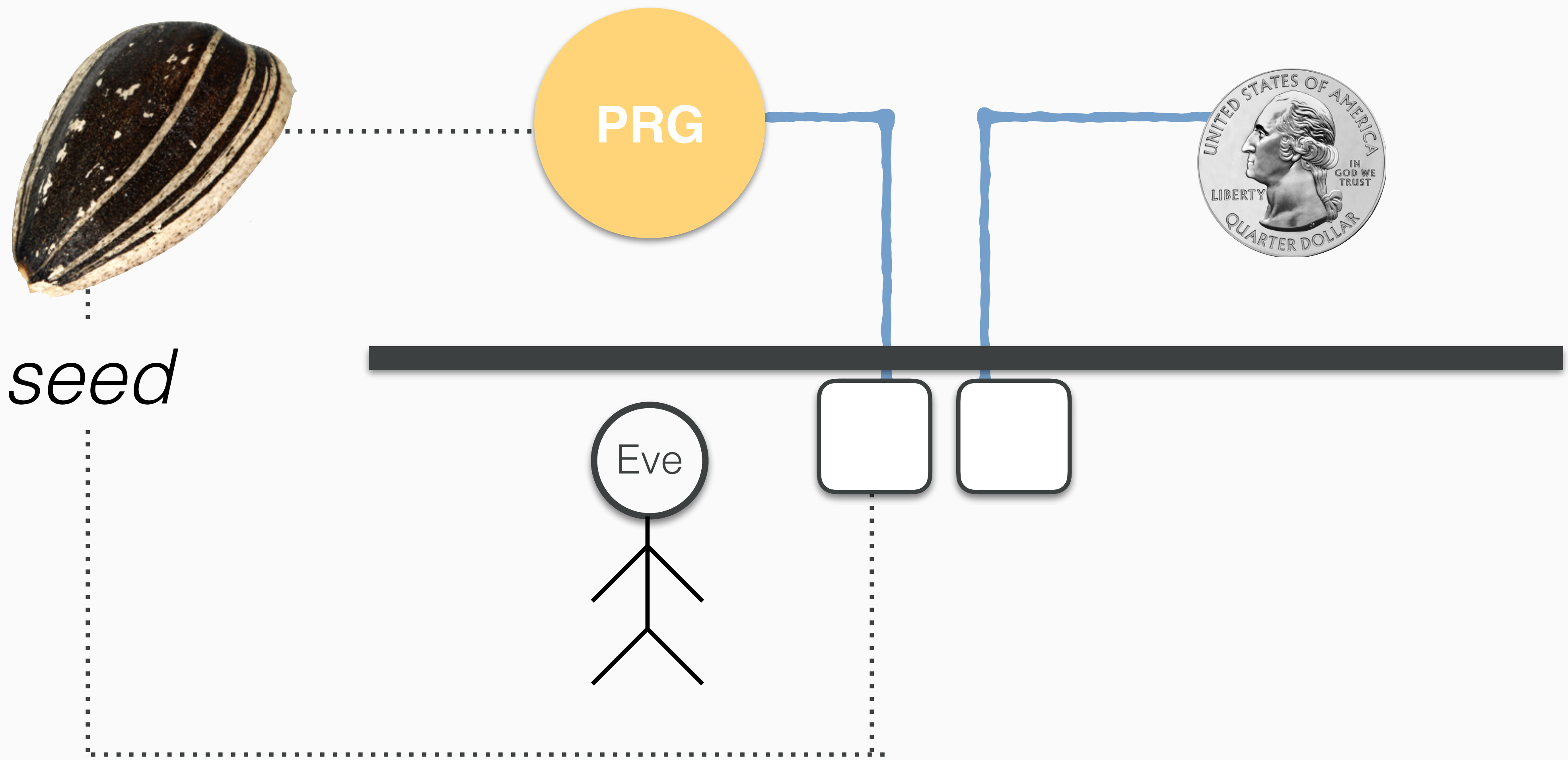
Why Did I Cheat Before?

- An object that generates pseudorandom numbers is called a PseudoRandom Generator, or PRG
- PRGs require what is called a “seed”, which is effectively the input to the OWF.



Why Did I Cheat Before?

- Once we use this seed once, we can reset the seed by combining the output of our PRG with the old seed:



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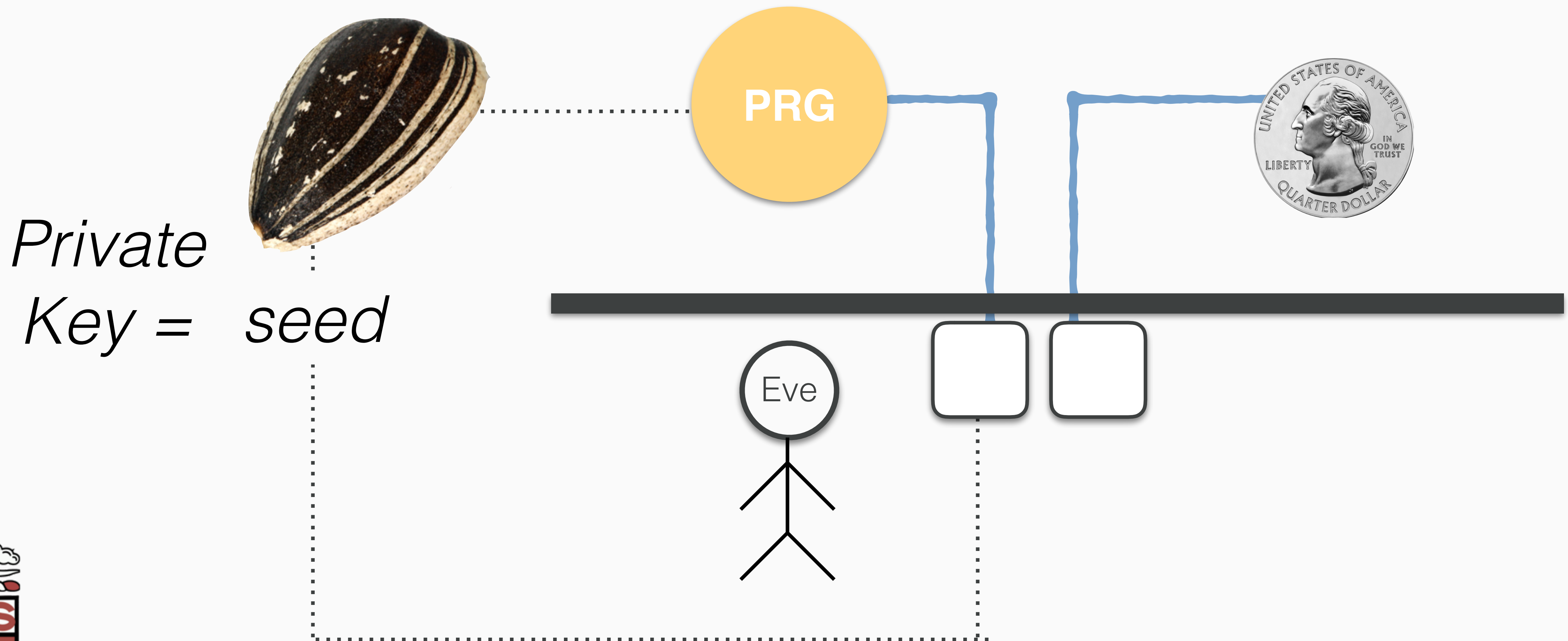


OWFs as Pseudorandom Generators

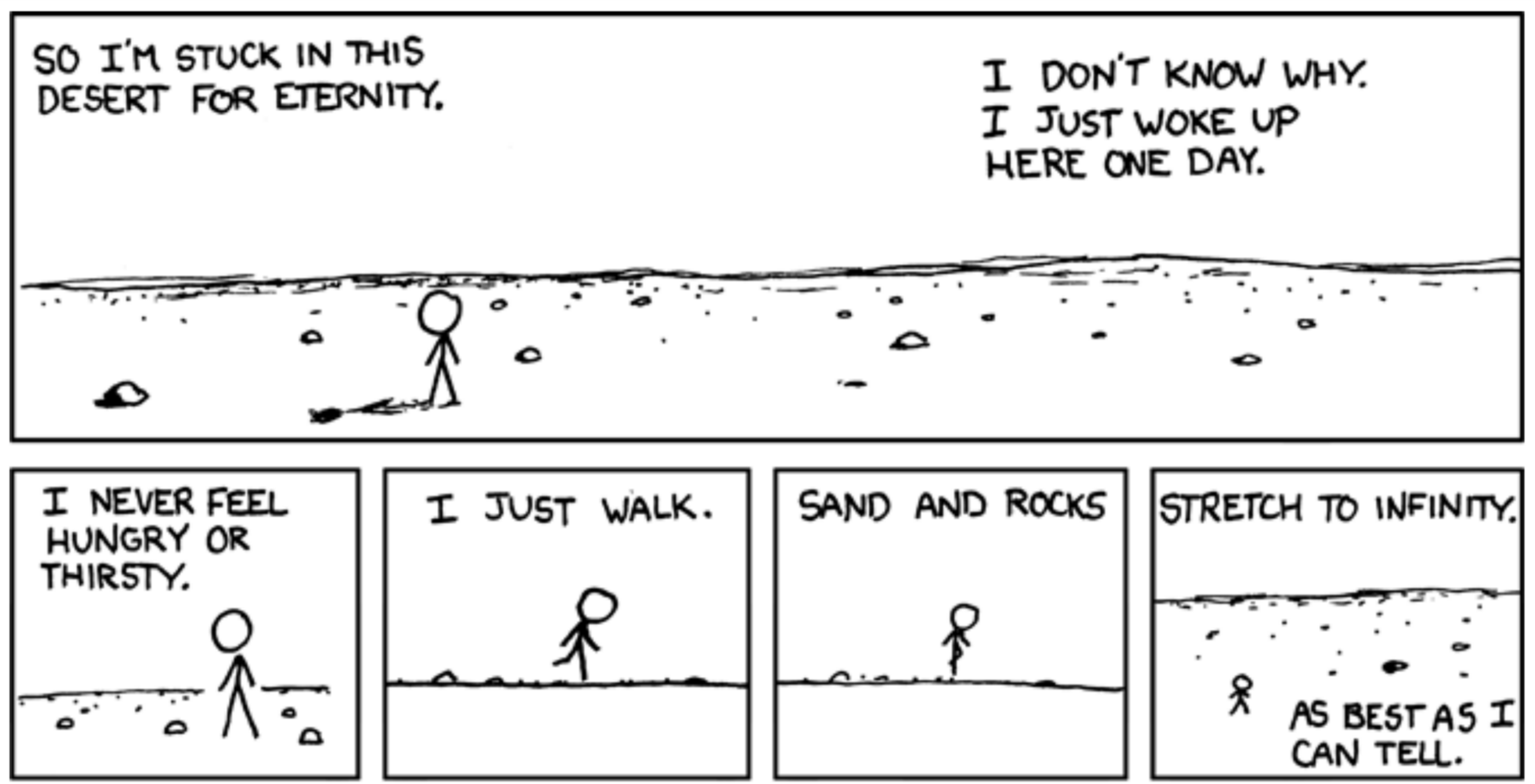
- Intuition: If it's easy for you to figure out why something happened, then it's not really random.
- One Way Function: It's hard to figure out the input, given the output.
- Conclusion: we can extend One Way Functions to create Pseudo Random Number Generators (and not cheat)!

Computation meets Biology

- Computation and:

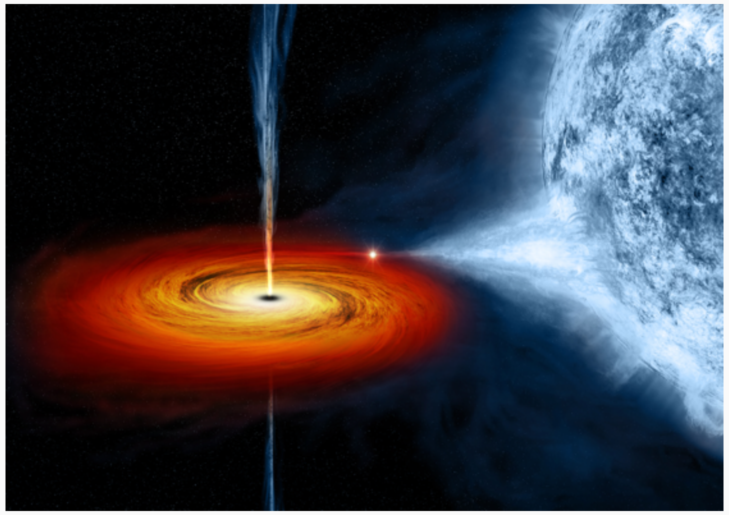
  1. Medicine
  2. Genetics
  3. Sustainability
  4. Neuroscience
  5. Evolution

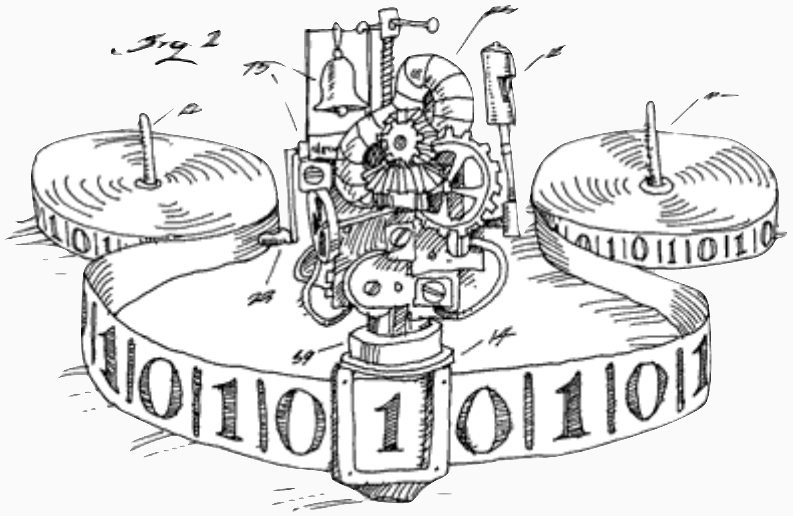
Digital Physics



Computation as a Tool for Understanding Reality

- Newton: use math to model the laws of the world.
- Turing: “the extent and limitations of mechanistic explanations of nature”





http://www.worldofcomputing.net/wp-content/uploads/2013/01/turingMachine.gif

1. Computation + Medicine

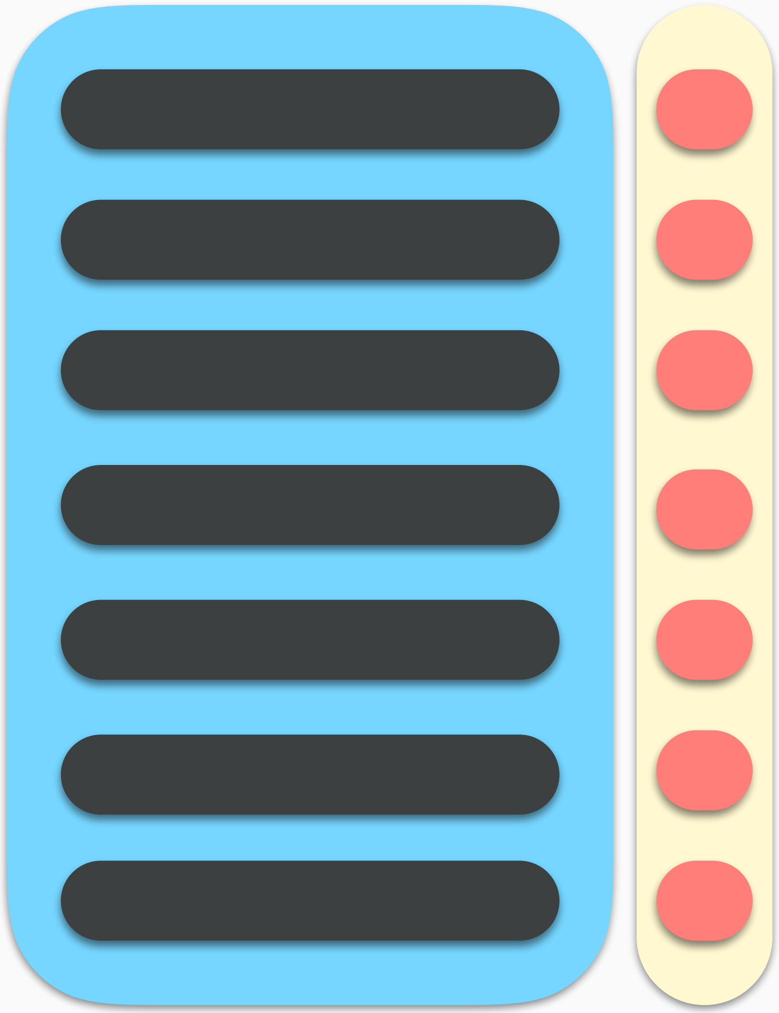
Medical Diagnosis

- INPUT: A patient’s symptoms
- OUTPUT: A medical diagnosis

Medical Diagnosis

+ a Database!

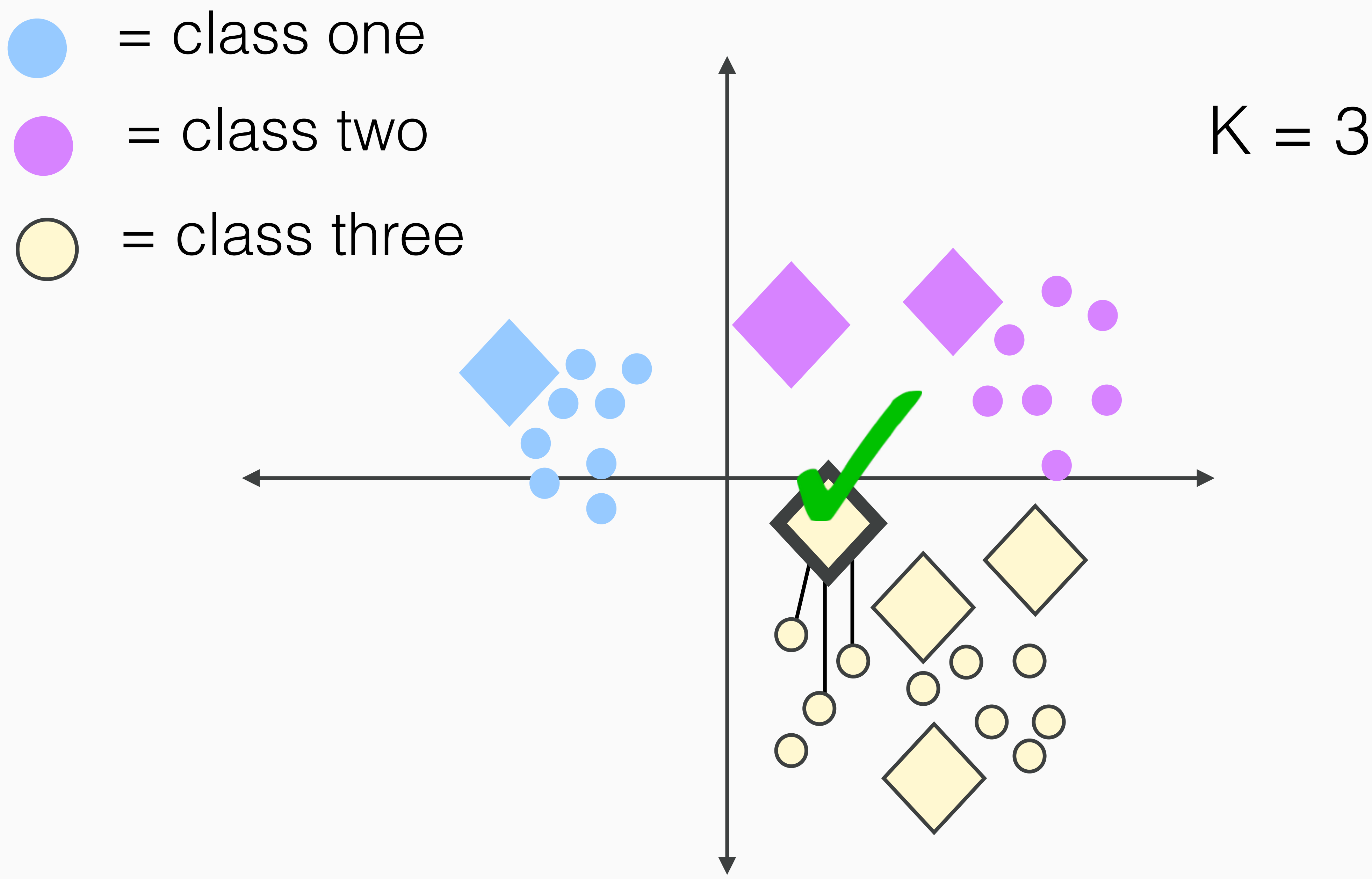
- INPUT: A patient’s symptoms
- OUTPUT: A medical diagnosis



= symptoms

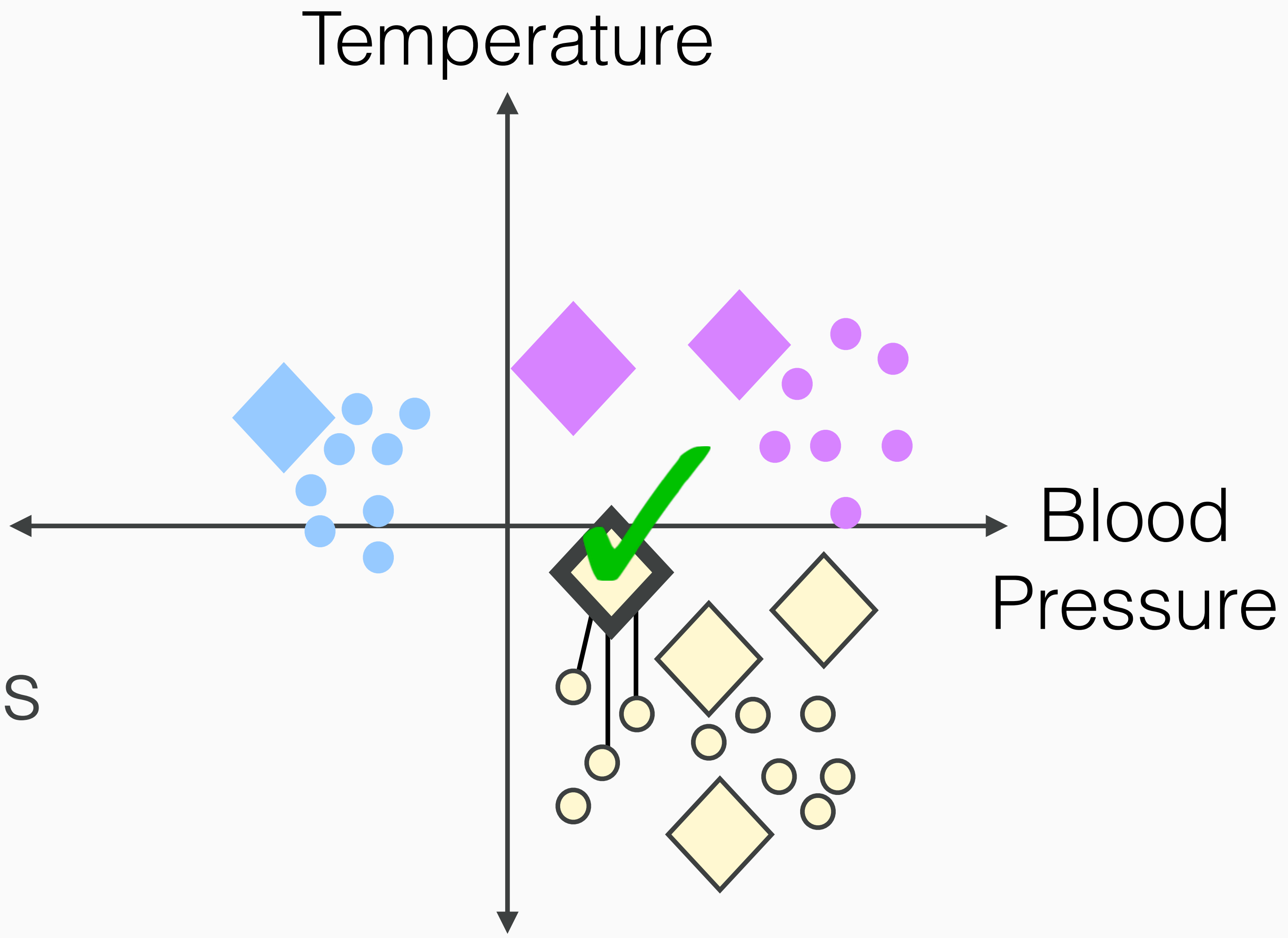
= diagnosis

K Nearest Neighbor



K Nearest Neighbor

- Labels are now diagnoses
- Training Data are symptoms
- Medical Diagnosis as ML!



IBM's Watson

Kidney Donors

- Suppose a friend needs a kidney, and you want to donate yours to help your friend.
- Kidneys have a "type", similar to blood; your friend needs a kidney of the right type.
- So instead you donate your kidney to a donor community; you give a kidney of any type, and get a kidney back for you friend of the right type.

Kidney Donors

- But once people get their kidney, they'll often back out of the donation!
- So instead, surgeons have started doing simultaneous kidney transplant surgeries, all at once, between circles of people.

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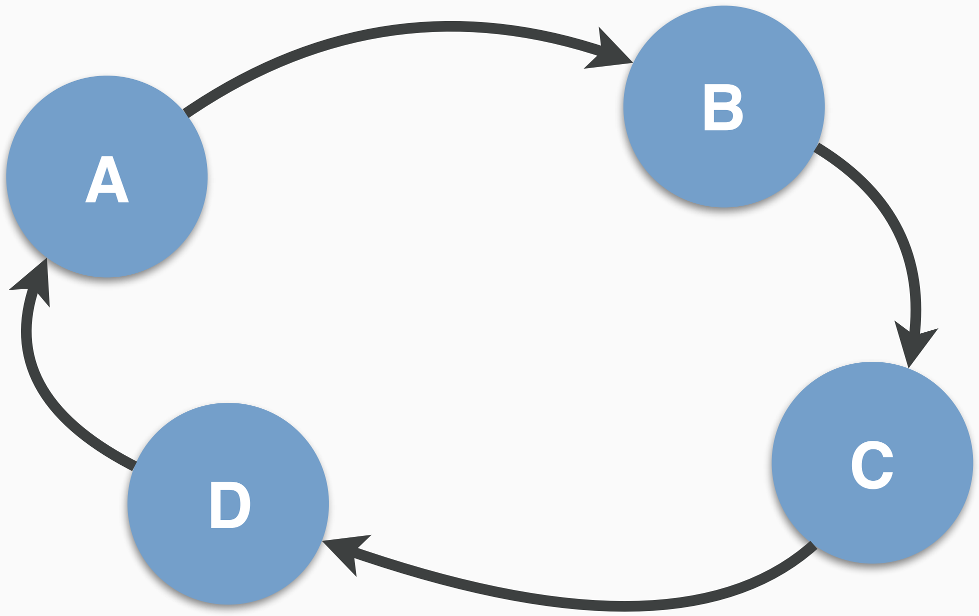
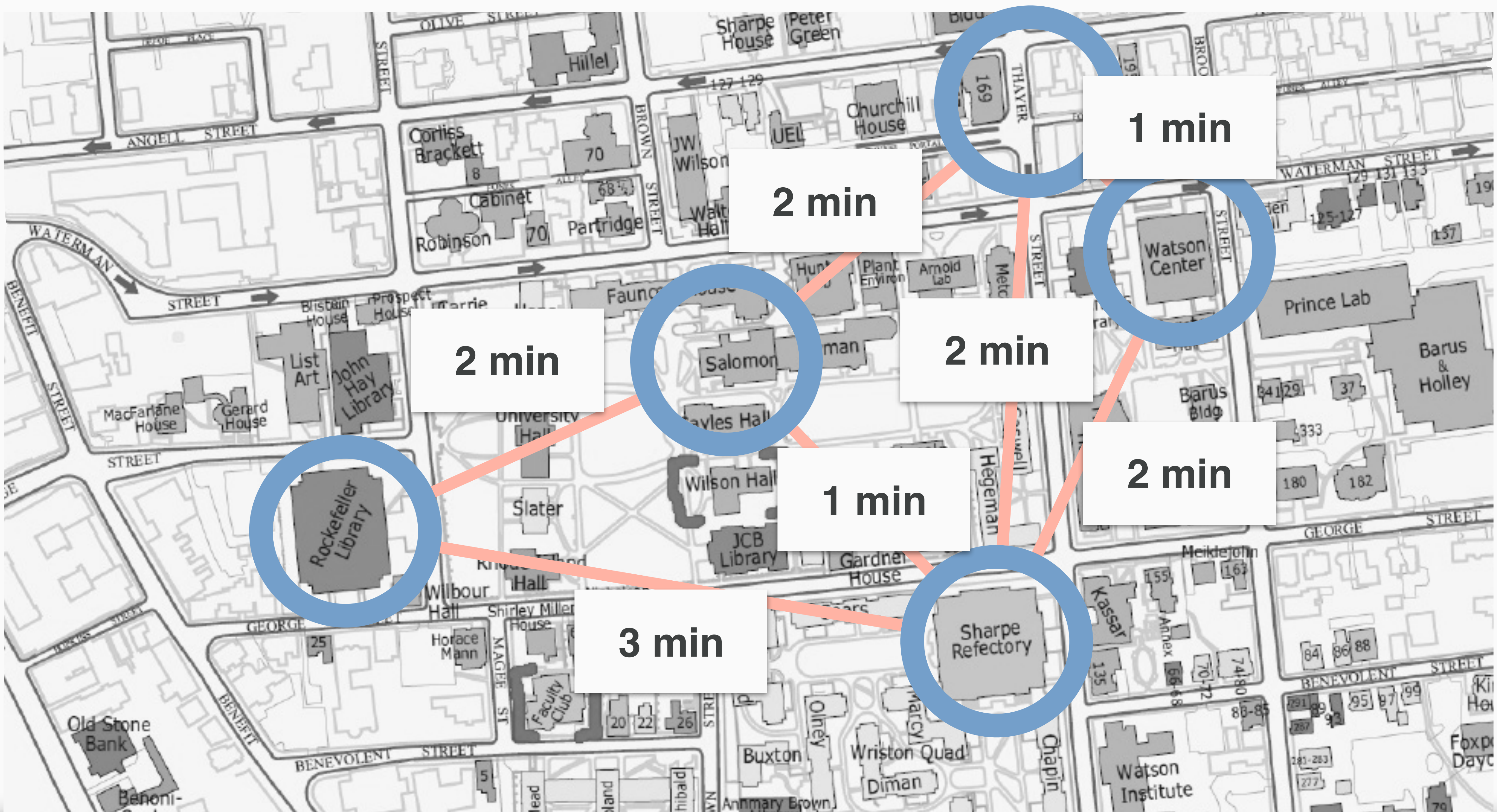
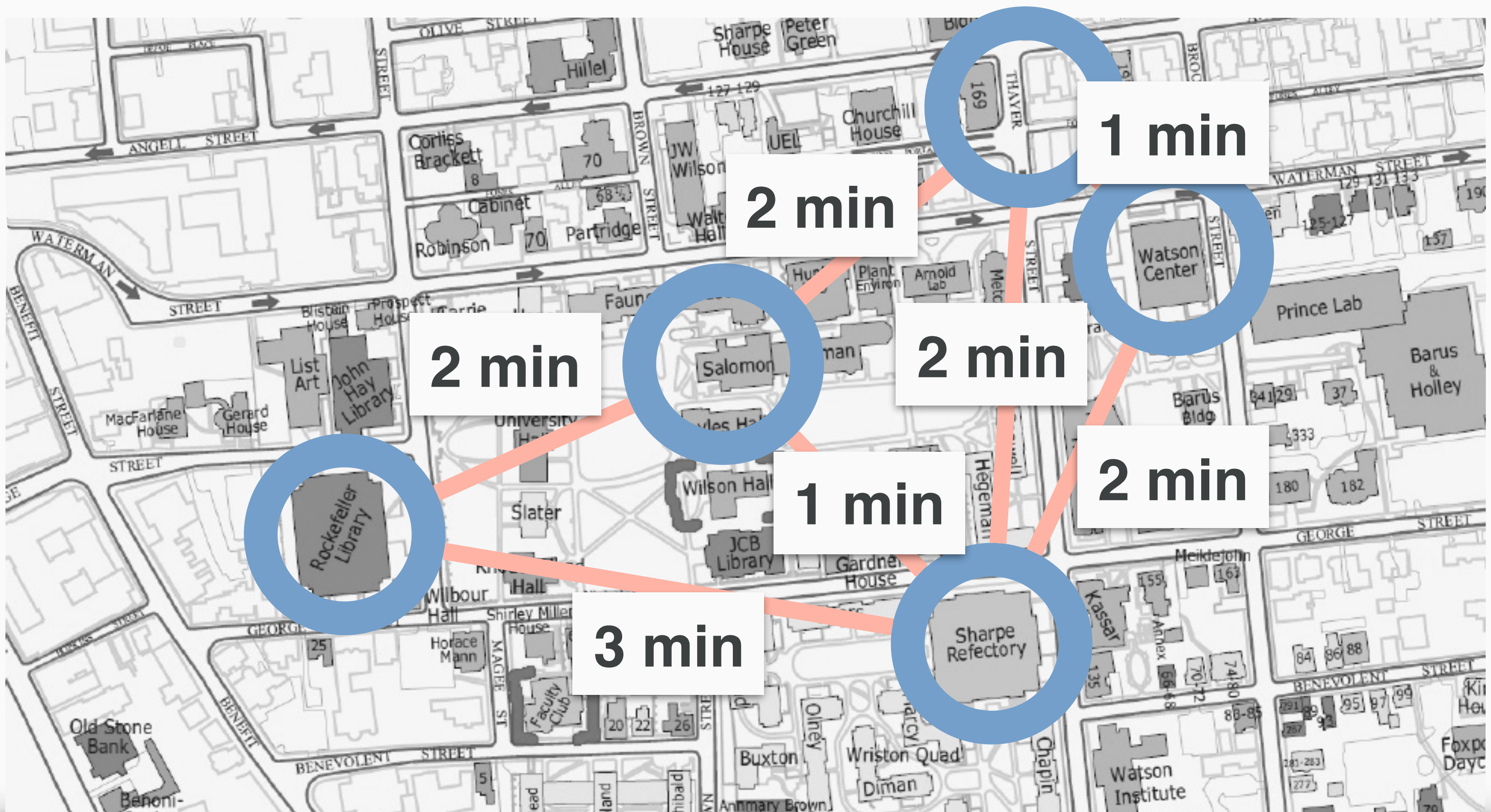


Remember Circles + Lines?



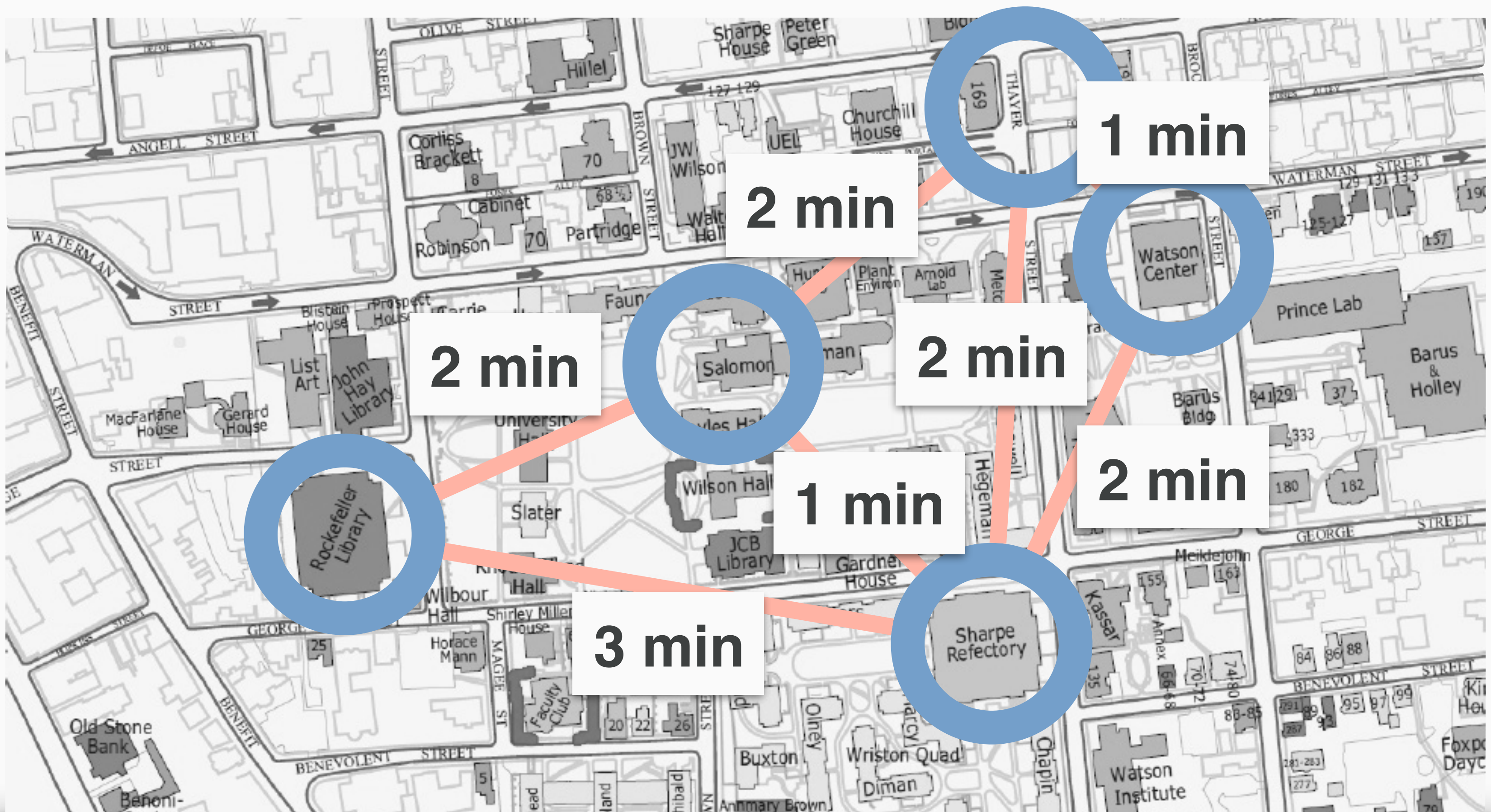
Circles + Lines!



Circle: an object (a location in this case)

Line: a relation between objects (tram, in this case)

Called a “Graph”



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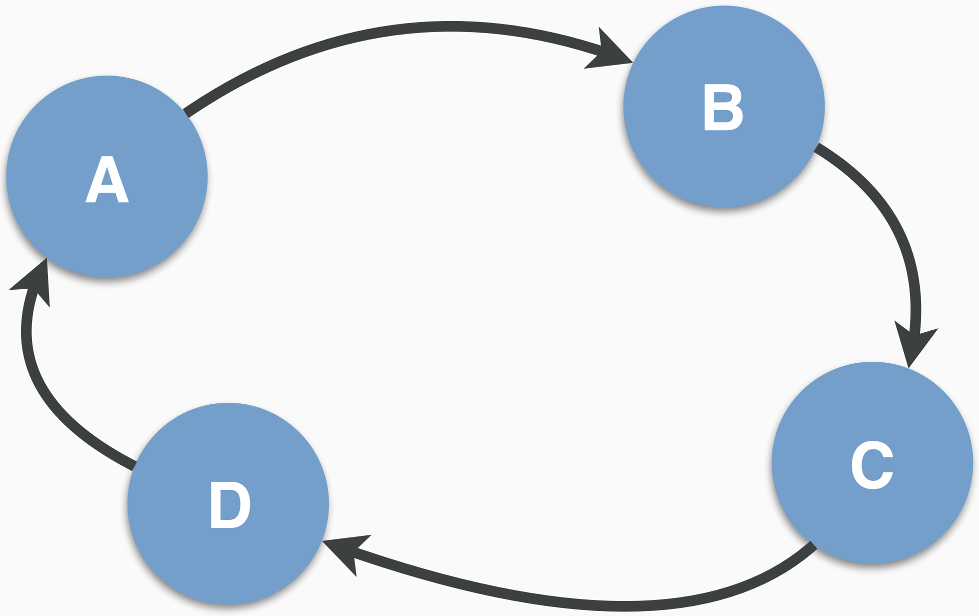
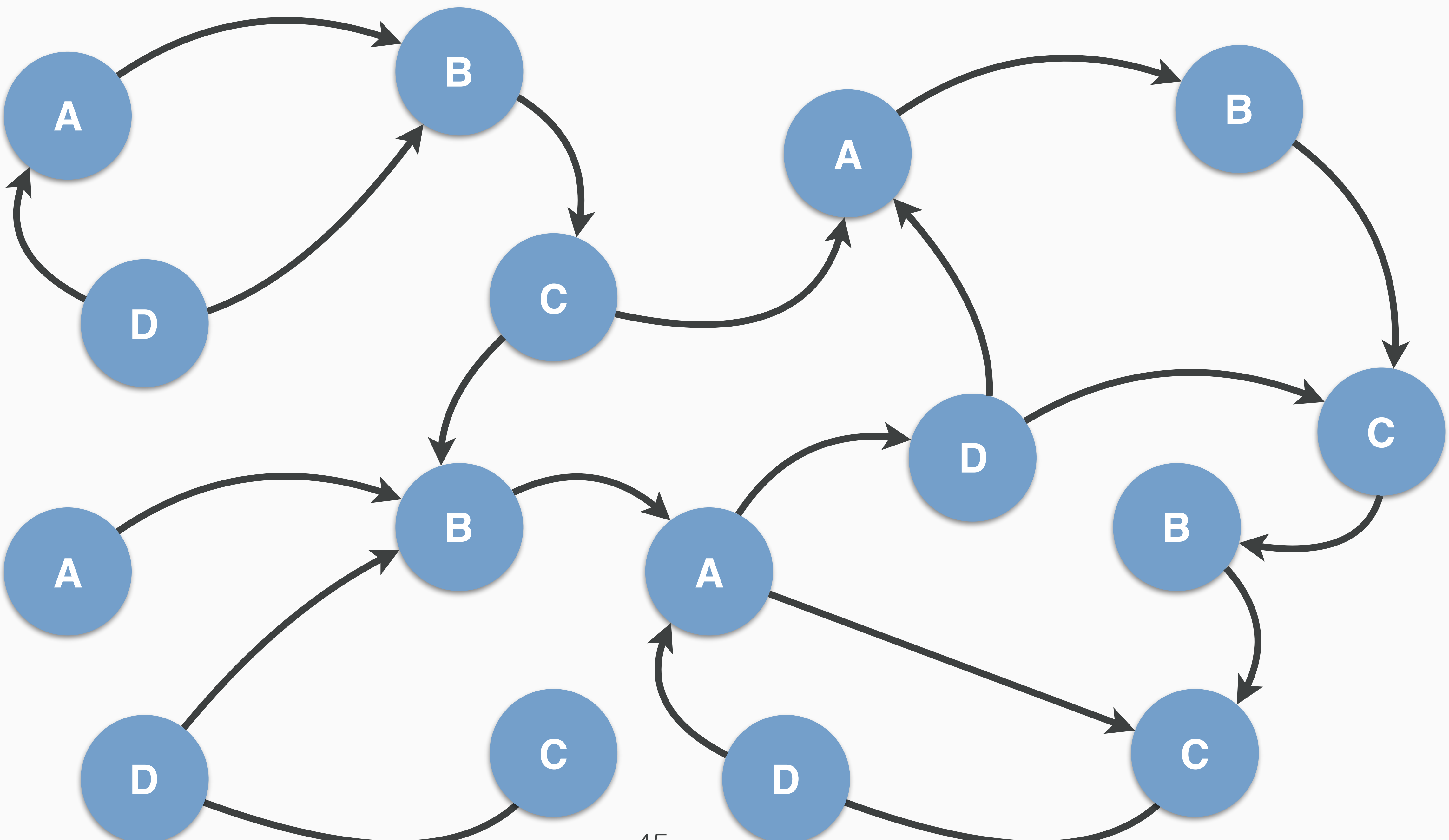
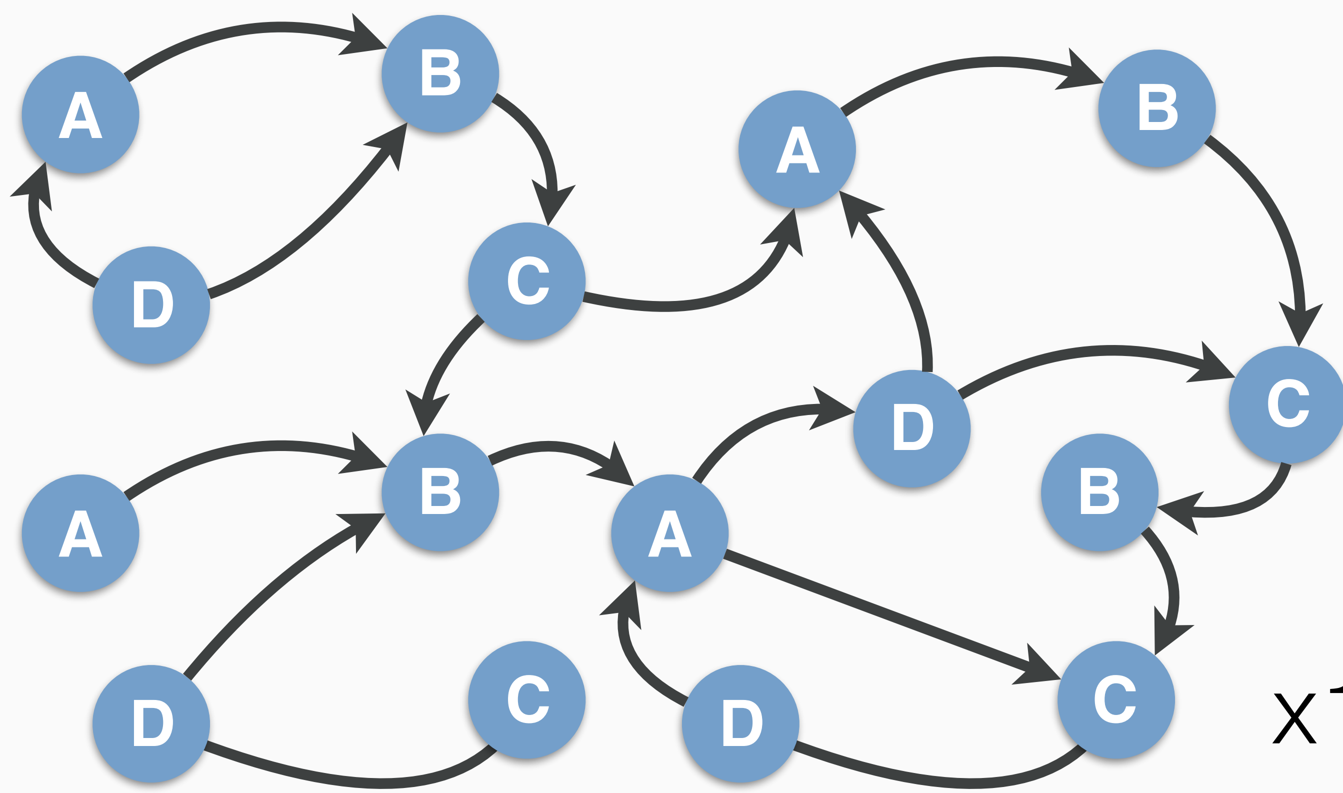


Find the Cycles!



Find the Cycles!

INPUT:

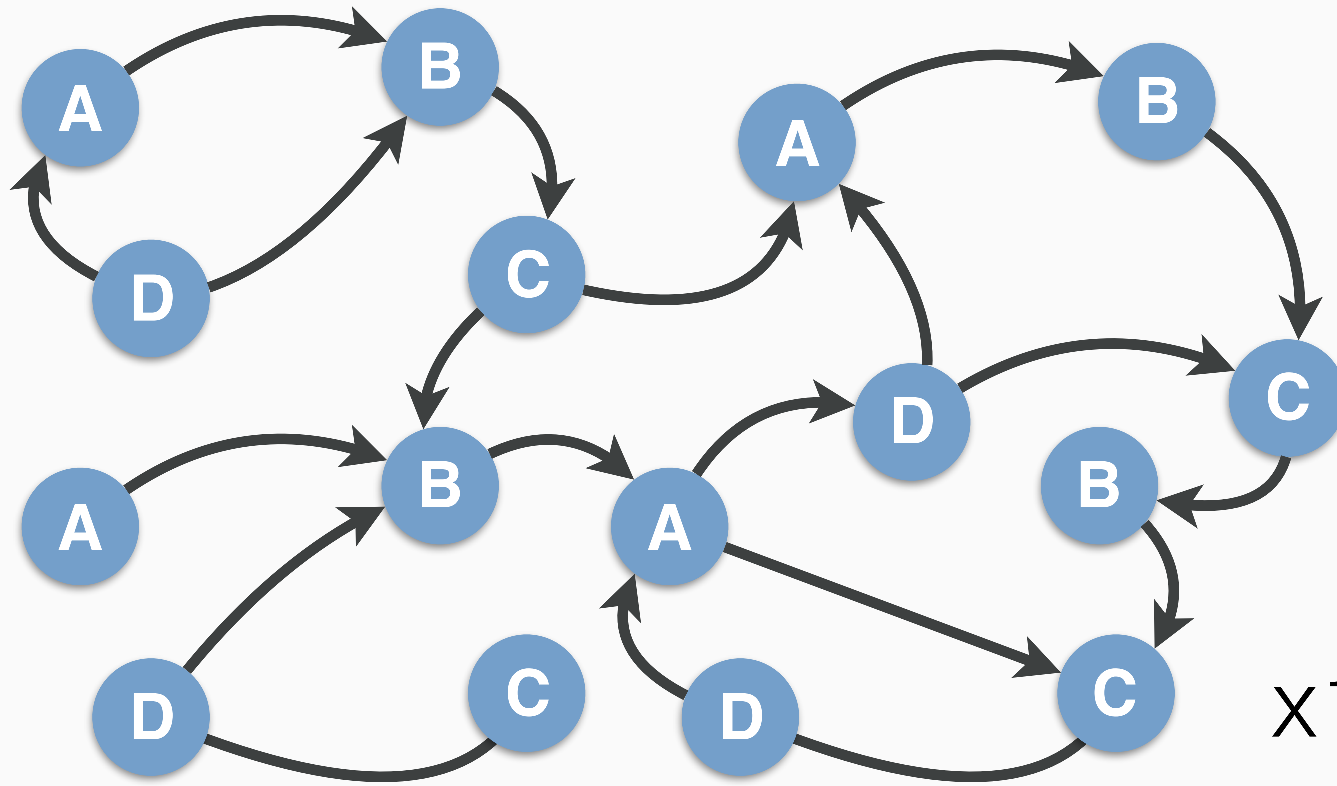


(with about x100000 more circles)

OUTPUT: A list of cycles

Find the Cycles!

INPUT:



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OUTPUT: A list of cycles

Computational Solutions!

Medical Imaging

Medical Imaging

Understanding Brain Region Functionality

[Ng, Milazzo, Atmman, 2015]

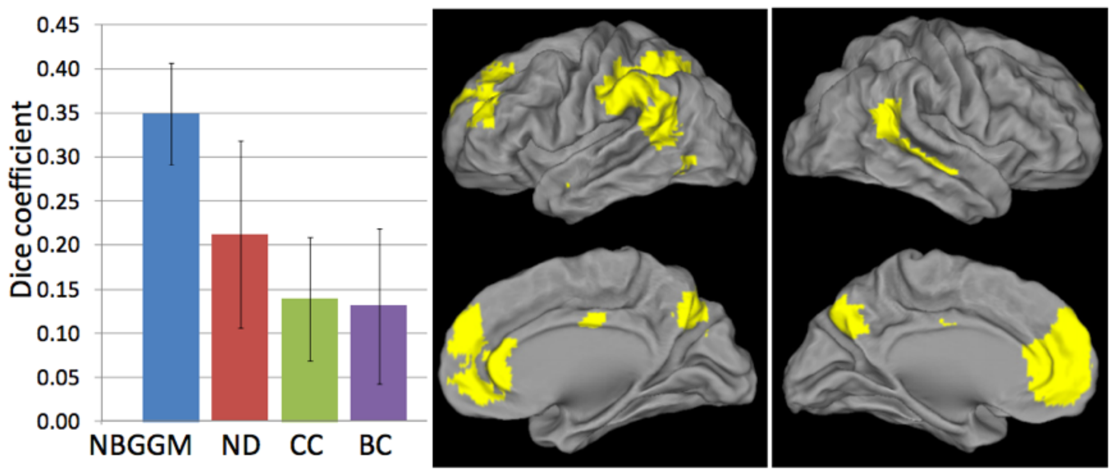
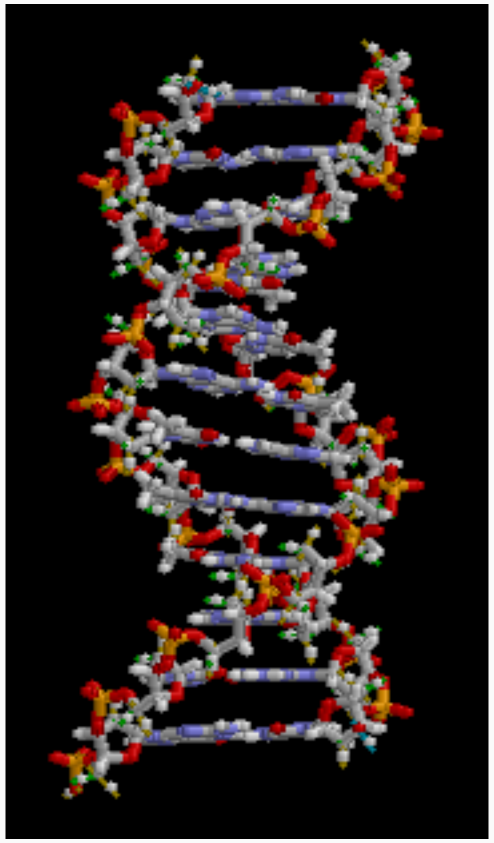


Fig. 3. AD vs HC. NBGGM provided significantly higher consistency in the identified brain regions than the contrasted methods. Regions found by NBGGM shown in yellow.

2. Genome Sequencing

- DNA: molecule for carrying genetic information
- Four “bit” values: A, G, T, C



Genome Sequencing

- Goal: understand what is going on in the DNA.
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AGAGATTAGCTAGCAATCGCGGGATAGCGCTAGCTAGCACGAGGGAGTTCCTAGAC

Genome Sequencing

- The tool we have for reading DNA gives us snippets:

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Genome Sequencing

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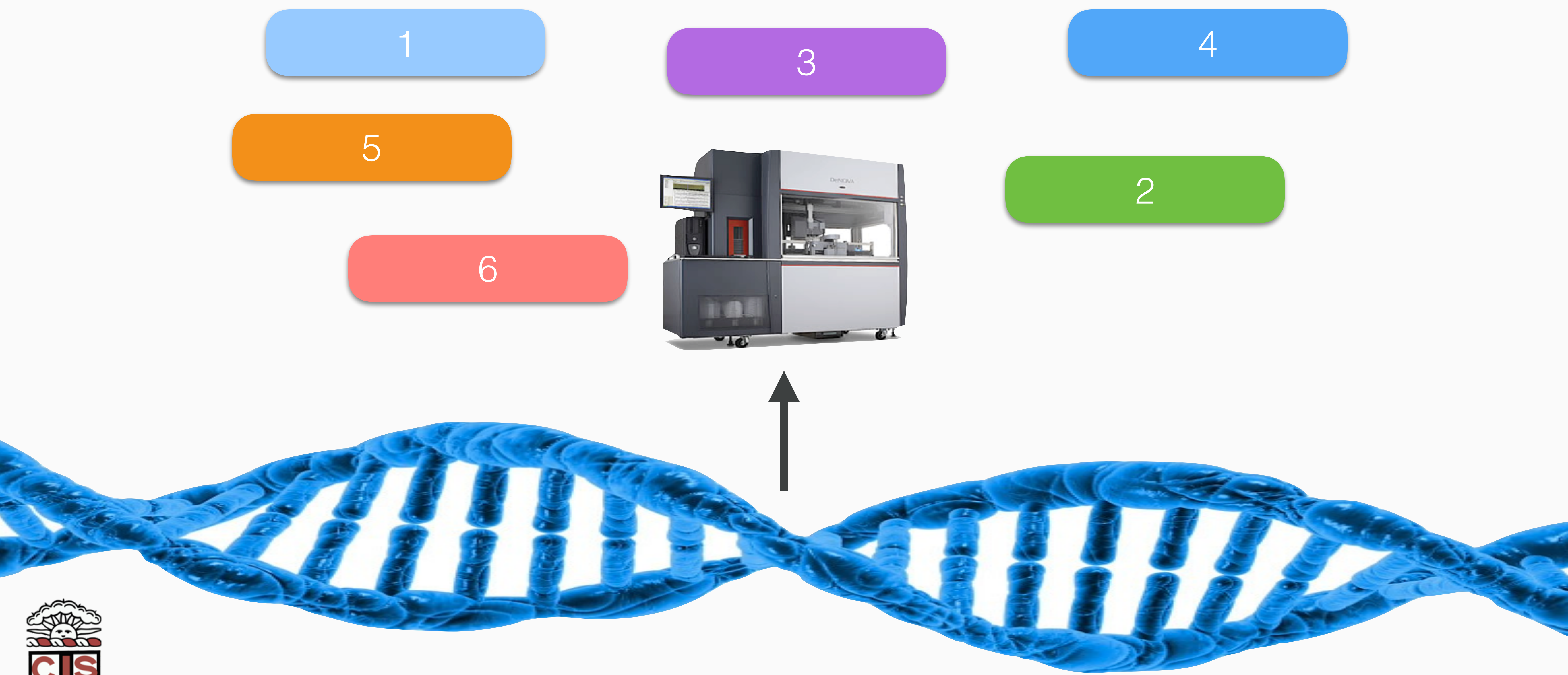


Genome Sequencing

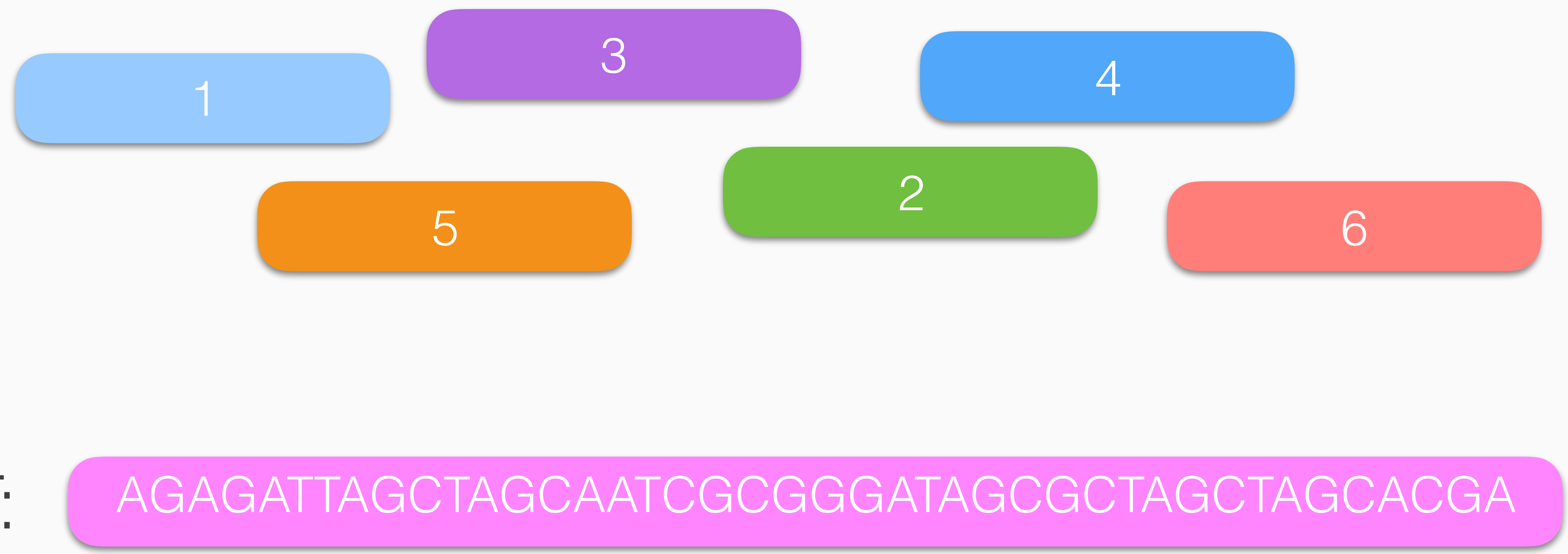
- Problem: Recreate DNA from snippets

Genome Sequencing

- Problem: Recreate DNA from snippets

INPUT:

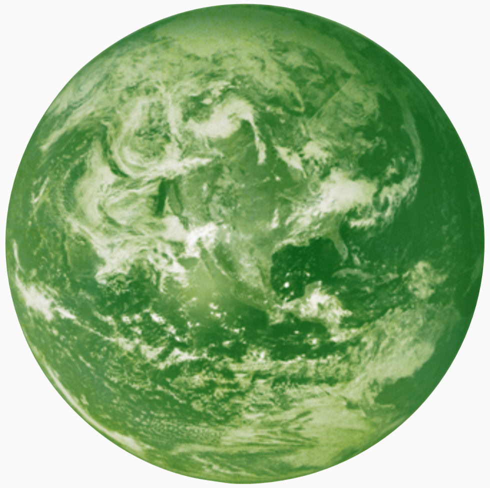
OUTPUT:



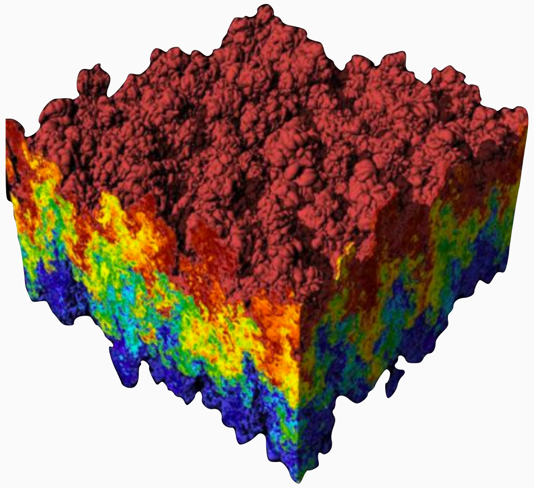
Computational Solutions!

Computation & Genome Sequencing

- Used for better understanding cancer mutations, cancer growth, occurrences of cancer, treatment.
- Used for computational evolutionary biology; evaluate disorders, changes of a species over time.
- And more!



3. Computation and Environmental Science



RL + Sustainability

- Reinforcement Learning:
  - Learn through reward/punishment
  - Learn a model of the world
  - Maximize long term reward

Renewable Resource Allocation (RRA)

- Resource Allocation: How to distribute a resource to a variety of entities that need/want it?

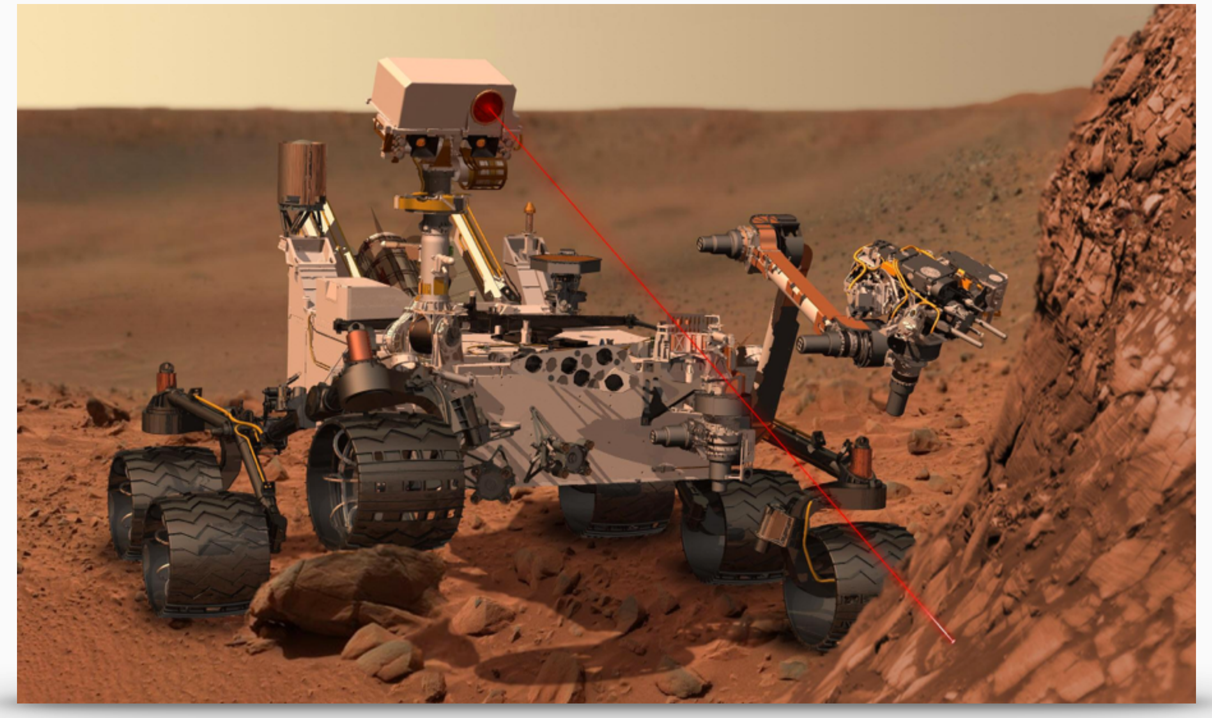
- *Renewable* Resource Allocation: How should our strategy differ when the resource is renewable?

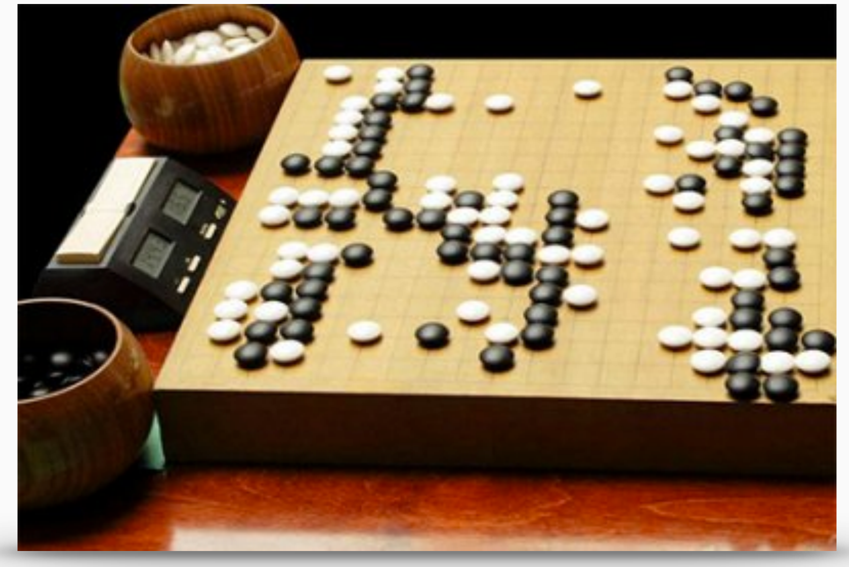
  - We have 10 carrots planted.

  - As of Friday, each carrot that is still planted will create two more carrots.

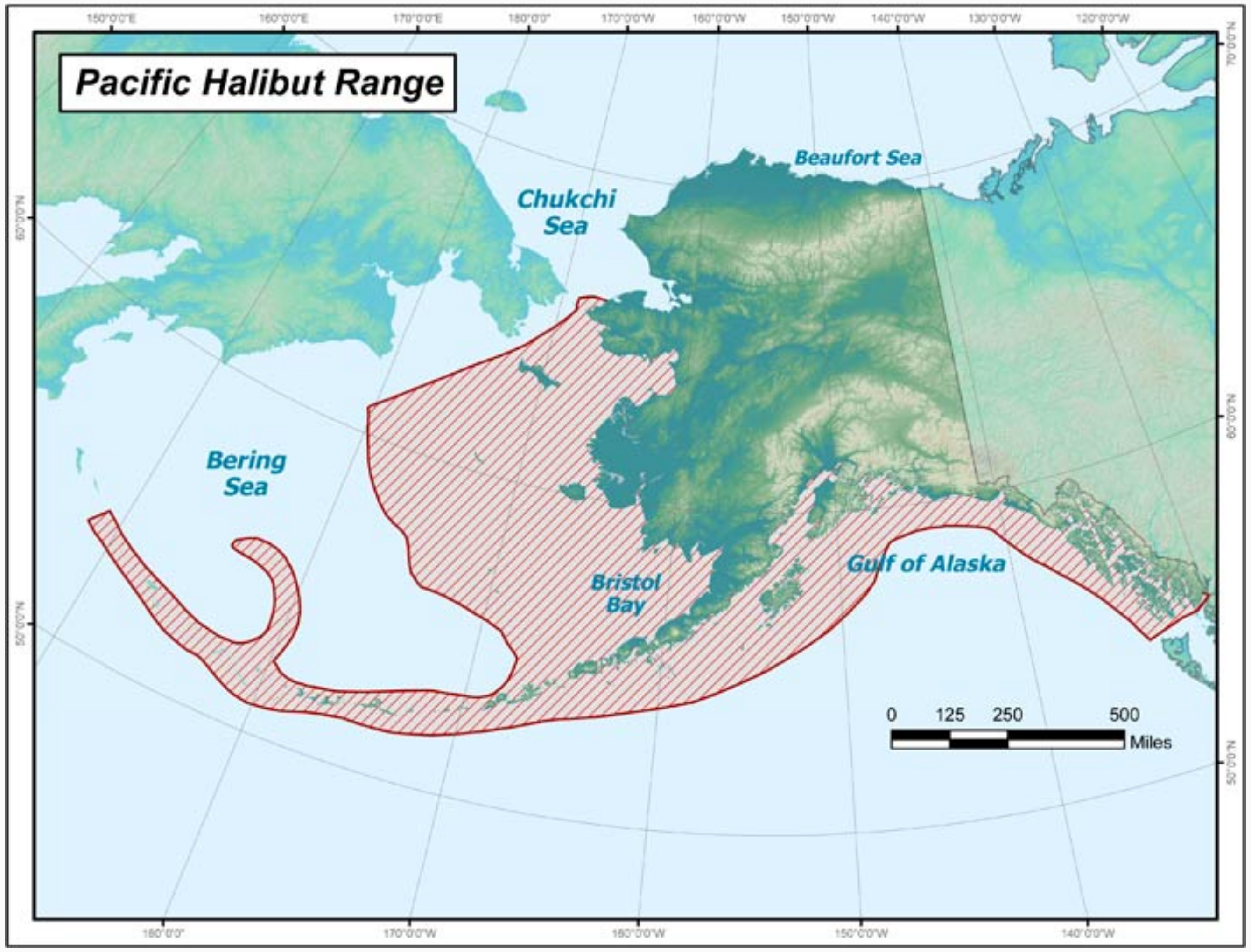
  - 20 people each want a carrot, now.

RL + RRA





The Pacific Halibut



Idea: If RL can solve Mario and Go, it ought to be able to solve other problems in the real world of similar difficulty.

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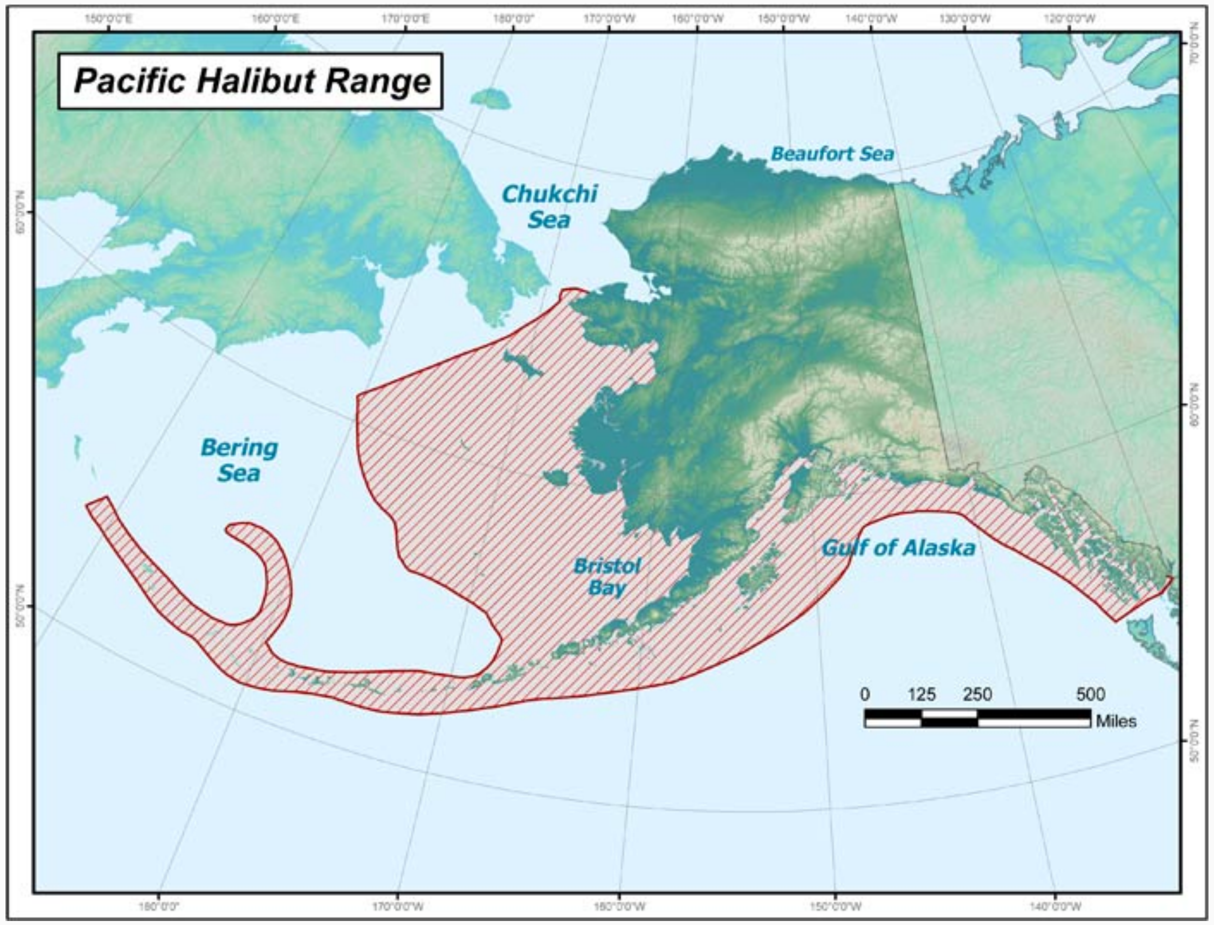

1. Learn a model of fish hatchery behavior

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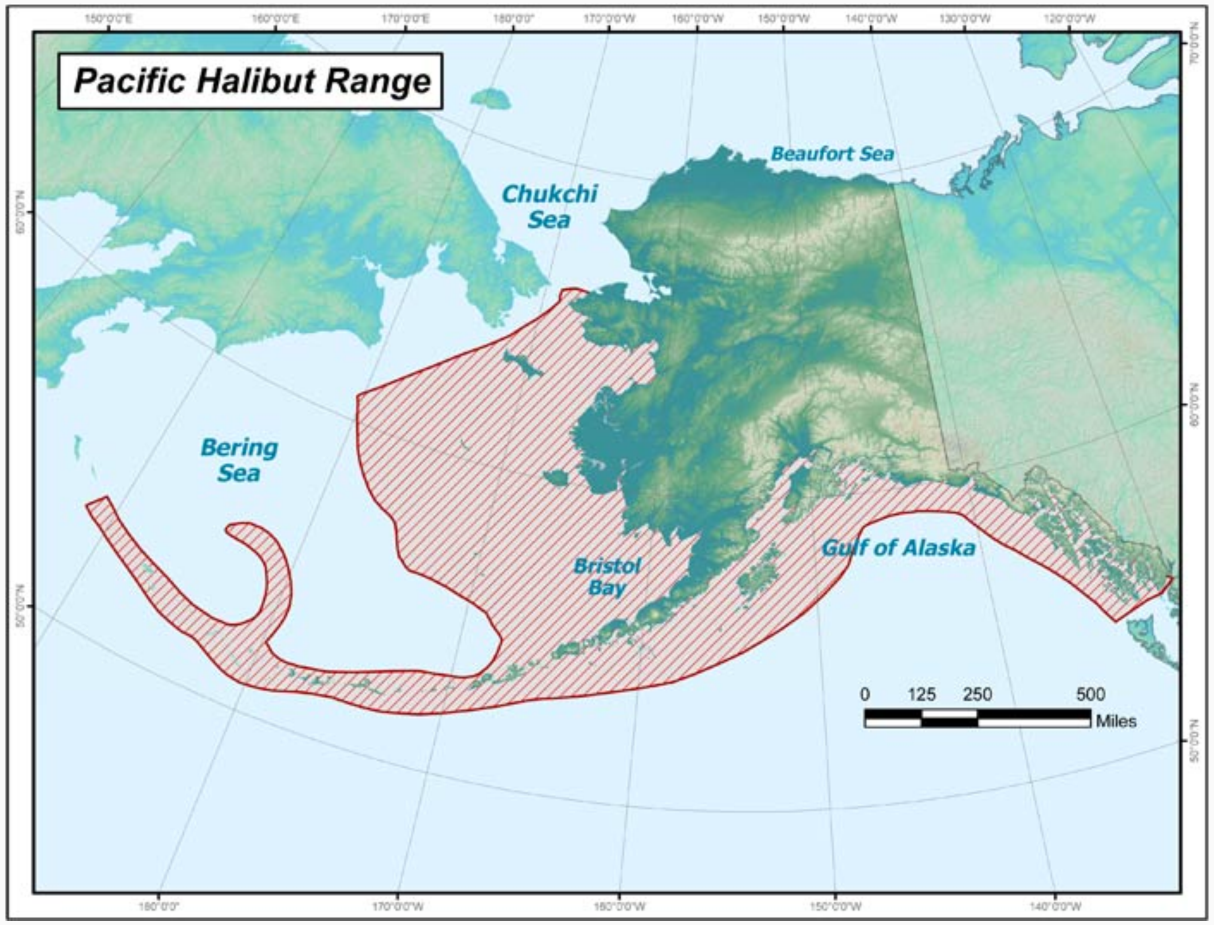

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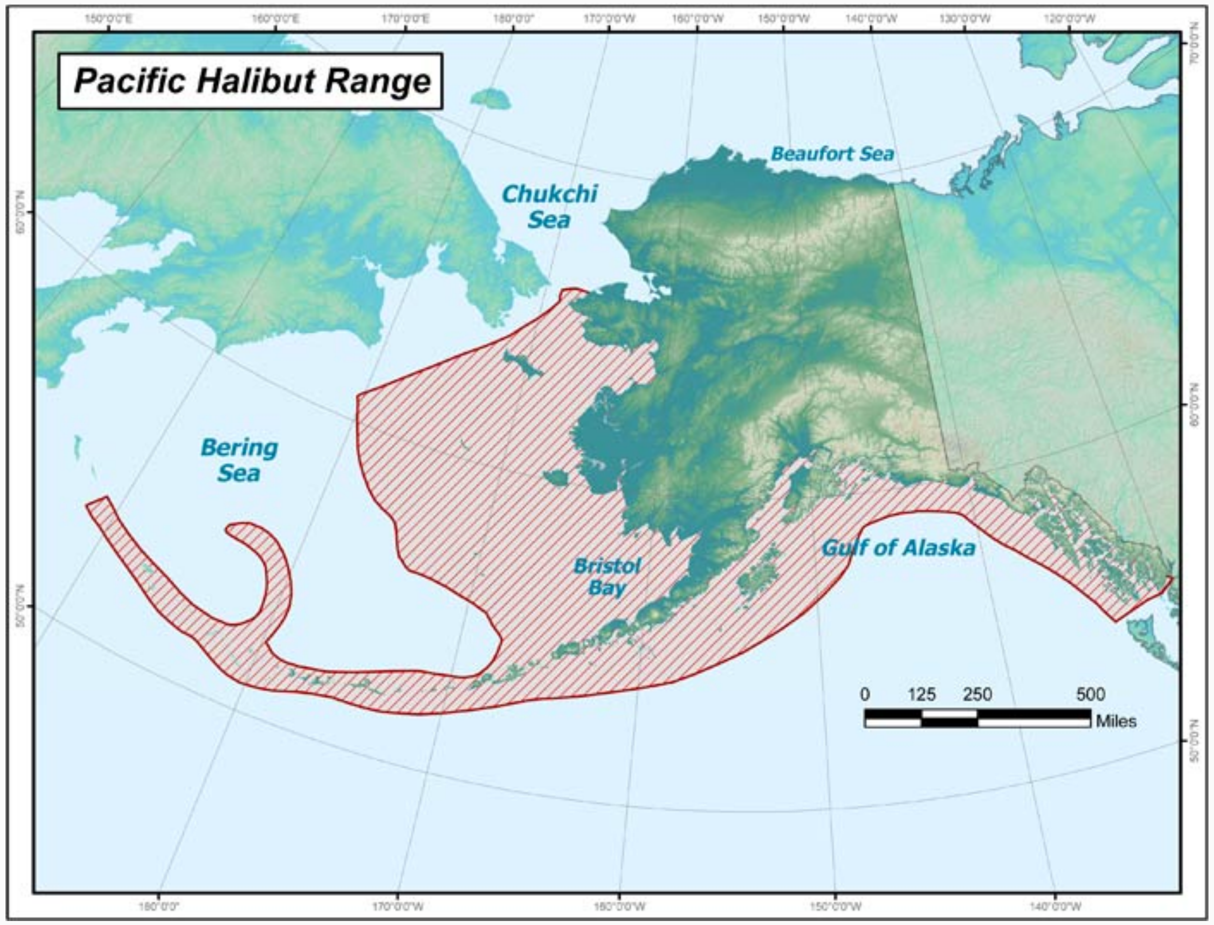

1. Learn a model of fish hatchery behavior
2. Simulate into the future what happens when making certain policy decisions
3. Find the strategy that maximizes reward

Idea: If RL can solve Mario and Go, it ought to be able to solve other problems in the real world of similar difficulty.

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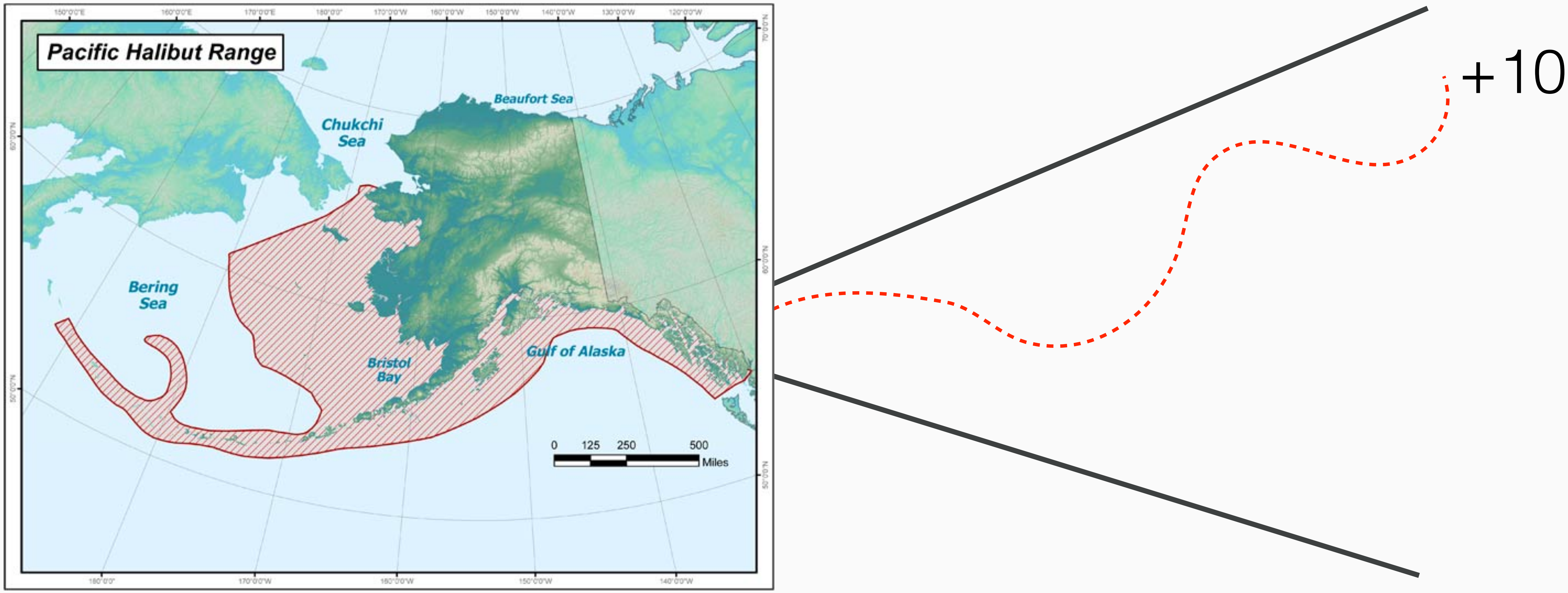

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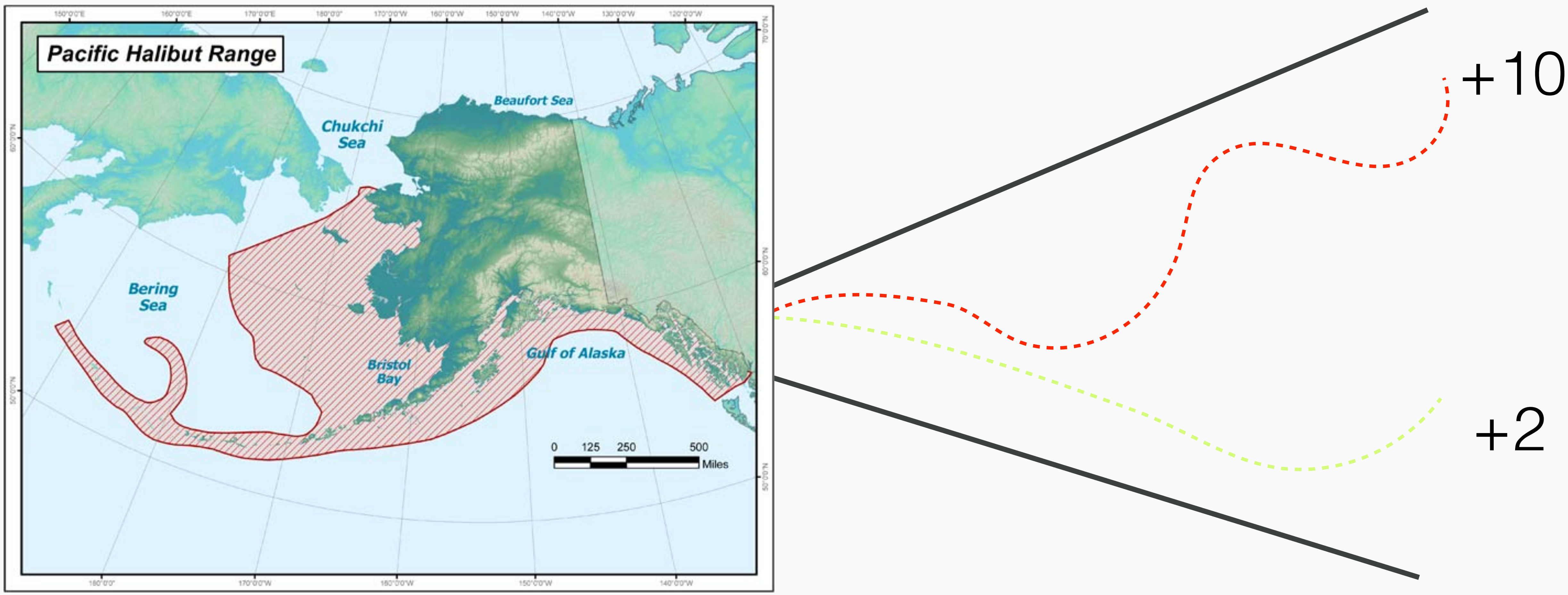

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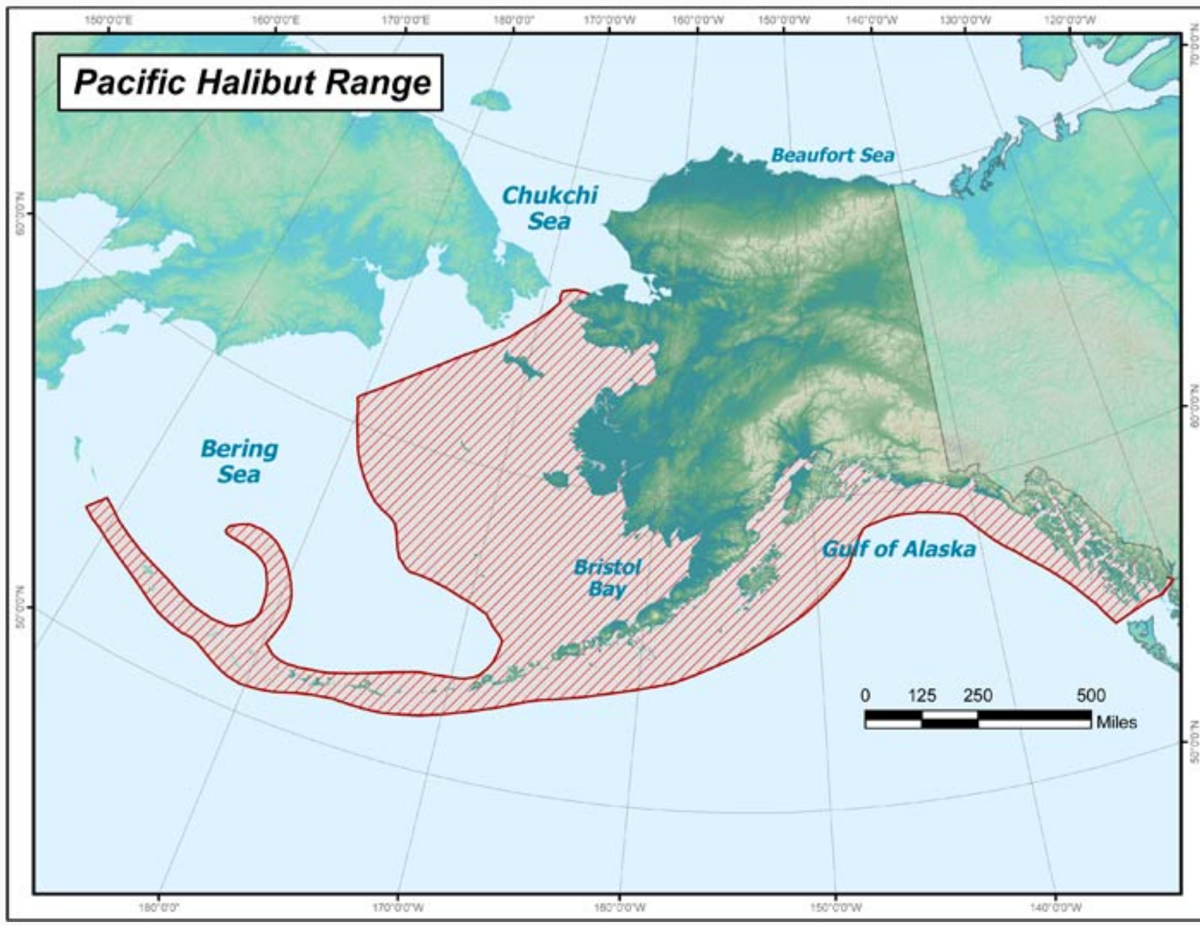

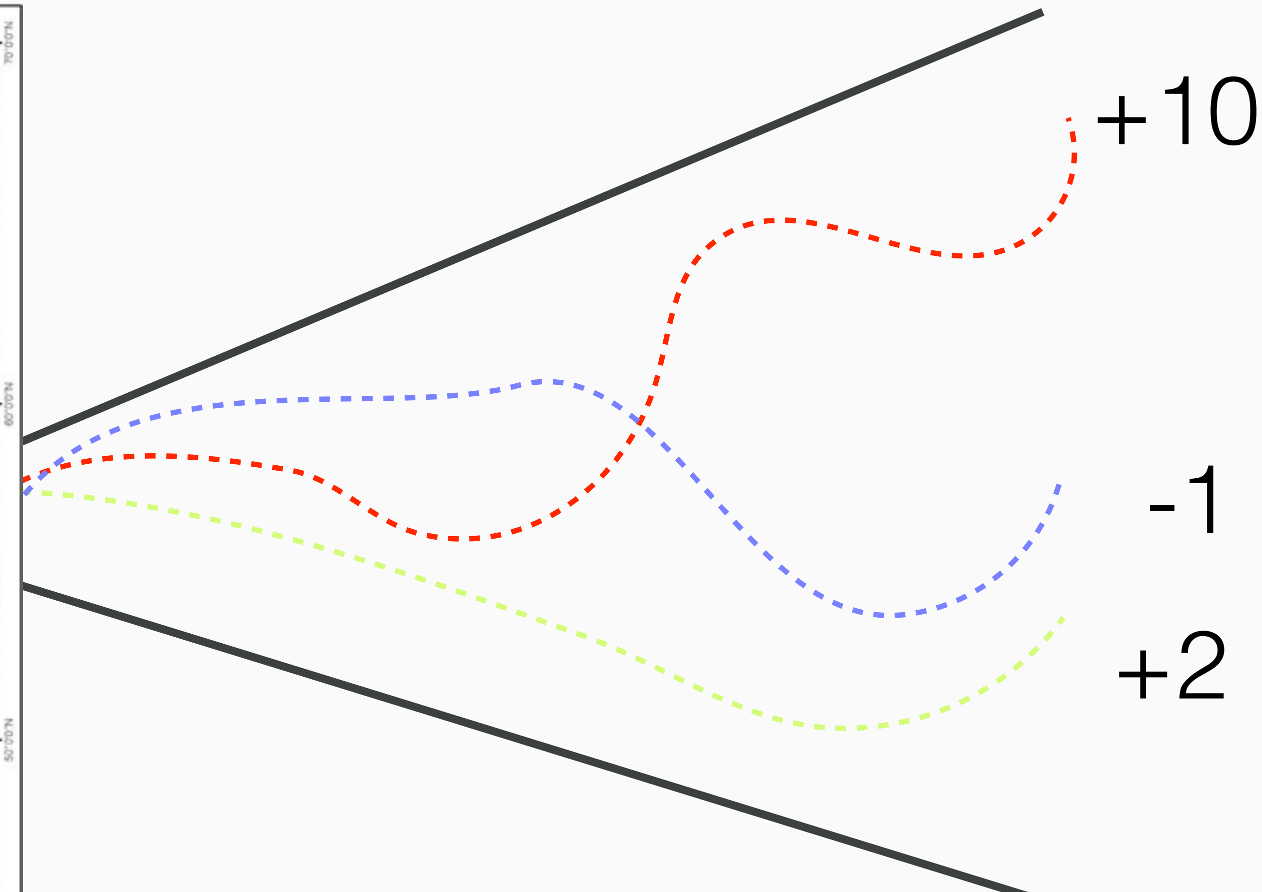

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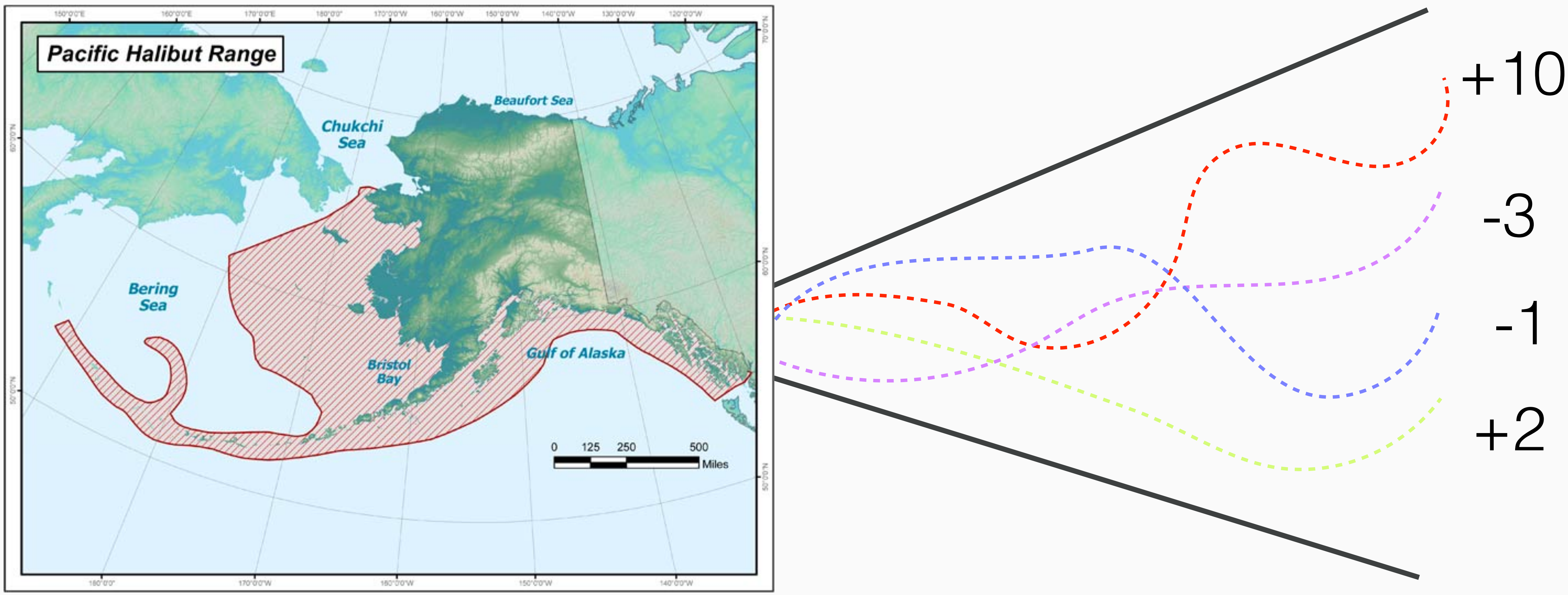

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4. Computational Neuroscience

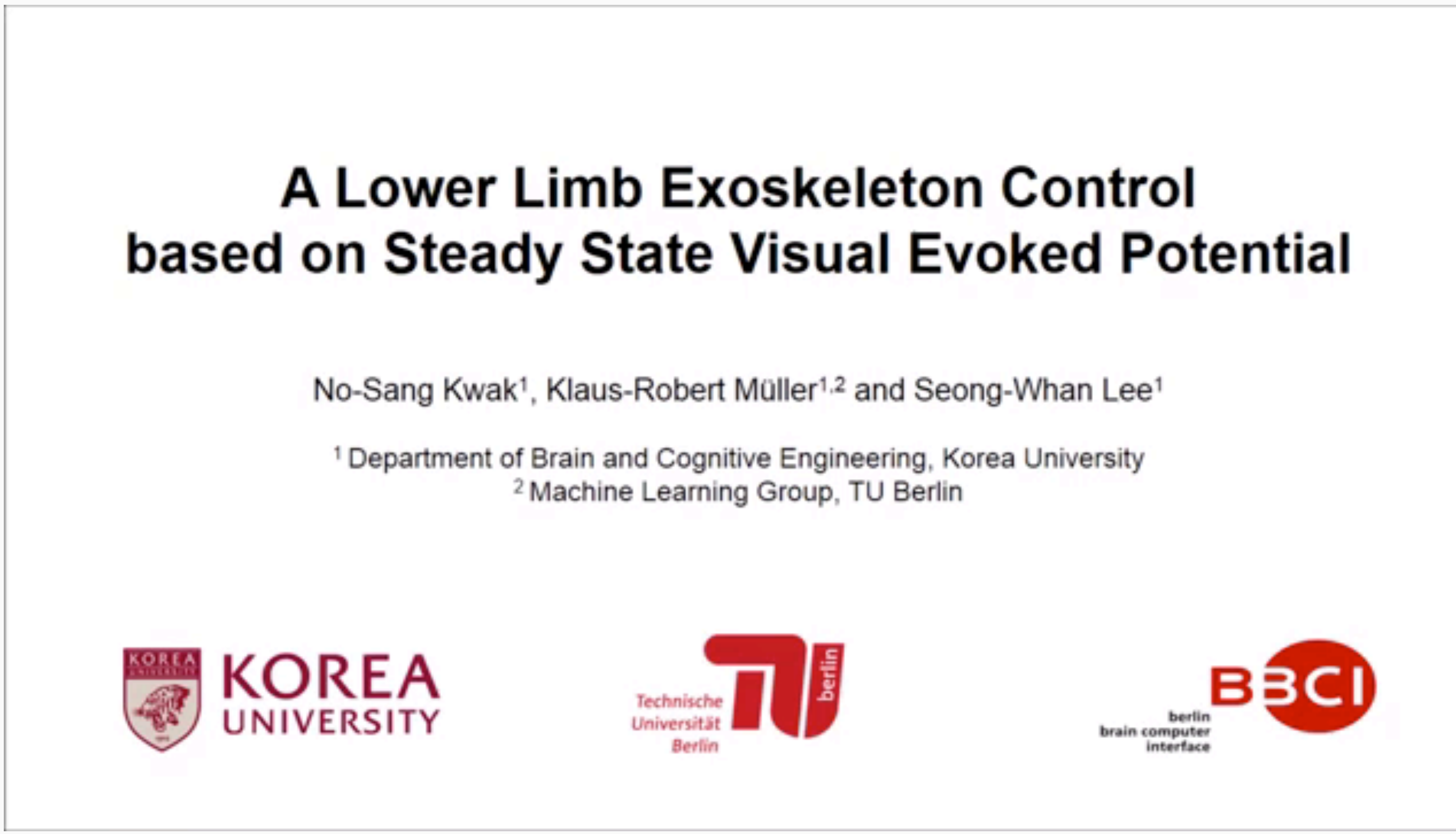
Vision

Diagnosing Alzheimers

[Rudzicz et. al 2015]

Brain Computer Interfaces

Brain Computer Interfaces



And Many More!

- Computational Evolutionary Biology
- Biological Computation (use DNA to compute!)
- Computational Pharmacology, Drug Discovery
- Computational Epidemiology
- … the list goes on!