Lecture 1: Tues Jan 17

- Quantum Information Science is an inherently interdisciplinary field (Physics, CS, Math, Engineering, Philosophy)
- About clarifying the workings of quantum mechanics.
    - We use it to ask questions about what you can and can't do with quantum mechanics
    - Can help solve problems about the nature of quantum mechanics itself.
- Professor Aaronson is very much on the theoretical end of research.
    - Theorists inform what practicalists make which in turn informs theorists' queries

There are several self-evident truths in the physical world. Quantum mechanics leaves some in place, and slashes others. To start with…

Probability ($p \in [0,1]$) is the standard way of representing uncertainty in the world.
Probabilities have to follow certain obvious axioms like:

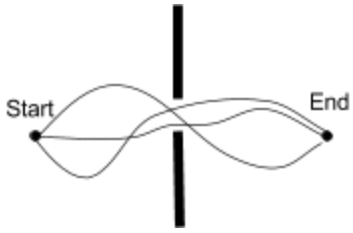
$P_1 + \ldots + P_n = 1$ mutually exclusive exhaustive possibilities sum to 1

$P_i \geq 0$

As an aside:

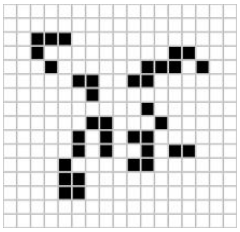
> There's a view that "Probabilities are all in our heads". Which is to say that if we knew everything about the universe (let's say position/velocity of all atoms in the solar system") that we could just crunch the equations and see that things either happen or they don't.

Let's say we have two points separated by a barrier with an open slit, and we want to measure the probability that a particle goes from one point to the other. It seems obviously true that increasing the number of paths (say, by opening another slit) should increase the likelihood that it will reach the other end.



We refer to this property by saying that probabilities are *monotone*.

Locality is the idea that things can only propagate through the structure of the universe at a certain speed.



When we update the state of a little patch of space, it should only require knowledge of a little neighborhood around it. Conway's Game Of Life (left) is an apt comparison: things you do to the system *can* affect it, but they propagate only at a certain speed.

Einstein's Theory of Relativity explains that a bunch of known physics things are a direct result of light's speed. Anything traveling past the speed of light would be tantamount to travelling back in time.

Local Realism says that any an instantaneous update in knowledge about far away events can be explained by correlation of random variables.

For example, if you read your newspaper in Austin, you can instantly collapse the probability of your friend-in-San-Francisco's newspaper's headline to whatever *your* headline is.

Some Pop Science articles may talk about seeing one particle's spin instantaneously as a result of knowing another particle's spin, but that's basically the same as the newspapers.

The **Church-Turing Thesis** says that every physical process can be simulated by a Turing machine to any desired precision.

The way that Church and Turing understood this was as a definition of computation, but we think of it instead as a falsifiable claim about the real world. You can think about this as the idea that the entire universe is a video game: You've got all sorts of complicated things like quarks and whatnot, but at the end of the day, you've got to be able to simulate it in a computer.

Theoretical computer science courses can be seen as basically math courses. So what *does* connect them to reality? The Church-Turing Thesis.

The **Extended Church-Turing Thesis** says that there's at most a polynomial blow-up for simulating reality.

The Church-Turing Thesis *seems* to be True.
The Extended Church-Turing Thesis *seems* to be False.