How weirdness turns into awesomeness

Quantum computing and its promise

What will the future look like?

You are probably under the age of 20. You, your children, or someone you know will see the year 2100

What will the year 2100 look like?

What will be the biggest challenges of this century?

Understanding your world and its future

One of the ways the world changes as we go into the future is with changes in technology.

...

We’re going to tell you about one of the major changes in technology that has already begun, and will continue to play out over your lifetimes.

Searching

Let’s say I have 100 boxes, and I hide $5 inside one of the boxes. Now I ask you to find the $5.



...


How many boxes do you have to open before you’ll (probably) find the money?

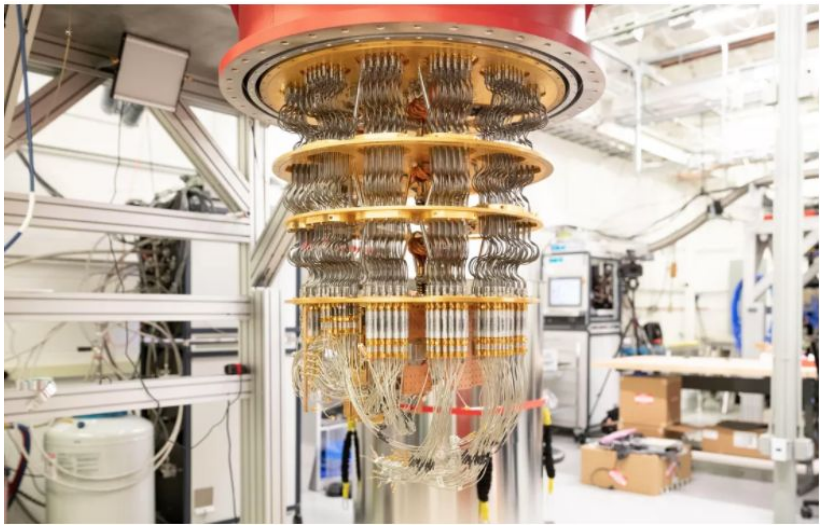
Quantum is weird

It would take about 50 tries before you have a good chance of finding the money.

A **quantum computer**, can find the money by opening only

$$\sqrt{100} = 10$$

boxes.



Quantum is Awesome

We'll talk about two things today:

- How is it possible for quantum computers to use less steps, at least for certain problems?

- Why is this important? What will it mean for the future?

The information age

The time we live in is sometimes called “the information age”

A way to store information is as 0’s and 1’s, or **bits**

=

0 1 1 0 1 0 1 ...

Computers

Computers are devices that do things to information.

picture

meme

Phones, laptops, and calculators are all examples of computers.

Classical and quantum information

Everyday information (text, pictures, video) is actually only one kind of information called **classical information.**

There is also something called **quantum information.**

Quantum information is very weird.

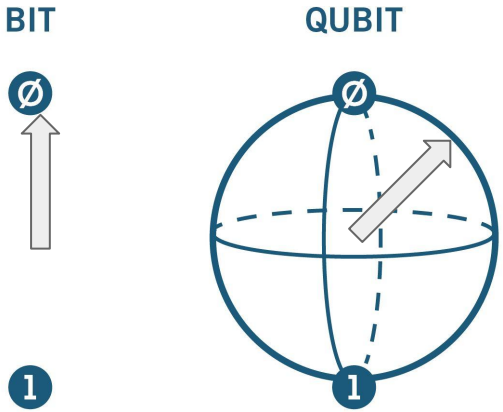
- It cannot be copied
- It cannot be erased
- Knowing everything about each part doesn’t tell you about the whole thing

Quantum Bits

Classical information can be stored as **bits**,

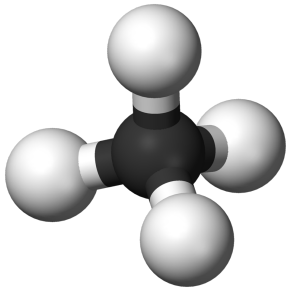
= 

Quantum information cannot be stored as bits. Instead, it is stored as **qubits**.

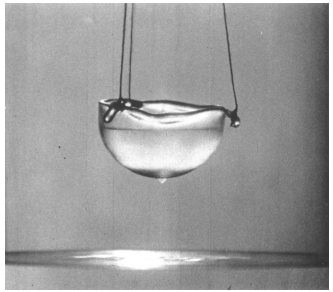


Exploring quantum information

Where can you find quantum information?



Small things



Cold things

You are interacting with the air, your seat, etc, so **you are classical information.**

Quantum Navigator

In the game, your avatar obeys the rules of quantum information.

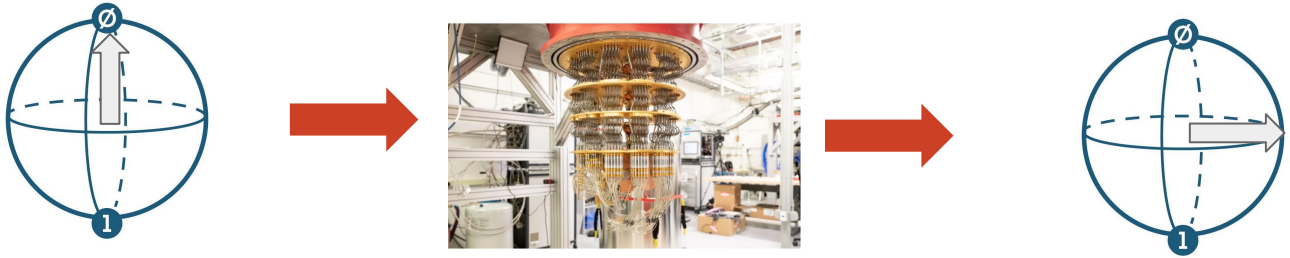
Learn to exploit quantum information to navigate through the levels!

Features of quantum information

What did you notice in the game?

Quantum computers

Quantum computers are devices that do things to quantum information.



There are some big problems that we face today that quantum computers can help us with.

I am Haber-Bosch

Ammonia is used as fertilizer, to grow food.

$$N_2 + 3H_2 \rightarrow 2NH_3$$

Most of the nitrogen atoms in your body have come from ammonia produced in what is called the **Haber-Bosch process.**

A problem

The Haber-Bosch process uses about 1-2% of the world's energy supply.

But, we know there is a better way to do this!

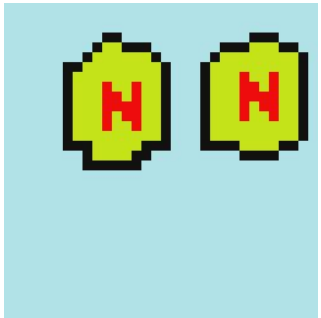
What does this pea plant know that we don't?!

Quantum simulation

What is a quantum computer good for?

This is the chemical reaction the world uses to make ammonia:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

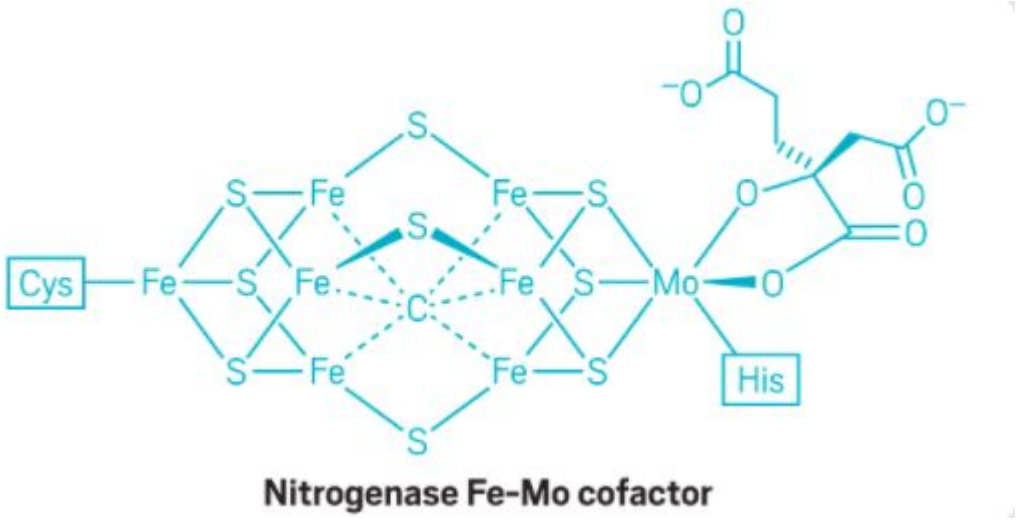


The nitrogen comes from the air, the hydrogen from natural gas.

The Fritz Haber (glasses used to be cooler)

An amazing molecule

We know that the pea plant uses a molecule like this to get nitrogen:

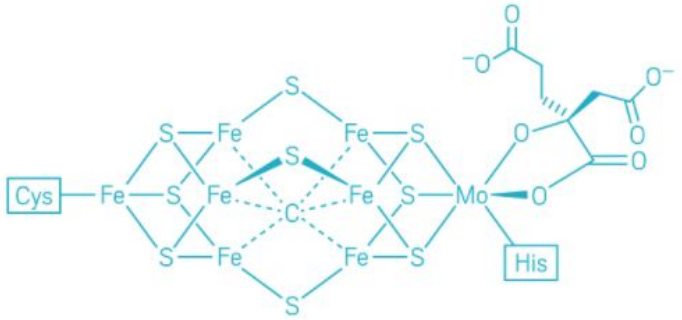


Nitrogenase Fe-Mo cofactor

We don’t understand how this molecule works!

Quantum simulation

How come we can't understand this?



classical

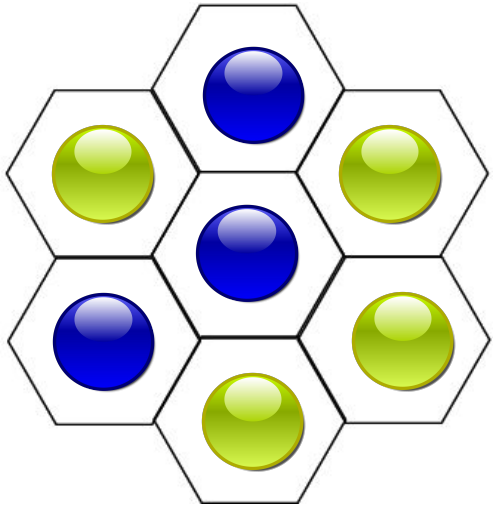
quantum

It is hard to understand **quantum information** using a **classical computer**

Optimization

To understand this problem in more detail, consider the following problem.

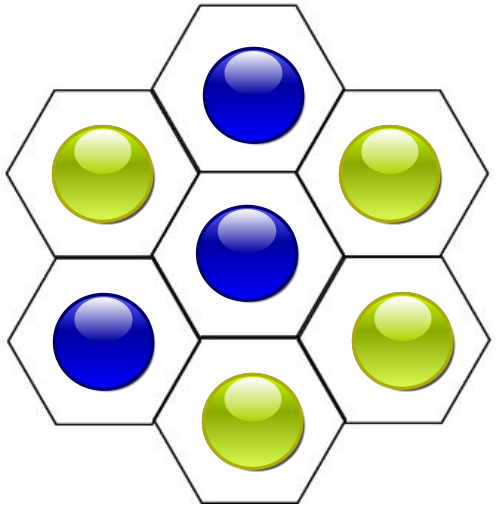
- Fill in the hexagons on the right with either blue or yellow spheres (bits)
- Try to have the least spheres of the same colour touching as possible.



Optimization

This is an example of an **optimization** problem - we're trying to fit something in while getting as close to a goal as possible.

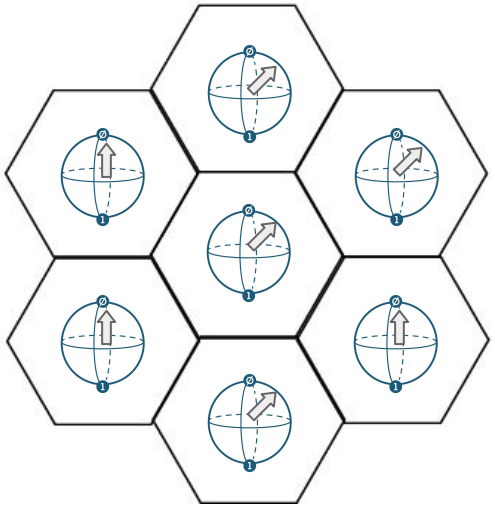
- It's straightforward to ask a classical computer to do this.



Quantum Optimization

To understand the quantum information in the pea plant, we need to solve a quantum version of this problem:

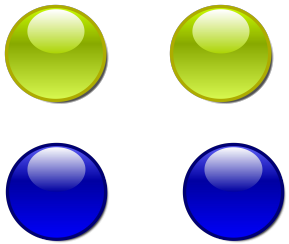
- A quantum computer is better suited to understanding this!



Laptop vs. Meat vs. D-Wave

Rules of the game:

- You must completely fill up the grid
- Try to avoid placing marbles of the same colour next to each other



Laptop vs. D-Wave vs. Meat

Let’s see what our best solution is...

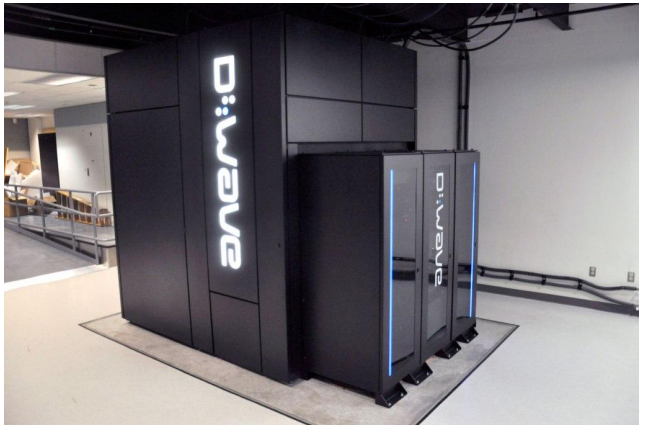
Laptop vs. D-Wave vs. Meat

Next we try a computer solution...

Laptop vs. D-Wave vs. Meat

Another possibility is to try out the computer made by D-Wave.

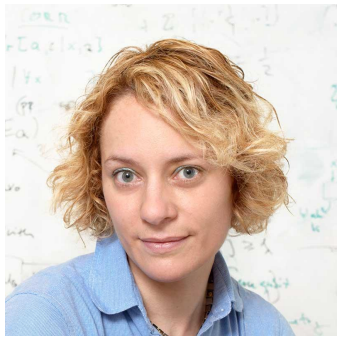
We're not sure what a **quantum annealer** is good at yet, so it's interesting to try things out!



Insert link to D-Wave solver

What about a quantum computer?

We do not yet have a quantum computer that we can use to solve the quantum version of this problem.

...

But, lots of people are working on it!

Quantum computing in the future

In the future though, we expect we'll have a quantum computer.

- We'll be able to understand Haber-Bosch, and hopefully save energy.
- We'll gain insight into how to make stronger metals, more conductive wires, ...

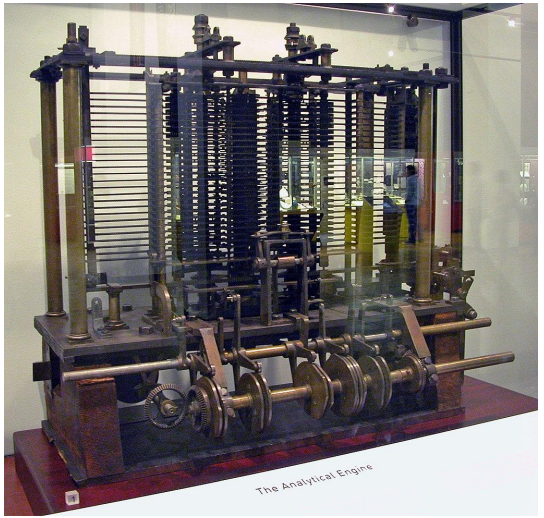
These developments will change our world in many ways.

Perspective

One of the first ever classical computers:

Built for:

$$\log 13 = ??$$
$$\log 14 = ??$$
$$\log 15 = ??$$



The inventors of the first computers did **not** expect you to be tweeting!

What unexpected uses will quantum computers have?