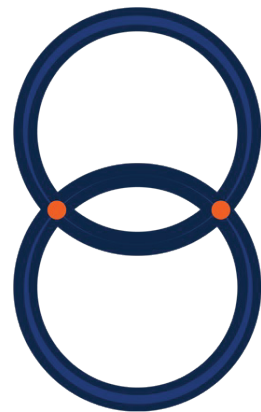


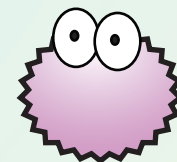
Welcome  
to the

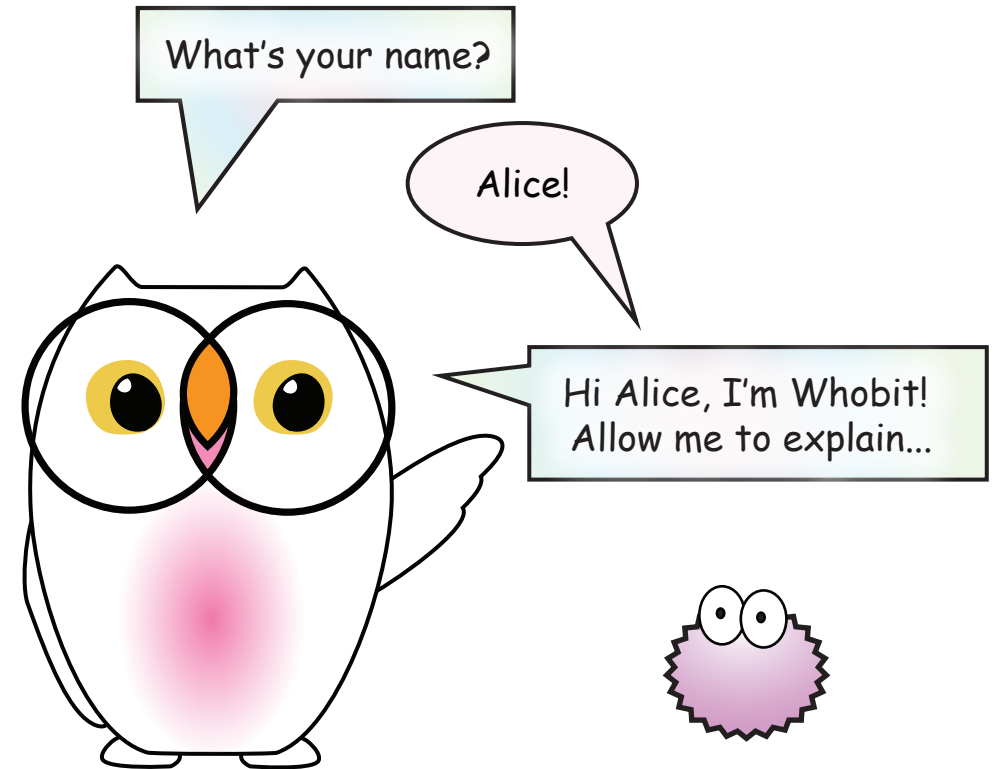
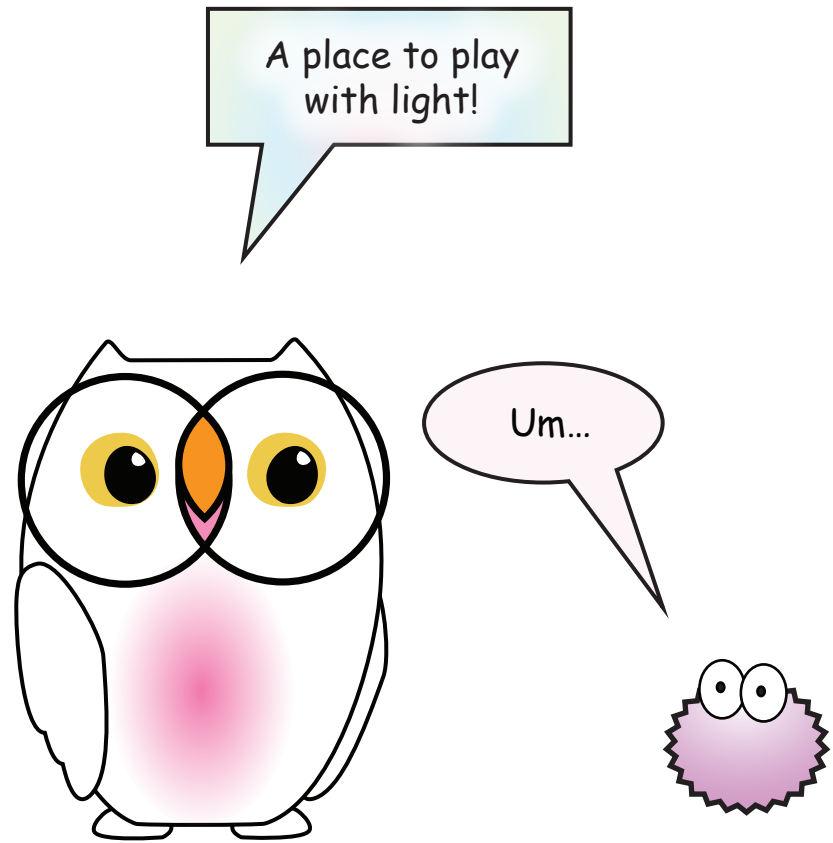


**PUBLIC  
QUANTUM  
NETWORK**



What's  
that?





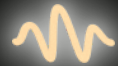
# Light is made of photons



Did you know?  
Human eyes can see  
as few as 1-3 photons  
in a dark room



Photons are  
packets of  
energy



Photons  
are cool...



Photons are waves



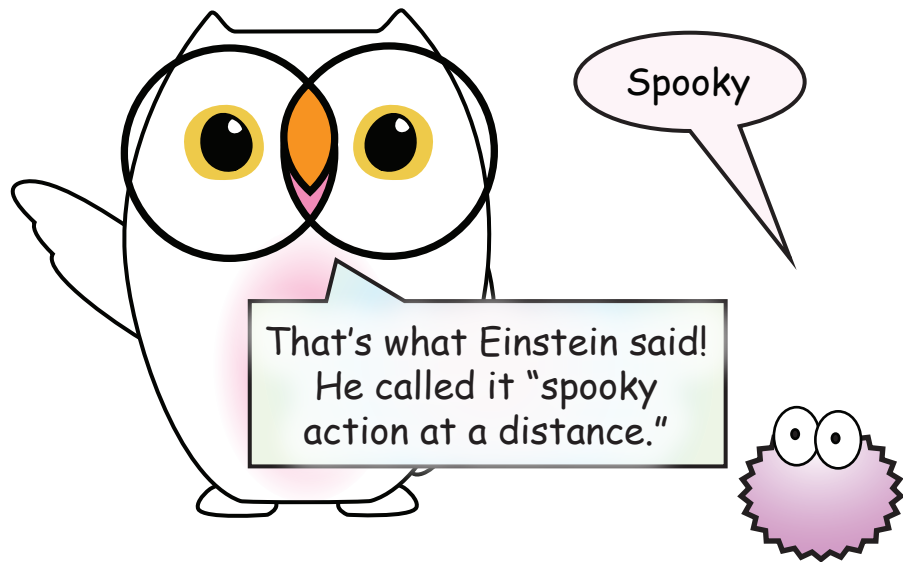
Two photons can be *entangled*, or act like they're connected, no matter how far apart they are.

Spooky

That's what Einstein said!  
He called it "spooky  
action at a distance."

Quantum physics does not yet have an explanation for how entanglement works. But the 2022 physics Nobel prize went to those who did the first experiments proving it's real.

Ooh...





Entangled photons are all around us, but it's hard to study them in the wild. The Public Quantum Network brings entangled photons to public spaces for people to play with.



There are entangled photons traveling from a lab at the University of Illinois Urbana-Champaign over to this library!

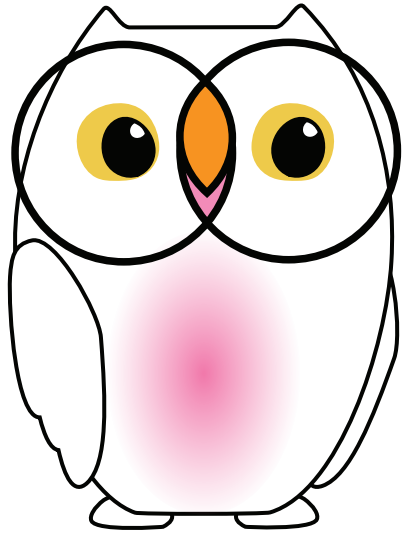


No way!



Optical fiber -- same type of fiber as carries the internet

Yeah. And using the setup, you can see some of the strange properties of light for yourself!



I'm game!



Before we begin: Polarizers only let through photons that wiggle a certain direction.



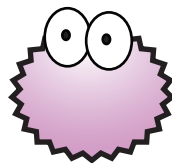


Polarizers ask photons to "choose" which direction they are wiggling. Quantum physics says the photons can be "undecided" beforehand, in what is called a **superposition**.

Does that mean everything in life is undecided beforehand?

We don't know yet. There are *theories* called *quantum interpretations* that suggest different answers.

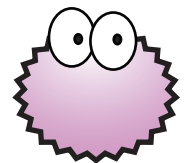
I appreciate your honesty.



OK, now let's play with photons. Using the setup, you can "ask" photons what direction they wiggle and see for yourself that they can "change their answers."

How?

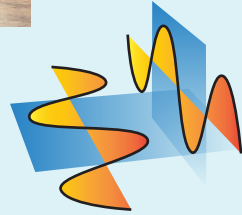
Here are some instructions:



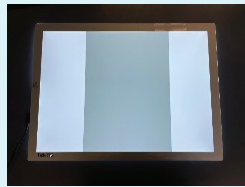
1. This is a polarizer.



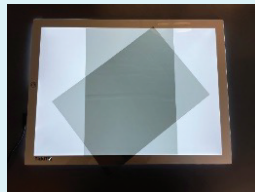
It only lets light through that wiggles a certain direction, like Horizontal or Vertical.



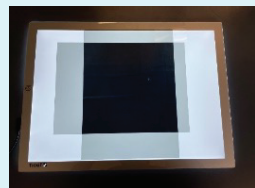
2. Place one polarizer on top of the light screen.



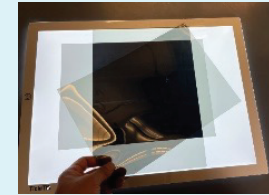
3. Then place a 2nd polarizer on top of the first one.



4. Rotate the 2nd polarizer only. Notice the light where they overlap changing brightness. Rotate to completely block the light.



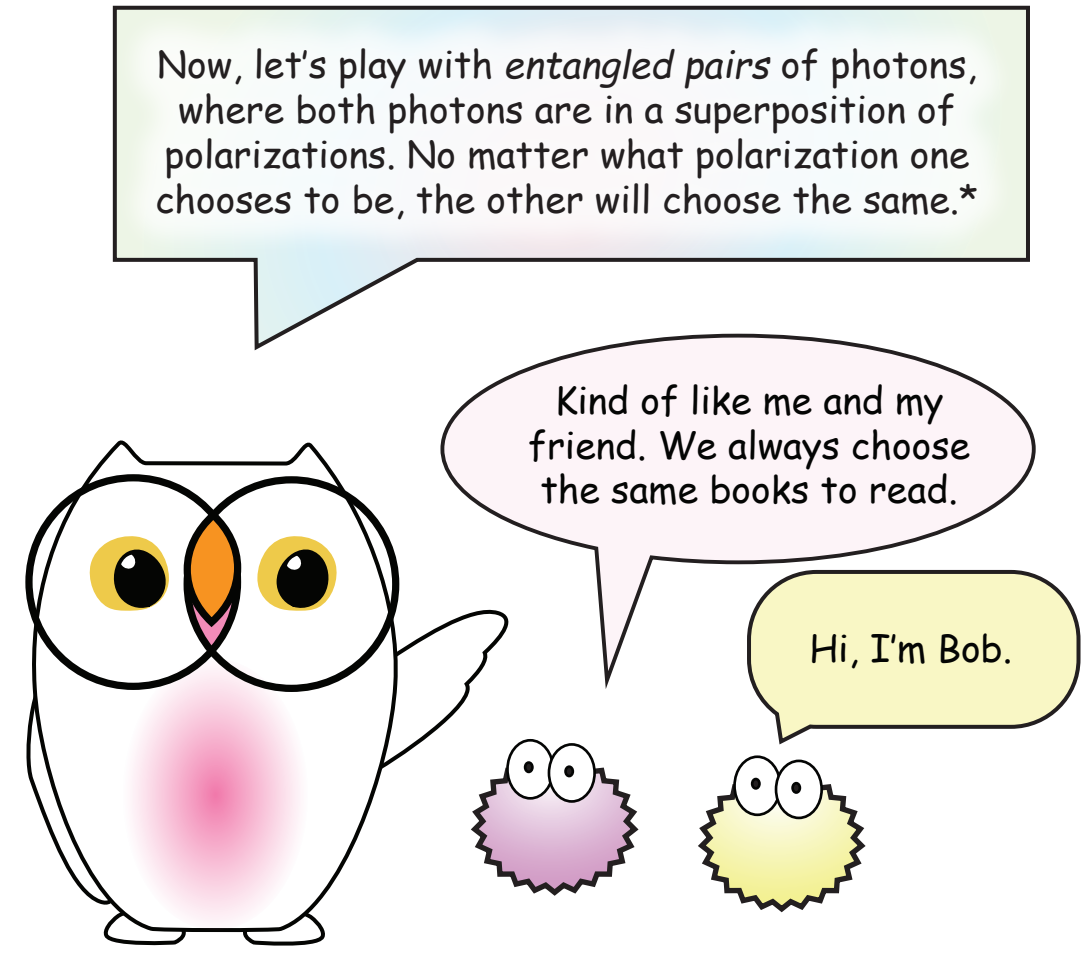
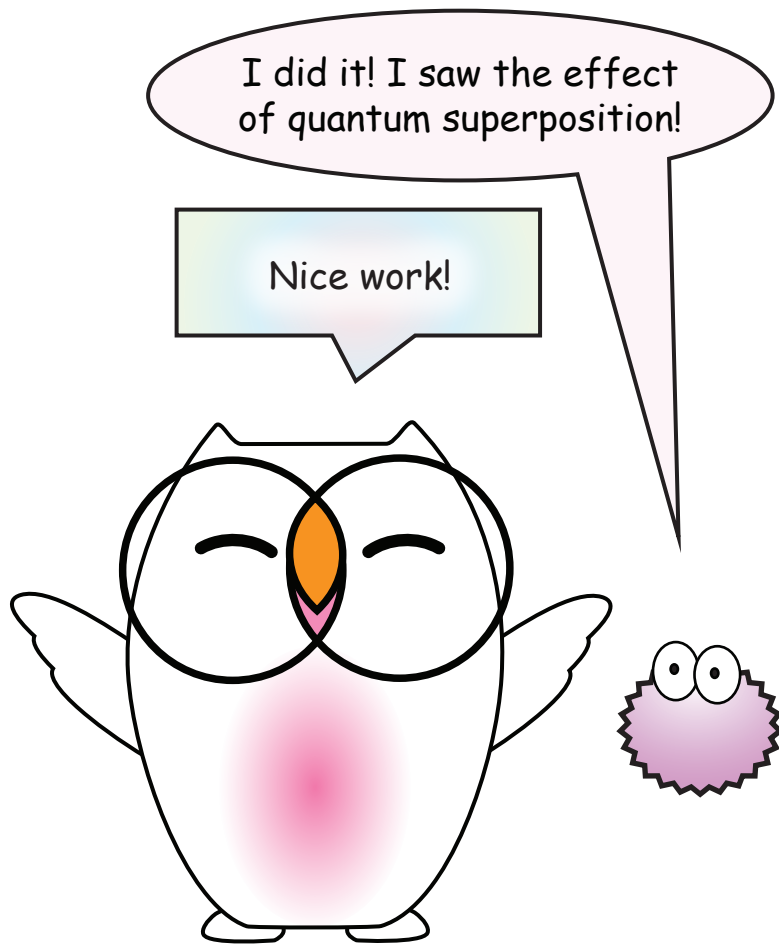
5. Place a 3rd polarizer on top of the second one and rotate it to be diagonal.



6. Now instead move the 3rd polarizer to insert it *in between* the 1st & 2nd polarizers, keeping it diagonal.

7. Do you see the difference in brightness between steps 5 and 6? The photons *changed*. At the middle polarizer, some became Diagonal, which is a superposition of Horizontal and Vertical!





\*Other types of entangled photons can choose opposites or other correlated combinations.



# PUBLIC QUANTUM NETWORK

Great! You and Bob can answer a series of questions on the touchscreens. When you answer the same, the photons "choose" the same polarization, because they're entangled.

## THE [INTER] NETWORK

Where everyone can play with quantum particles. Come explore with us!

The internet relies on a network of optical fibers, cellular towers, Wi-Fi, and cables. The optical fibers are long glass tunnels. Light travels through them carrying information (bits) to homes, libraries, schools, and more.

## QUANTUM TRAVELERS

Photons are individual packets, or quanta, of light. We can make the quantum version of a bit out of a photon and send it through an optical fiber network.

## JUST OUT OF SIGHT

Quantum mechanics is a theory that helps us understand how nature works when things get really tiny. Electrons, atoms, and photons are all examples of quantum particles.

## QUANTUM PARTICLES FOLLOW QUANTUM RULES

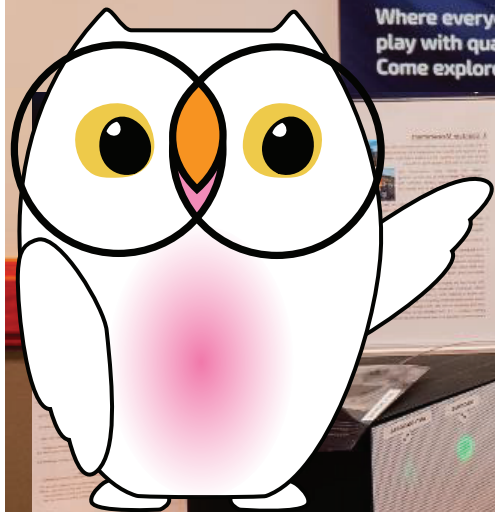
1. A particle's properties are **not** always set to one value. They can exist in a mixture, or **SUPERPOSITION**, of many options all at once.
2. **ENTANGLEMENT** ties the properties of multiple particles together.
3. **MEASUREMENT** randomly chooses from the different possible options for a property, destroying superposition and entanglement.

## MAKING CONNECTIONS

Entanglement lets us connect quantum objects, like particles, across a network. In the future, controlling entanglement will enhance sensing, computing, and communications.

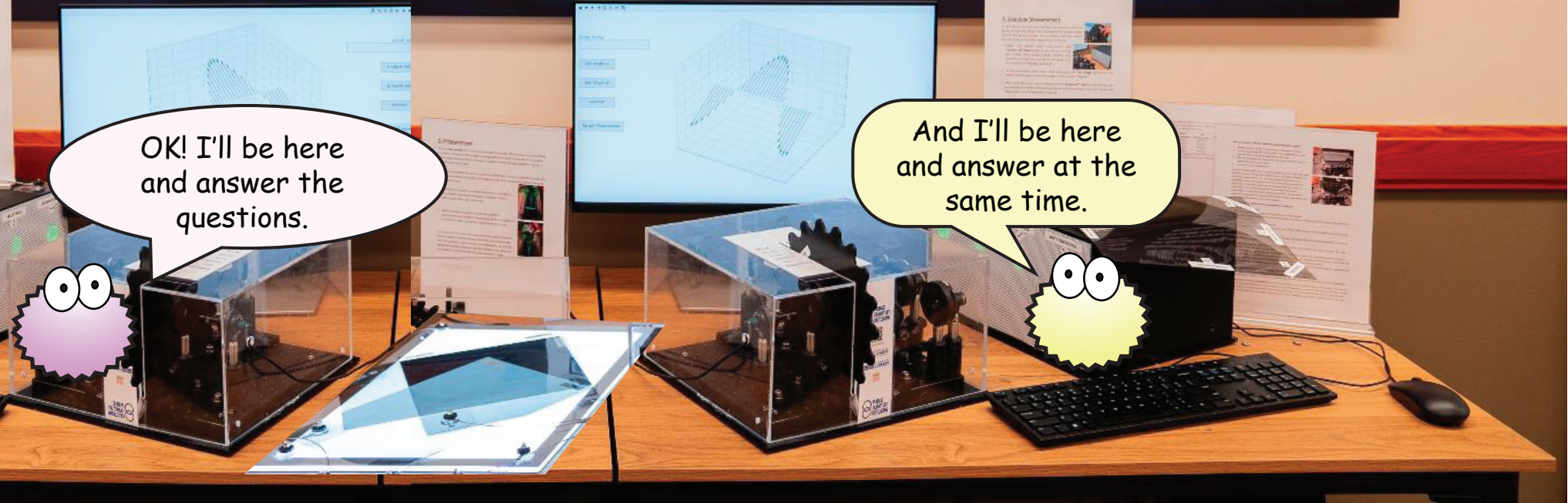
## TEST FOR YOURSELF

In the 1960s, a scientist named John Bell learned how to test whether or not objects were entangled. In this exhibit, you can probe entanglement, just as Bell did, and play with a quantum network.

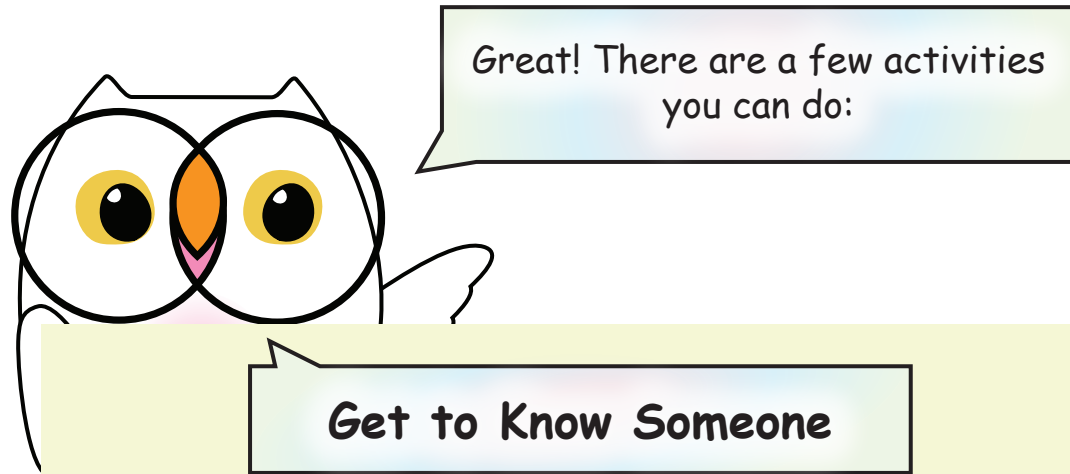


OK! I'll be here and answer the questions.

And I'll be here and answer at the same time.







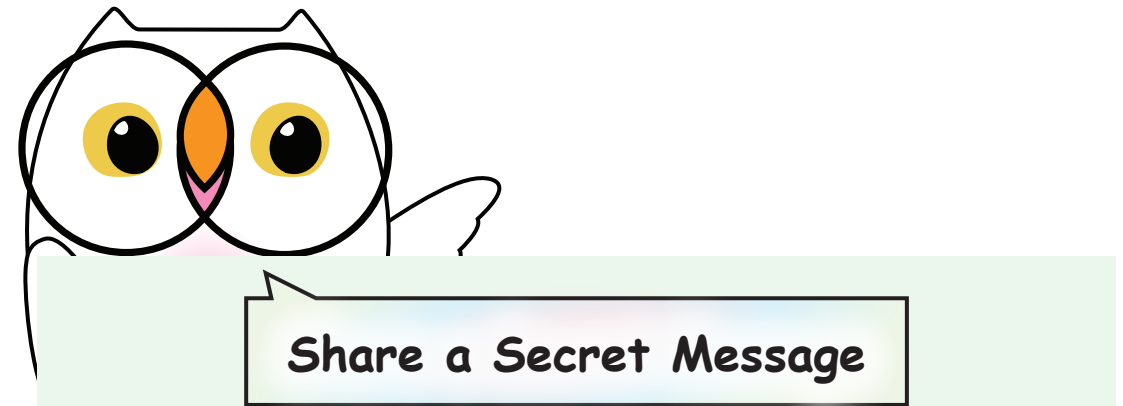
## Get to Know Someone

1. As you answer each question, photons are asked to choose from two possible polarizations. If you answer to the right, the photons choose between Horizontal or Vertical. If you answer to the left, they choose between Diagonal and Anti-diagonal.



2. Every time you both answer the same, the photons agree, too, because they're asked to choose from the same polarizations and they're entangled.
3. The more questions you answer the same, the more like entangled photons you seem to be!

**GOAL:** Just be yourself so you can get to know one another!



## Share a Secret Message

1. One of you chooses an emoji (shh! it's a secret!).
2. So that noone else can see it, we'll scramble the message using bits (0's and 1's). To reveal the message, you need to create shared bits by answering questions the same!
3. Every time you answer a question the same, both photons will be measured the same way. Because they're entangled, they will **always** give the same result (for example, both Horizontal), which would be **impossible** without entanglement.
4. If you answer questions differently, the photons are measured differently, and no useful bits are created.

**GOAL:** Keep trying to answer questions the same until the emoji is as clear as possible!





## Quantum Fortune (Cookie)

1. You choose how to measure your photons. You will do this many times.
2. Because the photons are in a superposition, or have the possibility of being polarized one way or another, the result is a series of 0's and 1's that are unpredictable!



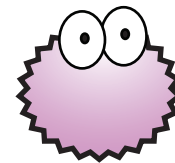
3. These 0's and 1's correspond to a "quantum fortune," which is shared with you!

...and we get a cookie?



Sorry, there's no actual cookie here!

Hey! We got a message using entangled photons!



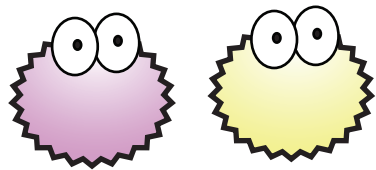
Lucky you,  
lucky me

What does it mean?



It's up to you to *interpret* the meaning... get it?

Ha ha... so...  
what else can we do?



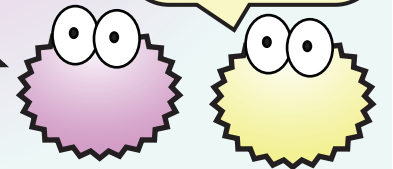
You can also do a "Bell test" proving the photons are entangled, which is the type of experiment that got the 2022 Nobel prize!

## Verify Quantum Link

1. Choose two angles at which to measure the photons going through the library.
2. Back at the lab, the photons that are entangled with the library photons are measured at an angle slightly different from the ones you chose.
3. By comparing the results for each set of angles, we can see whether the photons are really entangled. This is called a Bell test. If the value is greater than 2, this means the angles you chose allowed us to verify the entanglement!
4. Try different angles to see how the test depends on the angles you choose.

It's cool we can do the same experiment as the No-"Bell" prize!

Hee hee...



And when you're all done, please take the survey -- your answers help us improve the Public Quantum Network!

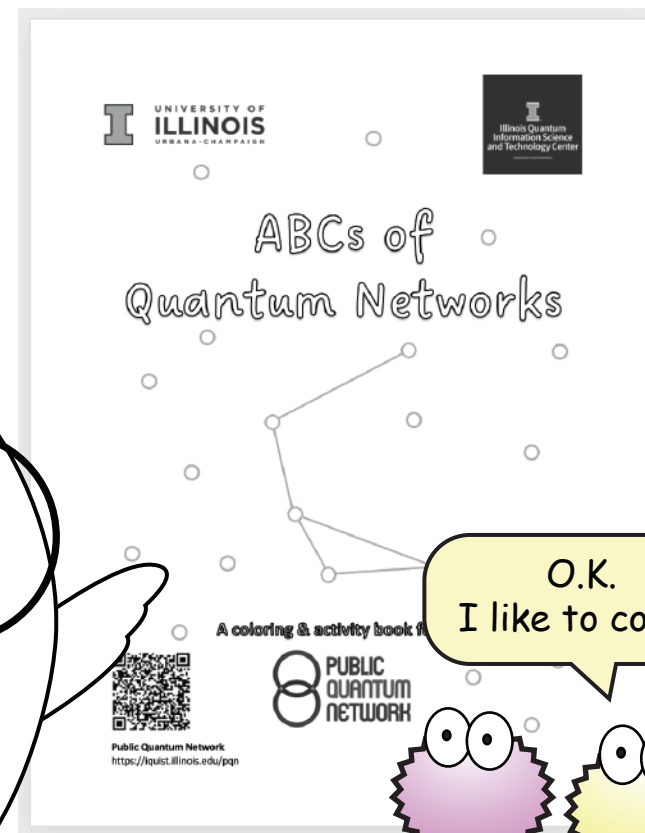
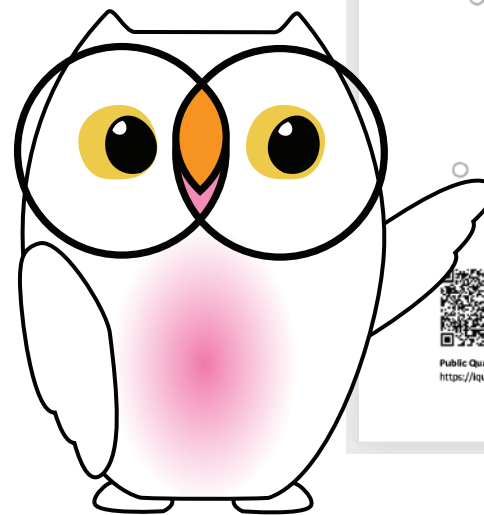


I don't usually do surveys, but I'm excited to help!

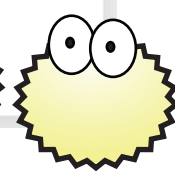
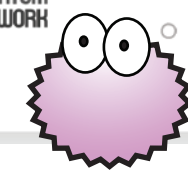
Do we get a cookie?



Umm, no... but check out the Public Quantum Network website for more information and activities, including a quantum network coloring book!



O.K. I like to color.



[pqnetwork.org](https://pqnetwork.org)

The Public Quantum Network  
is brought to you by



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