# OUR QUANTUM REALITY

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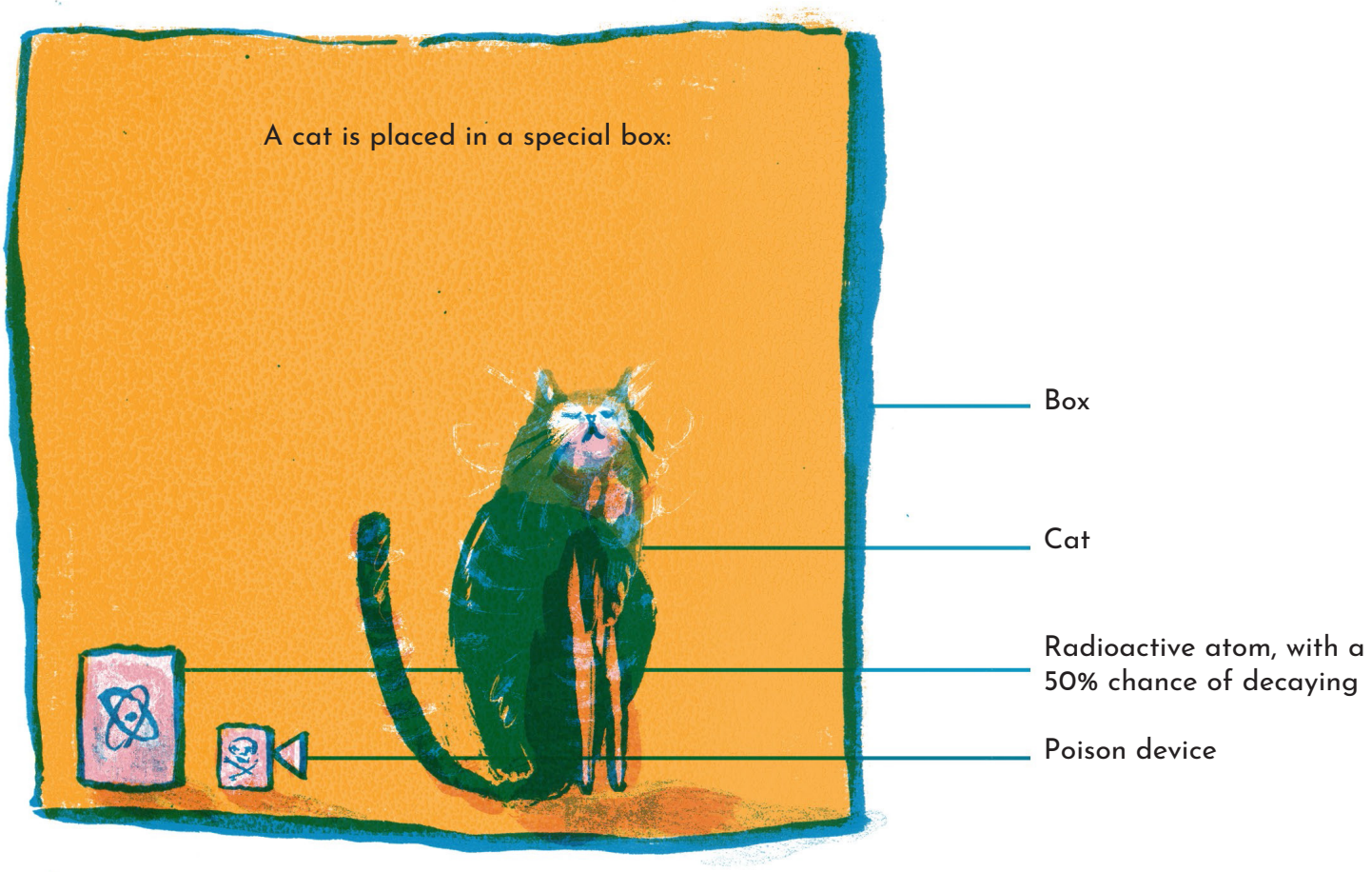
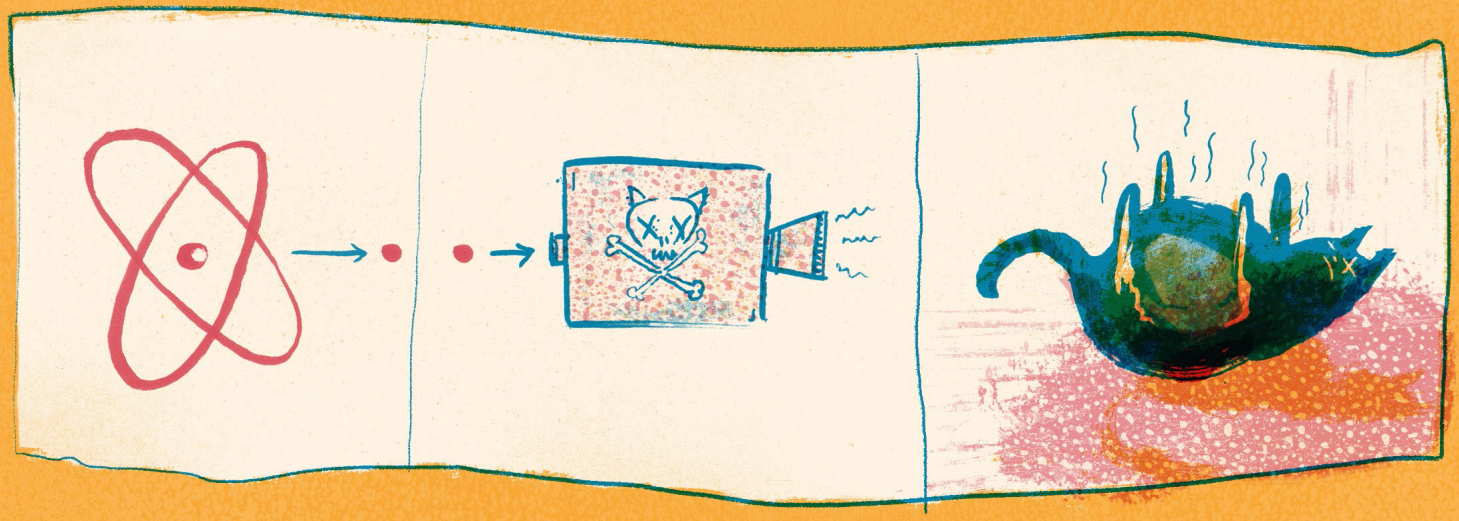
# Schrödinger's Cat

Schrödinger's cat is a thought experiment, devised by Erwin Schrödinger, that is designed to highlight some of the more bizarre implications of quantum mechanics.

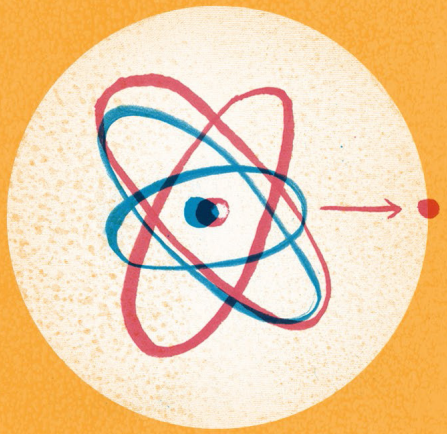


The atom has a 50% chance of decaying. If the atom does decay, then this triggers the poison to be released. If the poison is released, the cat is tragically killed:



But quantum mechanics is much more bizarre than this... In quantum mechanics, it is possible to put the atom into a state where it has both decayed, **and** not decayed, at the same time. We say that the atom is in a **superposition** of having decayed and not decayed..

But if the atom has **both** decayed and not decayed, then the poison will be released, and not released, simultaneously. This will result in the cat being both dead, **and** alive, at the same time!

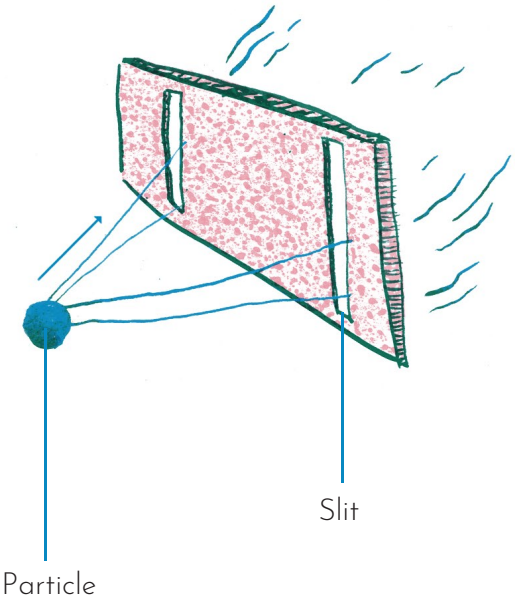


A cat that is simultaneously dead and alive

# Superposition

Quantum superpositions may sound absurd, but they have been confirmed many times in experiments:

- A single particle can exist in a superposition of two different locations, then travel through two slits simultaneously.
- The magnetic field of a particle (its "spin") can be in a superposition of pointing up and pointing down.
- The current in an electrical circuit can flow in both directions simultaneously.




What would happen if you opened the box?

But can **large** objects, such as cats, be in a superposition? Have you ever seen a dead-**and**-alive cat in everyday life? Why not? Should there be different laws for the cat compared to the atom? Or are we thinking about quantum mechanics in the wrong way?

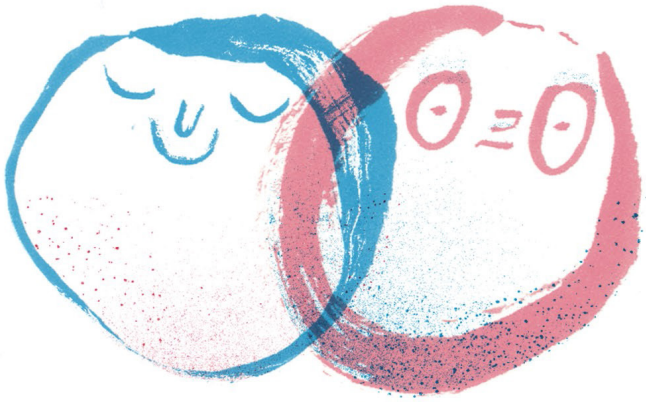
There are a number of different theories that try to resolve these conundrums. We will introduce three of these — each theory will try to explain Schrödinger's cat in a different way, and each will give us a unique picture of reality. Performing a precise Schrödinger's cat experiment is beyond current technology, so for now none of these theories can be proved wrong. You are free to choose whichever you prefer!

# Collapse

*"Maybe quantum mechanics is incomplete or incorrect."*

Some physicists have proposed to modify quantum mechanics by adding an extra law that makes the superposition state of the dead-and-alive cat "collapse" into being **either** dead **or** alive. But what should this extra law be? What causes the collapse?

Gravity could cause collapse: this would mean that small objects can be in a superposition, but large objects cannot. Or complexity could cause collapse: in this case a single particle can be in a superposition, but an object made of lots of particles cannot.



A single particle in a superposition

A microbe in a superposition

Maybe even consciousness causes collapse! Presumably cats are conscious? What about microbes?

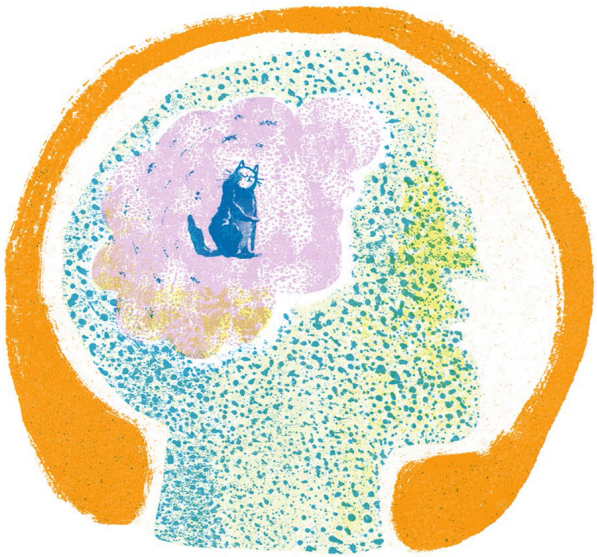
Whatever causes collapse, all these collapse theories predict that we humans cannot enter into a superposition because we are too massive, too complex, or too conscious.

The quantum state of a human collapsing

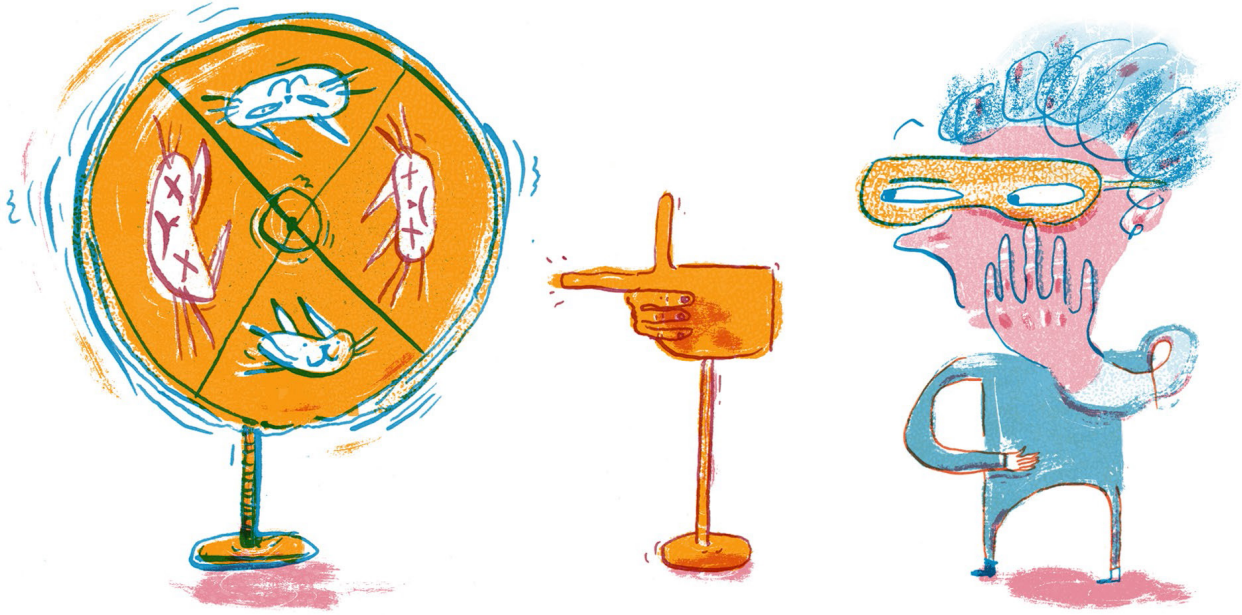
# State of Knowledge

*"Quantum mechanics does not need to be modified, but we're looking at it in the wrong way."*

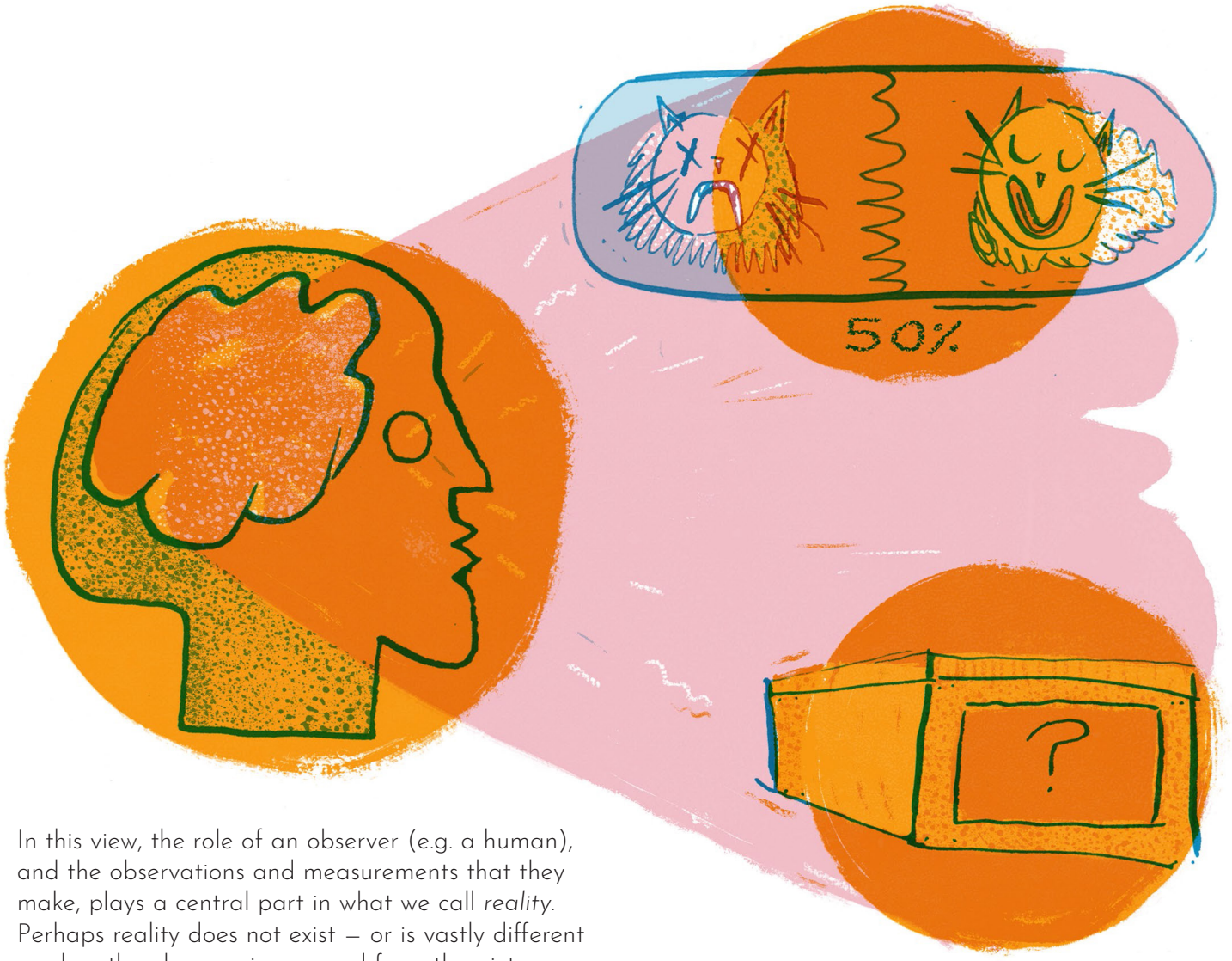
No experiment has ever disproved quantum mechanics, so many physicists do not want to modify the theory if possible. An alternative way to resolve Schrödinger's cat is to say that quantum mechanics **does not** tell us exactly what is happening **inside** the box before you open it. In this view, quantum mechanics can only tell us *what we expect to see* when we open the box.



More precisely, quantum mechanics tells us the probability of seeing different things when we open the box: If the atom has a 50% chance of decaying, then quantum mechanics tells us that, if we open the box, there will be a 50% chance that we will see a dead cat. But it is meaningless to ask **what state the cat is in** before the box is opened.



Quantum mechanics isn't about the cat itself; it's about **you**, and **your knowledge** of the cat.




In this view, the role of an observer (e.g. a human), and the observations and measurements that they make, plays a central part in what we call *reality*. Perhaps reality does not exist — or is vastly different — when the observer is removed from the picture.

Taking this view to its extreme, maybe it is meaningless to ask about the existence of **anything** before we observe it!

# Many Worlds

*"Quantum mechanics doesn't need to be modified, and it* ***can*** *directly tell us about the state of the cat."*

Other physicists think that quantum mechanics really does tell us *what is happening* inside the box. The cat really is dead and alive. But what would it be like to be the cat? Many worlds theory suggests that we should treat it as two cats, one dead and one alive. Each cat cannot see, hear, smell, taste, or ever interact with the other one. We can say they are in different **parallel universes**. Then, when you open the box, you split into two versions of yourself, one that sees the dead cat and one that sees the alive cat. Each version goes about their day, oblivious of the other version of you in the other parallel universe.

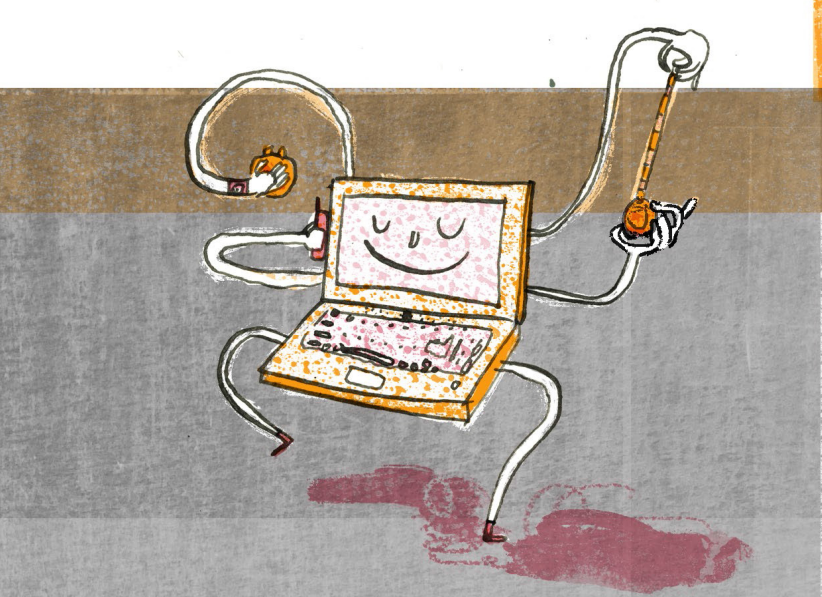

In fact, this theory predicts that there are infinite versions of you, in infinite parallel universes!


PHYSICS
Today
the cat is
out the box

# Shut up & Calculate

*"Who cares what quantum mechanics tells us about reality. We know it describes our experiments accurately, so let's just use its inherent power to transform technology."*

All of these theories fit with the experiments currently being performed in quantum mechanics (as they all fit with current experiments, they are often referred to as different **interpretations** of the same theory). So perhaps we don't need to *understand* quantum mechanics fully in order to use it — ultimately, does it matter whether the cat is dead or alive or both? Some scientists are more interested in what quantum mechanics can **do**. And it can do a lot. Technologies that utilise the power of quantum mechanics could be an integral part of our future.




The smallest unit of a computer is a bit. A bit can either be 0 or 1. But a **quantum computer** contains quantum bits, which can be 0 and 1 at the same time. Quantum computers can run multiple computations simultaneously — this allows certain computations to run much faster. In the future all computers might contain a "quantum processor".


Quantum cryptography uses the strange properties of quantum particles to allow 100% secure communication. This could be used for secure bank transfers and communication over the internet or telephone.

Quantum sensors and imagers use quantum superposition (and other quantum effects, such as *entanglement*) to make ultra-precise measurements of time, gravity, magnetic fields, and more.

This book is dedicated to M.L.

Dr Paul Knott is a quantum physicist working at the University of Nottingham, who currently holds a prestigious Research Fellowship from the Royal Commission for the Exhibition of 1851.

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