Schrodinger's Cat:

We put a cat in a chamber and allow some quantum system (perhaps a radioactive sample) which has a 50% (quantum, random) chance of occurrence to determine whether a big container of cyanide is opened at t=1 hr, killing the cat.

If the quantum system at t=1 hr was in a perfect coherent *superposition* state of "decayed and not decayed", it now seems that we have put the macroscopic cat into a *superposition state*:

$$|\psi_{cat}(t = 1\,hr)\rangle = \frac{1}{\sqrt{2}}(\,|alive\rangle \,+\, |dead\rangle\,)$$

The cat is not "alive *or* dead", it is a superposition of "alive *and* dead". As written, this is not a "mixed state", it a quantum superposition. (Or so it appears…)

We've seen superpositions of spins before and thought it was a little weird and hard to picture, but now that it's a cat, it becomes clear that this is VERY weird and essentially impossible to "picture". How can I make sense of it? How could it be true? Schrodinger thought this was demonstrating that there is something wrong with QM itself. Just as one example, if you "measure" the state of the cat (by merely opening the box and *looking)* this wave function must collapse to live or dead, with 50/50 chance of either. Does that mean you killed (or saved) the cat by merely LOOKING at it? How can looking kill a cat?! It seems to be nonsense (and I agree)

Does this mean that superposition states do not exist and QM is wrong? Definitely NO, we've seen plenty of such states in our "spin-1/2" particle world. They lead to interesting results that are measurable – e.g, the "superposition" (with equal phase) of spin up and spin down in z produces a state with DEFINITE (up) spin in the +x-direction, detectable by experiment!

The issue here is trying to convert that quantum superposition to a macroscopic superposition state. I think the "resolution" of this strangeness is that "looking" is not what constitutes a measurement. We have not operationally defined "measurement", but I claim that it arises from interacting a quantum system with the environment. In the case of a macro object like a cat, it is interacting with the universe (e.g. all the air molecules scattering off it – which scatter differently from a live or dead cat – and the production of various chemicals via biological reactions inside the cat too…) All together, there are *countless* irreversible consequences, each leaving markers in the rest of the world. Many tiny "measurements"… So the "cat's state" is constantly being measured by the vastly many interactions it has, resulting in a loss of any possible coherence between the "live" and "dead" states of the cat. If you don't have a *coherent* superposition, but merely a mixture… that's not strange at all. (I agree that WE don't know if the cat is alive or dead till we check. But the cat "knows", as do the bacteria in its guts, and the various chemicals floating in the air near the cat…)

The buzzword here is "decoherence". To maintain a quantum superposition state requires a *definite* (and delicate) PHASE relationship between orthogonal states. The more interactions you have, the harder it is to maintain this perfect and unambiguous phase coherence. In a macroscopic/thermal environment, all phase coherence between these (many-particle) macroscpic cat states are *rapidly* lost, and the system is INDEED in what McIntyre calls a "mixed state". So yes, there is only a 50% chance that the cat will be alive when you look, but its state just before you looked was already that… exactly like a flipped coin was "already" in the state you see when you peek at it. No "quantum collapse" occurs when you look at a coin, no "quantum collapse" occurs when you open the cat's box. Because the cat was NOT in the "superposition" state written above, it was in a mixed state of live and dead.

I realize I'm fudging a little here – what exactly constitutes a measurement, and how "macro" can a system get and still be able to maintain phase coherence between orthogonal states? These are ongoing research questions. Scientists at NIST are creating so-called "Schrodinger cat states" in which, say, *molecules* can be put into coherent quantum superposition states. A molecule has a lot of nuclei and electrons, it's a "many-body" system, so it's a highly non-trivial feat! These superpositions can, e.g. cause "interference" effects, just like we've seen in spin-1/2 cases. But going from "one molecule" to a cat may be an impossible leap…

Here's a metaphor - if you have a box with 1 atom in it, it's certainly not surprising to find "all" the atoms in the left half. It happens half the time! If you have a box with 4 atoms in it, it's a little surprising but far from improbable to find all 4 of the atoms in the left half. But if you have a box with Avogadro's number of atoms in it, all interacting with a thermal environment, it's really NEVER going to happen that all the atoms are in the left half! Similarly, I claim that while we may get molecules into coherent quantum superposition states, (and I cannot tell you precisely how "big" or "complex" such molecules can get…) it will surely NEVER happen that we will get cats into such a coherent superposition state. Schrodinger's process to CREATE a superposition naively ignored all the myriad interactions inside the cat and between cat and environment, so we don't get a simple transfer of quantum superposition state to cat state…

But it's fun to think about, and does show how curious and counter-intuitive superposition states are!