21. Survey of interpretations.

The primary peculiarity of quantum mechanics is that its mathematics can contain several simultaneously existing versions of reality. In many ways, this is not a problem because one can show that only one version of reality will be perceived, and that the theory gives all the right answers, such as the energy levels of hydrogen. The problem comes with the experimentally observed coefficient squared probability law, which cannot be deduced from the mathematics of basic quantum mechanics. Here we will give a critique, from my point of view, of several different interpretations, including those we have already examined. But as background it is important to note that there is no experimental or theoretical evidence for any of them.

Criteria for classifying interpretations.
(1).The interpretation should be clear about what matter consists of—wave function only, particles, state vectors, field operators, strings,….
(2). It should give its relation to the highly successful basic quantum mechanics.
(3). It should explain how one version is singled out for perception and how probability arises.
(4). It would certainly be preferable if there were direct experimental evidence for the interpretive scheme.
(5). Finally, one must judge the 'believability' and consistency of the interpretation.

The Everett many-worlds interpretation.

This consists of basic quantum mechanics, so there is no problem with (1) and (2). It correctly explains everything except probability. However, no version is singled out for perception, so in spite of some claims, this interpretation cannot account for probability. It is not even possible to *define* probability—probability of what?—*within* the scheme of basic quantum mechanics, where the state vector evolves deterministically and every outcome is perceived on every run of an experiment. Thus the many-worlds interpretation falls short.

Mathematical collapse interpretations.

In a mathematical collapse interpretation, the coefficients change smoothly with time until just one of the coefficients is non-zero. This satisfies the first three criteria. But the problem is that the most explicit model, the GRW-Pearle proposal, uses a number of assumptions which are difficult to justify—instantaneous and detailed passing of information between separate universes, for example, as well as an interaction chosen solely because it gives the right answer (rather than being justified by appeal to some reasonable set of principles). Further, collapse has not been detected in a number of fairly sensitive experimental tests to find it. So the collapse interpretation is not satisfactory at this time.

Hidden variable interpretations.

This is probably the second most subscribed-to interpretation (after collapse). In it, one branch of the wave function is singled out as the 'real' branch—or rather (because there is no collapse) as the branch that we as observers will perceive. If we use the Bohm version of this interpretation, then in the spin ½ S-G experiment, there is a point 'particle' that zigzags around inside the region where the wave function is not zero. The mathematics implies this point will end up either on the path that the + state takes or on the path that the – state takes (in accord with the probability law). If it travels on the + path, the + state will be the one perceived (when a detector is set up and the observer looks at the detector reading).

But there are problems. The main one I see is that there is no reasoning given as to why our perceptions cannot correspond to the version that is *not* singled out. *Why can't* our perceptions correspond to the |-> state when the zigzagging particle picks out the |+> state? Both the not-chosen and the chosen versions have valid associated quantum versions of the brain, so why should the state *not* chosen by the particle be forbidden from corresponding to our conscious awareness? It's not sufficient to just say 'that's the way conscious perception behaves;' one must explain *why*. (Does the point particle itself have the rudiments of consciousness associated with it, for example?) Another problem is the need to assume a very specialized distribution of trajectories.

The Copenhagen interpretation.

Historically, this was the first major interpretation. Through the principle of complementarity, it essentially tries to keep classical ideas while allowing for the successful quantum results. In my opinion, it does not engender any understanding to how probability is to be integrated with basic quantum mechanics. Nor does it tell just what the physical world is constructed from; it seems to say (there are several versions of this interpretation) that microscopic systems are composed of state vectors and macroscopic systems are composed of actual particles. This is not satisfactory.

Instrumentalist interpretation.

This simply gives the Born $|a(i)|^2$ formula as the way in which probability is to be calculated. It does not shed any light on the probability-basic quantum mechanics link, and it does not say what physical reality is constructed from. So it is, in my opinion, not an acceptable interpretation. In fact, it could hardly be called an interpretation.

Consistent histories interpretation.

I don't understand this interpretation so I cannot critique it.

The ensemble or statistical interpretation.

In this interpretation (as I understand it), the state vector does not refer to an individual system. Instead it refers to an ensemble of systems, an imaginary collection of systems that each correspond to one of the quantum states. For example, if the state vector is a(1)|+>+a(2)|->, this refers to a collection (ensemble) of, say, $N|a(1)|^2$ states |+> and $N|a(2)|^2$ states |-> (with N very large). The 'actual' state will be either a single state with properties corresponding to |+> or a single state with properties corresponding to |->.

This interpretation does not seem sufficiently well-developed. The nature of the 'actual' state is, as far as I know, not specified. What does a system with spin +1/2 correspond to? Do the 'objects' in the ensemble satisfy equations of motion? Does this picture run afoul of the Bell-Aspect results that there can be no objects with localized properties? Because of this indefiniteness, which presumably cannot be satisfactorily remediated, I do not think this is a successful interpretation.

Non-materialist interpretations.

All the above might be called 'materialist' interpretations; they assume the observer is just an object, not different from other objects in any fundamental way. None of the materialist interpretations currently succeed and there is no reason to be optimistic they ever will.

Physicists are obliged to make every effort to show there is a satisfactory materialist interpretation of quantum mechanics. But there is no convincing argument that I know of which implies the correct interpretation is *necessarily* materialist. So it seems reasonable to investigate possible forms for non-materialist interpretations, where the observer has a property which is not shared by other physical objects. This is done in Part V, where it is seen that, to make such an interpretation work, one must make a number of substantial assumptions that are not easy to defend.