Origins: Modern science

After the First World War, a group of mathematicians, scientists and philosophers formed the *Wiener Kreis*, in English called the *Vienna circle*. They were unhappy with the metaphysics of the German idealists, who focused on first principles of knowledge and the fundamental nature of being.

The Vienna circle, with members like Moritz *Schlick*, Otto *Neurath* and Rudolf *Carnap*, felt idealist questions about the self and existence were meaningless because they were unanswerable. They proposed a new philosophy of science called **logical positivism**.

The logical positivists redefined science as the study of **meaningful statements** about the world. For a statement to be meaningful it has to be verifiable, which is known as the **verification criterion**. It means that it should be possible to determine the truth of a statement.

There are two types of meaningful statements. Analytical statements and syntactical statements. **Analytical statements** are tautological, necessarily true. Examples are "bachelors are unmarried" and "all squares have four sides". They are **a priori statements**, like definitions and purely logical statements.

They don't depend on the state of the world and therefore don't require observation to be verified. They can be used in mathematics and logic. New combinations of analytical statements can be verified with formal logic.

Syntactical statements depend on the state of the world. Examples of syntactical statements are: "All bachelors are happy" and: "All cats are born with tails". These statements are **a posteriori**; they can *only* be verified through observation. The logical positivists thought these statements should be always **publicly accessible**.

Also, statements are not allowed to refer to **unobservable entities** like "electron" or "gravity", because they can't be observed directly.

If a statement makes reference to an unobservable entity, is not tautological or not logically or empirically verifiable, then that statement is meaningless. Subjects like metaphysics, theology and ethics were thereby nicely excluded from science.

Of course the criterion of verification through observation couldn't deal with the problem of *induction*. No amount of confirmatory evidence is ever enough to definitively prove or verify a statement. It's always possible a contradictory observation will be found in the future. So the strong criterion of verification was weakened by requiring only **confirmation** instead of verification.

Another very strict rule also had to be changed. Not allowing reference to unobservable entities created big problems. Entities like "electron", "gravity" and “depression” cannot be observed directly, but they are indispensable in scientific explanations. This, together with the problem of induction, led to a more moderate version of logical positivism called **logical empiricism**.

Karl Popper, who was nicknamed "the official opposition" by the Vienna circle, was one of their main critics. He argued that the distinction between meaningful and meaningless statements should be based on the criterion of ***falsification***, not verification.

Karl Popper argued that we can never conclusively verify or prove a statement with observations, but we can conclusively disprove it with contradictory evidence. According to Popper a statement is meaningful only if it’s **falsifiable**.

Popper proposes that scientists should actively engage in "risky experiments". These are experiments that maximize the chance of finding evidence that contradicts our hypothesis. If we find such contradictory evidence, we inspect it for clues how to improve our hypothesis. The hypothesis is provisionally supported, only if contradictory evidence is absent.

Now, Willard van Orman Quine showed that this criterion is also problematic. In the Duhem-Quine thesis, he states that no hypothesis can be tested in isolation; there are always background assumptions and supporting hypotheses.

Now if contradictory evidence is found then according to Popper, our scientific explanation is wrong and should be rejected it. But according to Quine we can always reject one of the background assumptions or supporting hypotheses instead. This way we can salvage the original hypothesis.

Thomas Kuhn pointed out that science doesn't develop out of strict application of either the verification or the falsification principle. Hypotheses aren't immediately rejected or revised if the data don't agree with them.

Science takes place within a certain framework or paradigm. Hypotheses are generated that fit within this paradigm. Unexpected results lead to revision of hypotheses but only as long as they fit the framework. If this is impossible, the results are just ignored. But when more contradictory evidence accumulates, a crisis occurs, which leads to a paradigm shift. A new paradigm is adopted and the cycle begins again.

Even in it's weaker form of logical empiricism, logical positivism couldn’t stand up to the critique of Popper, Quine and others. Since then, we’ve progressed to a more pragmatic philosophy of science.

Today scientists follow the **hypothetico-deductive** method, combining induction and deduction, requiring falsifiability and accepting repeated confirmation only as provisional support for a hypothesis.

Philosophically, many scientists would probably be comfortable with **Bas van Fraassen's *constructive empiricism***, which states that science aims to produce empirically adequate theories.

Knowledge requires observation, but unobservable entities are allowed. Accepting a scientific theory doesn't mean accepting it as definitive, a true representation of the world. According to a constructive empiricist, a scientific statement is accepted as true *as far as our observations go*; whether the statement truthfully represents the unobservable entities simply cannot be determined. We just have a current best explanation for our observations. That's it.