Origins: Scientific method

We need the **scientific method** to make sure our attempts to explain how the world works result in valid knowledge. Opinions, beliefs, casual observation and informal logic won't do; they are too *subjective* and too susceptible to *error*.

The scientific method is based on *systematic observation* and *consistent logic*. Applying the scientific method increases our chances of coming up with valid explanations. It also provides a way to evaluate the plausibility of our scientific claims or *hypotheses*, and the strength of the empirical evidence that we provide for these hypotheses in our empirical study or research.

The scientific method can be described according to six principles. If our study meets these principles, then it can be considered scientific. Our hypothesis can then be compared to, and compete with other scientific claims to provide the best possible explanation of the world around us.

The first principle requires that a hypothesis is **empirically testable.** This means that it should be possible to collect empirical or physical evidence, or *observations*, that will either support or contradict the hypothesis.

Suppose I hypothesize that my cat loves me more than he loves my fiancé. To test this hypothesis empirically we need to collect observations, or *data*.

But how can we observe how much the cat loves us? We can't ask the cat about his feelings. Suppose we both agree that a cat is unable to express love the way humans do. Well, then there is nothing to observe; the hypothesis is not empirically testable.

The second principle is **replicability**. A study and its findings should be **replicable**, meaning we should be able to consistently repeat the original study.

If the expected result occurs only *once* or in *very few* cases, then the result could just have been coincidental. A hypothesis is more plausible if it is repeatedly confirmed. And this requires that it is possible to repeat or replicate a study.

Let's say I've convinced my fiancé that if the cat loves someone more, the cat will spend more time on their lap. Now suppose I observed that this week the cat sat on my lap twice as long as on my fiancé's lap. Does that mean my hypothesis can be accepted? Does the cat love me more?

Well, the hypothesis would be considered plausible if we can show that the result is the same in the following weeks. But what if the cat dies after the first week of observation? Then we would not be able to check the hypothesis for ourselves. The study is no longer replicable!

To see if results replicate, we have to be able to repeat the study *as it was originally conducted*. Suppose we do something differently and we find different results. Is this a failure to replicate? No, the failed replication could be caused by our change in procedure.

The third principle of Objectivity aims to allow others to repeat the study by themselves, without need for the original researcher. **Objective** literally means that it shouldn't matter who is performing the study.

Anybody should be able to get the same results based on the description of the assumptions and procedures. A researcher should therefore be as **objective** as possible about assumptions, concepts and procedures. This means that all these elements should be *clearly* and *explicitly defined*, leaving no room for subjective interpretation.

Suppose I count my cat's face rubbing as an expression of love, but I fail to explicitly tell my fiancé about this. Then my procedure for measuring love is subjective. Even if we systematically observe the cat at the same time, the result will depend on who is observing him. I will conclude the cat shows love more often than my fiancé will.

In this example, the results are subjective and therefore incomparable, and we might not even be aware of it. If we do not explicitly discuss and agree on what counts as love and what doesn't, then our measurement procedure for cat love is not objectively defined.

The fourth principle is **transparency**. Being **transparent** is closely related to being objective. In science *anyone* should be able to replicate your results for themselves, your supporters but also your critics.

This means that researchers need to ***publicly share*** what assumptions were made, how concepts are defined, what procedures were used and any other information that's relevant for accurate replication.

The fifth principle states that a hypothesis should be **falsifiable**. Falsifiability is a very important principle. A hypothesis is falsifiable if we are able to at least *imagine* finding observations that will contradict our hypothesis. If we can't imagine what such contradictory data would look like, well then the hypothesis cannot be disproven.

Ask any person with a very strong, for example, religious belief what evidence would convince them that their belief is false. No matter what contradictory evidence you propose, they will probably argue that these facts do *not* contradict their strong belief. This puts statements based purely on belief, such as religion, outside the domain of science.

If there is no form of evidence that will be accepted as disproving a hypothesis, then it is pointless to argue about the hypothesis or to even look for confirmation, since the conclusion is already drawn.

Ok, let's move on to the sixth and last principle of **logical consistency**. A hypothesis should be logically consistent or coherent. This means there shouldn't be any internal contradiction, for example if a supporting assumption disagrees with the hypothesis.

The conclusions based on our observations should also be *logically consistent*. This means, among other things, that researchers should be consistent in what they count as confirmatory and contradictory evidence.

Let me explain this using our cat example: I hypothesized that my cat loves me more and so I expect him to sit on my lap longer. What if he spends more time on my fiancé's lap? I could say that the cat can feel that sitting on my lap is uncomfortable for me. So the cat will sit on my lap less often *because* he loves me more. Of course this is logically inconsistent.

I've changed the interpretation of the results after the data are in to suit my hypothesis. Incidentally, this also makes my hypothesis unfalsifiable; I will always conclude that my cat loves me, whether he sits on my lap often or not at all.

So to summarize, the scientific method requires that we formulate hypotheses that are:
empirically testable: meaning the hypothesis can be supported or contradicted by *observations*;
replicable: meaning the hypothesis can be tested *repeatedly*;
objective: meaning the hypothesis can be tested *independently* by others;
transparent: meaning the hypothesis and results are *publicly shared* so they can be tested *by anyone*;
falsifiable: meaning that finding *contradictory evidence is a possibility*;
and finally: **logically consistent**: meaning that the hypothesis is internally consistent and the conclusion to support or reject the hypothesis, based on the observations, is logically sound.

One final point: the scientific method is only effective when it is used with the right attitude. In order to come up with better hypotheses, researchers need to be critical of their own studies and those of others. This means they have to be **open** and **transparent**; they have to accept critique and let go of their pet-hypotheses if others provide better explanations.

Only then can science function like an evolutionary system, where only the fittest, or most plausible hypotheses survive.