Quantitative Methods

Module 1: Origins

1.01 Origins: Non-scientific methods

To see why we need the scientific method, let's take a look at what people base their knowledge on in day-to-day life. People can accept something as true based on **intuition** or **belief**. Let's consider my own strong belief that my cat Misha loves *me* most of all people in his life. I just *know* he loves me more than anyone else, I feel this in my heart of hearts.

Is such a belief a good basis for knowledge? Well no, simply believing something doesn't make it so. Things we believe in strongly can turn out to be false. Also, what if someone else holds an opposing belief? What if my fiancé believes that Misha loves *him* more? There is no way to settle who is right *just* by pitting our beliefs against each other.

We could count the number of supporters for each belief and require a majority or **consensus**. But this isn't a very solid basis for knowledge either. Just because most people accept something as true doesn't mean it *is* true. For centuries practically everybody thought the earth was flat. Turns out they were wrong; it's round.

Another source of knowledge is an **authority**'s opinion; also not a very good source. The opinion of authority figures like political leaders, experts, scientists, is just that, an opinion. Authorities may have access to more or better knowledge but they also have an important personal stake in getting their views accepted. Their careers and reputation depend on it.

Suppose my fiancé gets a so-called cat-whisperer to declare that Misha loves him more. Of course I'm going to be skeptical about this expert opinion, especially if my fiancé paid for it. I could find my own cat expert to oppose my fiancé's cat whisperer but then we would just have two opposing opinions again. What we need is **evidence**.

So how do we use evidence to settle the argument of whom Misha loves more? Well, suppose I regularly *observe* that after getting home from work, Misha always comes to sit on *my* lap and not my fiancé's. I'm supporting my *statement about the world*, that Misha loves me more, with an *observation of the world*, namely on whose lap he sits after work.

This gathering of evidence through **casual observation** is a better foundation of knowledge than the previous ones, but still not good enough. This is because people just aren't very good at observing. We tend to selectively observe and remember things that agree with our beliefs. For example, I might have forgotten - very conveniently - that Misha always sits on my fiancé's lap at breakfast. There are many biases besides selective perception that make casual observation a tricky source of knowledge.

The same goes for our ability to use logic. Logical reasoning would seem like a solid basis for knowledge. But our informal logical reasoning isn't always consistent. There's an almost endless list of 'fallacies' or logical inconsistencies that people regularly make in their day-to-day reasoning.

If we want to develop accurate knowledge, make sure that our explanations of the world are valid, then we need something more. We cannot depend on subjective and unverifiable sources like beliefs, opinions and consensus; and we can't trust casual observation and informal logic because they can be heavily distorted by our beliefs. We need ***systematic* observation**, free from any bias, combined with **consistently applied logic**. In other words, we need the **scientific method**.

1.02 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.

1.03 Origins: Scientific claims

Until now I've talked about *statements*, *hypotheses* and '*explanations* of the world around us'. And I've used these general terms without specifying what they mean exactly. It's time to clarify this.

Scientific claims about the world around us can be categorized into different types. Some scientific claims describe or explain more phenomena than other claims. Also, some scientific claims provide more plausible descriptions or explanations of the world around us. We find some claims to be more certain, better supported by evidence, than others. In *science* the most basic claim is an **observation**. An observation can be an accurate or inaccurate representation of the world. Suppose I observe that my cat, which has a ginger-colored coat weighs 6.5 kilograms.

Most scientists would accept this observation as a probably fairly accurate reflection of a specific aspect of the world around us, assuming the weight scale is valid and reliable. But in terms of explanatory power, they would find this observation very uninteresting, because an observation on it's own is not very informative; it doesn't describe a ***general relation between properties*** and it doesn't ***explain*** anything.

That doesn't mean observations are unimportant; Observations are the *building blocks* of the empirical sciences. But they're not very useful on their own. An observation on its own is the least interesting type of scientific claim since it has no explanatory power. Observations become useful when they are used to confirm or contradict a **hypothesis**. A hypothesis is a statement that describes a *pattern* or *general relation* between *properties*. A hypothesis can also *explain* the pattern that it describes.

Take this hypothesis: ginger cats will on average be overweight more often than cats with a different color fur. And I could extend this hypothesis with an *explanation* for the relation between fur color and obesity, for example by stating that the genes for ginger fur color and signaling fullness of the stomach are linked.
The plausibility of a *hypothesis* can range from very uncertain to very certain. A hypothesis can be unsupported and therefore uncertain, for example if it's new and still untested. A hypothesis can also be strongly supported by many empirical studies and therefore more certain.

A special type of hypothesis is a **law**. Laws are very precise descriptions of relations or patterns; so precise that they are usually expressed as mathematical equations. They are also generally very well-substantiated; that's how they got so precise.
For example if I drop my cat's food bowl from a height of 56 meters and I know the earth's gravitational constant, then I can predict very accurately how long it will take for the bowl to hit the ground, by using Newton's gravitational laws. Laws allow for very precise predictions, but they usually don't *explain* the relationships they describe, in this case between distance, time and gravity.

Of course in the social sciences laws are hardly ever formulated. We understand too little of people and groups yet to be able to specify patterns in their behavior with such a degree of precision that we can postulate scientific laws.

Ok, so this leaves us with the term **theory**. In day-to-day life 'theory' means an unsubstantiated statement, an educated guess. In *science* however, 'theory' refers to a broad, overarching explanation of many related phenomena. In the natural and behavioral sciences, a theory is built up out of hypotheses that are *very strongly supported by empirical evidence*.

In the social sciences, where *qualitative* and *historical comparative approaches* are more dominant, a theory is considered highly plausible when it has withstood attempts to refute it, based on logical grounds as well as historical or qualitative analysis. So in science, theories are the most well-established explanations, the closest thing to certainty that we have, because they consist of hypotheses that have survived the scrutiny of the scientific method.

Of course this doesn't mean that scientific theories are certain or true. There have been many well-substantiated theories that were ultimately replaced, like Newton's mechanics that made way for the special theory of relativity. In science there is no certainty, only a provisional best explanation.

1.04 Origins: Classical period

The first thinkers to seek natural or earthly explanations instead of divine explanations were ancient Greek scholars like Thales, Pythagoras and Democritus. But the first to really consider *how* to obtain knowledge were Plato and Aristotle, more than 2.300 years ago.

To **Plato** the external world and the objects in it are just imperfect reflections, or shadows, of '*ideal*' forms. These ideal forms are often portrayed as casting shadows on a wall. Plato was a philosophical *realist*; he thought reality, in his case the world of forms, exists *independently* of human thought. To Plato these forms are not just abstract concepts in our mind, they really exist, but separately from the physical world.
Plato thought that since the physical world we see is an imperfect reflection of reality, we can't learn the true nature of reality through sensory experience. He insisted that knowledge about the ideal forms can only be gained through *reasoning*. Plato is therefore referred to as a *rationalist*.

Plato's student **Aristotle** was a *realist*, just like Plato. He thought that reality exists independently of human thought. But to Aristotle reality *is* the physical world. There is no separate plane of existence where abstract forms live.
Aristotle also disagreed with Plato on how we can gain knowledge about the true nature of things. Aristotle was an *empiricist*. He believed our

sensory experience gives an accurate representation of reality, so we can use our senses to understand it. He believed that ultimately, knowledge comes through *observation*.

But that doesn't mean Aristotle was interested in observations only. He still saw reasoning as the best way to understand and *explain* nature; he in fact developed **formal logic**, more specifically the *syllogism*. Here's an example of a syllogism:
"All humans are mortal, all Greeks are humans, and therefore all Greeks are mortal". If the two premises are true, then the conclusion is necessarily true. By using this conclusion as a premise in a new syllogism, our knowledge builds.

Of course this only works if the premises are true. Consider this one: "All mammals are furry, all cats are mammals, therefore all cats are furry". The first premise is false, which means the conclusion is not necessarily true. Not a good basis for building knowledge! So how can you be sure a premise is true? Well you can prove it using another syllogism, but of course you have to keep proving *those* premises, so there has to be a set of starting premises that you can accept as undisputedly true.

According to Aristotle these **fundamental premises** can be determined through *observation* of basic patterns or regularities in the world. Unfortunately he wasn't aware that some of his own observations were too selective, leading to fundamental premises that we know now are just plain wrong. For example, he thought, based on his observations, that insects have four legs, and that men have more teeth than women.

Aristotle probably came to these conclusions based on observations of the mayfly which walks on four legs, but like other insects actually has six legs; it's also likely that he examined his own teeth and those of male friends but only examined the teeth of servant-women who were more likely to be malnourished and have less teeth. He didn't realize it, but his observations were inaccurate. Even so, Plato's and Aristotle's views remained dominant for almost 2000 years! It took until the end of the 16th century for people to realize that Plato and Aristotle's views were flawed.

How did the scientific method develop after Plato and Aristotle? Well, the ancient Greeks made many scientific advances. For example, **Ptolemy** described the movement of planets by placing the earth at the static center of the universe with the planets, including the sun, in a circular orbit, each moving in their *own* little cycle along their orbital path.
These cycles within cycles were necessary to explain the weird phenomenon of retrograde motion, where planets would sometimes move backwards. Ptolemy's model allowed for accurate predictions, but it's thought that people didn't really believe that it described the *actual* motion of the planets; it only *'saved the phenomena'*.

After the demise of the Greek city-states, during the rise and fall of the Roman Empire and the first centuries of the middle ages, very few scientific advances were made. Plato's and later Aristotle's philosophical ideas remained dominant until a new scientific revolution at the end of the 16th century, starting the age of enlightenment.

But, let's look at the developments that led up to that revolution. First, around the turn of the 10th century, Arab and Persian scholars such as **Ibn al-Hasan**, **Al Biruni** and **Ibn Sina** started using *systematic observation* and *experimentation*, emphasizing *unbiased observation* and not just logical reasoning.
Second, building on the work of their predecessors, the Englishmen **Grosseteste** and **Roger Bacon** advocated the use of both *induction* and *deduction*. Induction means using particular observations to generate general explanations. Deduction means predicting particular outcomes based on general explanations.
A third important development was the invention of the printing press. This created the perfect conditions for a scientific revolution. More scholarly works became available to a wider audience. Among these works was "*De revolutionibus orbium coelestium*" by **Copernicus**.
This was the fourth important development to lead up to the scientific revolution. In Copernicus' new model of planetary motion, the planets, including earth, moved in circles around the *sun*.

Now this didn't exactly agree with religious doctrine; the Church accepted Aristotle and Ptolemy's model with *earth* at the center of the universe. Many historians believe Copernicus was afraid to publish his work because he feared the Church would punish him for contradicting their doctrine. He did eventually publish his new model. But he added a special dedication to the pope, arguing that if *Ptolemy* was allowed to formulate a model with strange cycles that only *'saved the phenomena'*, well then he should be given the same freedom.

He was implying that *his* model was also intended, not as an accurate representation, but just as a pragmatic model. Whether he truly believed this is unclear. He died shortly after the publication, which actually did not cause an uproar until 60 years later.
Now according to many the scientific revolution and the age of enlightenment started with Copernicus. But others feel the honor should go the first man to refuse to bow to the Catholic Church and maintain that the heliocentric model actually described physical reality. This man of course, was **Galileo Galilei**.

1.05 Origins: Enlightenment

Galileo is considered the father of modern science because he set in motion the separation of science from philosophy, ethics and theology, which were all under strict control of the Catholic Church. Others had already quietly advocated a scientific approach based on observation and experimentation, instead of using theological reasoning. But Galileo was the first to do this very explicitly.

He also opposed several of Aristotle's theories, which were accepted by the Catholic Church as doctrine. For example, he disproved the Aristotelian view that heavy objects fall to the earth more quickly than lighter objects. Galileo did this with a thought experiment, showing that besides observation, he also valued logical reasoning.

Of course he is most famous for disputing the Aristotelian and Ptolemaic view that the earth is the center of the universe. He supported Copernicus' heliocentric view, where the sun is the center of the universe. Galileo made systematic observations of the planet Venus that could only be explained if the planets revolved around the sun, instead of earth.
Now, to Copernicus the heliocentric model just '*saved the phenomena*', meaning that the model accurately predicts our observations of planets, but that it doesn't actually correspond to physical reality. In contrast, Galileo had no problem claiming that the earth really revolves around the sun. The Catholic Church did not appreciate Galileo's disruptive ideas. They brought him before the inquisition and put him under house arrest until his death.

René Descartes, of the Cartesian coordinate system, was a contemporary of Galileo. Although Descartes also rejected many of Aristotle's ideas, Descartes did agree with Aristotle that knowledge should be based on first principles. Because he felt our senses and mind can be easily deceived, he decided to discard every notion that is even the least bit susceptible to doubt. And once he had removed everything that he doubted, he was left with only one certainty, namely that he thought and therefore he must exist. '*Cogito ergo sum*'. This eventually led him to conclude that we only know the true nature of the world through reasoning.

Francis Bacon thought, just like Descartes, that scientific knowledge should be based on first principles. But in contrast to Descartes, Bacon maintained that this should happen through *inductive methods*. Induction means that observations of particular instances are used to generate general rules or explanations. Suppose every time I've encountered a swan, the swan was white. I can now induce the general rule that *all* swans are white.
Bacon believed that all knowledge, not just the first principles, should be obtained only through this inductive method, generating explanations based on sensory experiences. This is why he is considered the father of **empiricism**, where empiric means relating to experience or observation.

Now, David **Hume** took empiricism to the extreme, accepting *only* sensory data as a source of knowledge and disqualifying theoretical concepts that didn't correspond to directly observable things. This led him to conclude that the true nature of reality consists only of the features of objects, not of the physical objects themselves. This extreme form of empiricism is called **skepticism**.
I'll give you an example. Let's take as a physical object a cat. Now what makes this cat a cat? Well its properties: its tail, whiskers, coloring, fur and body shape... If you take away all the properties that make it a cat you are left with… well, nothing. The essence of the cat is in its features.

Hume also showed us the **problem of induction**: even though you've consistently observed a phenomenon again and again, there is no guarantee

your next observation will agree with the previous ones. For a long time, from the perspective of Europeans at least, all recorded sightings of swans showed that swans are white. Only after Australia was discovered did we find out that there are also black swans.
In other words, no amount of confirmatory observation can ever conclusively show that a scientific statement about the world is true. So if you require that all knowledge must be based on observations alone, that means you can never be sure you know anything!

Partly in reaction to Hume's skepticism, at the start of the 19th century a philosophical movement known as **German idealism** gained popularity. The idealists believed that we mentally construct reality. Our experience of the world is a mental reconstruction. Scientific inquiry should therefore focus on what we can know through our own reasoning. Now, the Idealists concerned themselves mainly with questions about immaterial things like the self, god, substance, existence, causality. They were also criticized for using obscure and overly complicated language.

On the eve of the Second Industrial Revolution around the turn of the 19th century, scientists started to lose patience with the metaphysics of the idealists. Their musings on the nature of being had less and less relevance in a period where scientific, medical and technical advances were rapidly being made.
At the start of the 20th century a new philosophy of science, came on the scene that proposed a radical swing back to empiricism. This movement is called logical positivism.

1.06 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. Analytic statements and synthetic statements. **Analytic 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 analytic statements can be verified with formal logic.
Synthetic statements depend on the state of the world. Examples of synthetic 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.

1.07 Origins: Epistemology

Before you accept the hypothetico-deductive method as the best way to gain knowledge about the world, there are at least two important philosophical questions *about knowledge* that you should answer for yourself.
The first question concerns the nature of reality: What is real, what exists, and therefore what is out there that we can gain *knowledge* of in the first place? The philosophical field that deals with these types of problems is called **ontology**: The study of being.
The second question concerns the way in which knowledge can be **acquired**. Assuming there is a reality out there that is in principle knowable, then what knowledge of reality is accessible to us and how do we access it?

The field of philosophy that is concerned with these types of problems is called **epistemology**, the study or theory of knowledge. I'll start with the last questions first. Assuming there is a reality out there that is knowable, how do we obtain this knowledge? Well there are many different *epistemological* views; I'll just discuss the two most important views here.

First there's **rationalism**. Rationalists hold that knowledge is gained through reason. Using our mind's capability for logical, rational thought, we can deduce truths about the world without having to resort to experience. Philosophers like *Plato* and *Descartes* coupled rationalism with the idea that at least some of the abstract concepts about the structure of nature are *innate, we* were born with them.

That means our mind simply has the capability of understanding these concepts because we already know them. We just have to "remember" or "recognize" them by using our reason.

Empiricism opposes this view. According to the empiricist view, sensory experience is the most important way, according to some strict empiricists even the only way, to obtain knowledge about the world.
Aristotle is considered the first empiricist. He thought that the foundational truths about nature come from sensory experience. We can obtain more knowledge through deductive reasoning, but observation is the basis of all our knowledge.

Aristotle didn't believe in innate ideas, in fact he coined the term "***tabula rasa***" to indicate everyone is born as blank slate: our knowledge is not predefined, the mind is open to any idea. Of course Aristotle wasn't a radical empiricist. He didn't object to rational thought entering into the mix and he wasn't worried about using abstract, not directly observable concepts.

I guess *Galileo* can be considered a moderate empiricist. He put a lot of emphasis on observation and experimentation but he also relied heavily on logical reasoning. Galileo in fact famously said that the book of nature is written in the language of mathematics. He had no problem using thought experiments and included references to "unobservables" in his hypotheses.

Later empiricist such as *Bacon*, but especially *Hume* and the *logical positivists* were very strict empiricists, maintaining that *only* sensory experience could lead to true knowledge about the world. They considered statements about unobservable, universal properties that cannot be observed directly, to be meaningless.

The contemporary flavor of empiricism, is *Van Fraassen*'s **constructive empiricism**. It emphasizes the role of sensory experience in both inductive and deductive methods, but it allows for theoretical terms that don't have physical, directly observable counterparts. In constructive empiricism, the aim is to come up with empirically adequate explanations, which can be considered 'true' – they accurately describe the world - as far as the observables go.
A constructive empiricist would say that the truth or falsity as far as the *un*observables go, simply cannot be determined. This recognizes that knowledge is provisional because it always remains possible that new contradictory evidence will be found someday.

1.08 Origins: Ontology

Let's turn to the subject of **ontology**, or the study of being, which asks: What is the nature of reality? Well, there are many competing views. And before we dive into the philosophical views themselves I'll first explain two main points on which these views differ from each other.

The first main point is whether reality exists *independently* of human thought.
When we refer to objects we perceive in the world, are we referring to *actual entities that exist outside of us*, or are we referring to mental representations that are constructed by our mind and that can only be said to *exist in our mind*?
The second main point concerns the ontological status of **particulars** and **universals**. With particulars I mean specific *instances* or occurrences in which a property can be observed. With universals, or *unobservables*, I mean general properties that cannot be observed directly.

Let me give an example. Love is a general property that we cannot observe directly, but that is instantiated, or expressed, in behavior. So when my cat climbs on my lap and takes a nap, that could be a *particular* instance of the *universal* property 'love'. Another example of an unobservable, *universal* property is gravity. Gravity is expressed in *particular* instances, for example when I drop my cat's food bowl and it falls to the ground.
So let's look at some different ontological views and see where they stand on the question of particulars versus universals and the question whether reality exists externally or only in the mind.

Idealism is a philosophical view that states that reality, as we perceive it, exists entirely in our mind. The existence of an external, physical world is irrelevant, since our perception of it is determined by our mental processes. Reality *is* in effect a mental construct. 'Gravity' and 'Love' exist, but only in our mind. The same goes for their particular occurrences. So an Idealist would say that the cat sleeping on my lap and the bowl falling to the ground are also mental constructions.
The question whether universal, unobservable entities are real, external, independent entities is therefore less relevant for Idealism because both particulars and universals are considered to exist; they're just both mental representations.

Idealism can be contrasted with **materialism.** Materialism is a position that accepts an external world independent of our mind. Materialism also states that everything in this independent physical reality consists entirely of matter. This means that everything is a result of the interaction of physical stuff, including our consciousness, feelings and thoughts. These are all byproducts of our brain interacting with the physical world. The exact opposite of idealism, it's material versus mental! Materialism is only about what stuff is made of. Like idealism, it's not strongly associated with a view on the distinction between universals and particulars.

Realism is a different position. Just like materialists, realists maintain that external reality exists, independent of human thought. But realists also maintain that universals like Love and Gravity are 'real'. In what form these exist depends on your flavor of realism. **Platonic realism** refers to Plato's position that universals like Gravity and Love really exist independently from our observation, but on a separate, abstract plane.

Scientific realism is more moderate and states that it's possible to make consistently supported claims using universals in statements about observable phenomena. In scientific realism, universals like Love and gravity are therefore given the same ontological status as observable particulars. Unobservables are assumed to exist, since they're useful and often even necessary to formulate successful scientific claims.

Finally we have **nominalism.** This view opposes realism as far as universals are concerned; it accepts reality as independent of human thought but denies the existence of universals. In nominalism there is no such thing as Gravity or Love; there are only falling objects and cats that frequently sit in your lap purring. According to nominalists, we just use the terms Gravity and Love because they help us to make sense of the world, but these universals don't actually exist.

1.09 Origins: Approaches

The development of the scientific method I've discussed up until now was focused mainly on the *natural sciences*: physics, astronomy, biology. But during the second half of the 19th century, the social sciences started to arrive on the scene. During this time, people were shifting back to the ontological view of **realism**, which assumes that the physical world is 'real'; the world we perceive is *external* and *exists independently from our thought*.

The *epistemological* view was becoming more '*positivistic'*, meaning that scientists thought that we can gain knowledge about the true nature of the world through observation and experimentation. This realistic, positivistic view was mostly applied to natural phenomena. But as the social sciences developed and became distinct scientific fields, the question rose whether the realistic view should also be applied to social and psychological phenomena.

According to the view called **objectivism**, the ontological position of realism *does* indeed apply. Psychological and social phenomena like 'intelligence' and 'social cohesion' are *external, independent* properties that exist separately from our mental representation of these properties.

Objectivism can be contrasted with **constructivism**. According to constructivism, the nature of social phenomena depends on the social actors involved. This means reality is *not* independent and external; instead, reality is considered primarily a *mental construction* that depends on the observer and the context.

For example, properties like 'happiness' or 'femininity' are not external, not unchanging and cannot be objectively defined. How these properties are perceived and what they mean depends on what culture and social group the observer is part of, and the specific historical period.

So if our psychological and social reality is constructed, subjective and elusive, how do we obtain any knowledge about it? What epistemological position fits the ontological position of constructivism? Well, in fact there's a group of related views, called **Interpretivism**.

These **interpretivist** views all assume that a researcher's experience or observation of a social phenomenon can be very different from how the people who are involved in the social phenomenon experience it themselves. The focus should therefore lie with understanding the phenomenon from the point of view of the people involved.
The three interpretivist views I want to discuss are called **hermeneutics, phenomenology and verstehen**. They differ slightly on how this understanding of psychological and social reality can be gained.

Let's look at **hermeneutics** first. The term hermeneutics comes from the theological discipline concerned with the interpretation of scripture. Hermeneutics aims to explain social phenomena by *interpreting* people's behavior within their social context. Researchers need to take context into account and try to understand how people see the world in order to understand their actions.

Phenomenology is closely related to hermeneutics. It starts from the premise that people are not inert objects. They think and feel about the world around them, and this influences their actions. To understand their actions it is necessary to investigate the meaning that they attach to the phenomena that they experience.
This means investigating how people experience the world from their perspective. And to achieve such an understanding of someone else's experiences, researchers need to eliminate as many of their own preconceived notions as they possibly can.

Verstehen is the third interpretivist view. It has close ties with Hermeneutics and Phenomenology. Verstehen is mainly associated with sociologist Max Weber. Verstehen refers to the empathic understanding of social phenomena. Researchers need to assume the perspective of the research subjects to interpret how they see the world. Only then can a researcher try to explain their actions.
For example, if European researchers investigate 'happiness' in an isolated Amazonian tribe, they should do so from the tribe's perspective, taking the tribe's social context into account. For this tribe, it might be that the community is more important that the individual. This could mean that happiness is considered a group property that does not even apply to individuals. Now in order to grasp such a totally different view of the world, researchers need to immerse themselves in the culture of the person or group they are investigating.

Now of course there are some problems with the constructivist, interpretivist view. First, there is the problem of **layered interpretation**. The

researcher interprets the subject's interpretations, and then interprets the findings again as they're placed in a framework or related to a theory. With every added layer of interpretation there is more chance of misinterpretation.
A second, more serious problem is the **lack of comparability of outcomes**. When in our example happiness is subjective and means different things in different cultures we just cannot compare them. This means we can never come up with general theories or universal explanations that apply to more than just particular groups in particular periods in time.
A third problem is a difference in **frame of reference.** If the frame of reference of the researcher is very different, it can be hard for the researcher to assume the subject's point of view. This makes it hard to find out what the relevant aspects of the social context even are.

The **constructivist-interpretivist** view is generally associated with a **qualitative** approach to science. That means observations are made through unstructured interviews or **participatory observation**, where the researcher becomes part of a group to observe it.
The data are obtained from one or just a few research subjects. The data are analyzed qualitatively by interpreting texts or recorded material.

In contrast, the **objectivist – positivist** view is associated with **quantitative** research methods. Observations are collected that can be counted or measured, so that data can be aggregated over many research subjects. The subjects are intended to represent a much larger group, possibly in support of a universal explanation. The data are analyzed using quantitative, statistical techniques.

Now although a *qualitative* approach is usually associated with a *constructivist* view of science and a *quantitative* approach with an *objectivist* view, there is no reason to limit ourselves to only qualitative or only quantitative methods.
Both approaches have their advantages and drawbacks. For some research questions a qualitative approach is better, in other cases a quantitative approach is more appropriate. In fact, a **mixed-method approach**, where both methods are used to complement each other, is steadily gaining popularity.

1.10 Origins: Goals

Of course the ultimate, general goal of science is to gain knowledge. But we can distinguish more specific **goals**. These goals differ in terms of the *type of knowledge* we want to obtain and for what *purpose* we want to obtain it.

Universalistic research tries to provide explanations that apply generally. For example, we could hypothesize that playing violent computer games leads to aggressive behavior. The specific game, or the type of person playing it, is not relevant here, because we assume the relation between violent game play and aggression holds for any violent game, be it GTA, Call of Duty, any other game. We also assume the relation holds for men and women, of any age, in any cultural setting. Universalistic research aims to describe or explain phenomena that apply to all people or all groups, or societies.

The scientific method can also be used for **Particularistic** research purposes. Particularistic research is aimed at describing or explaining a phenomenon that occurs in a specific setting or concerns a specific group.
For example, we could investigate the change in the number of Dutch teenagers hospitalized for alcohol poisoning just after the legal drinking age was first raised from 16 to 18 years in the Netherlands.
The point here is to investigate the size of an effect for a specific group in a specific location, during a very specific time. We wouldn't necessarily expect to find the same effect in a different country or in ten years time, if the drinking age was changed again.

Ok, so the goal of research can either be universalistic or particularistic. Or in less fancy terms: aimed at obtaining general versus specific knowledge. A very closely related and largely overlapping distinction is between **fundamental** and **applied** research.
Applied research is directly aimed at solving a problem. It develops or applies knowledge in order to improve "the human condition".
Suppose we want to help depressed people and we think that depression is caused by loneliness. We could create a program that aims to lower depression by making people less lonely. We could give lonely depressed people a cat to take care of and investigate if their feelings of depression actually go down now that they're no longer lonely.

Applied research can be contrasted with **fundamental research**. In fundamental research, the aim is to obtain knowledge just "for the sake of knowing"; the only purpose of fundamental research is to further our understanding of the world around us, nothing more. It doesn't have an immediate application; it doesn't directly solve a problem.
For example, we might investigate the relation between loneliness and depression in a large-scale survey study, to see whether people who feel lonelier also feel more depressed, and vice versa.

The aim here is to show there is a *relation* between loneliness and depression. Maybe we want to see if this relation exists for both men and women and for different cultural and age groups. But note that we do *not* state how depression can be treated. The goal is to know more about the relationship, not to help depressed people.

Most *fundamental* research is *universalistic*. But in some cases fundamental research *can be particularistic*, for example when research is done in a very specific setting. For example, we could investigate the relation between playing violent computer games and aggressive behavior in a very specific group of young delinquent first offenders in Amsterdam who all come from privileged backgrounds.
This very specific problem group could provide interesting insight into the relation between violent game play and aggression. Note that we're not

investigating how to rehabilitate or prevent recidivism in this group.

Applied research is often *particularistic*, aimed at solving a problem for a specific group, in a specific context, but it *can be universalistic*. Take the cat-intervention aimed at lowering depression. We could expand this applied research study by comparing a group of people that take care of a friendly cat that seeks their company and a cat that avoids any contact.
This helps us to find out more specifically what type of treatment is effective. But it also adds a universalistic element: we can investigate what it means to be lonely. Is the mere presence of a living being enough, or is interaction required?

In many cases applied research produces results that lead to new insights. These insights can be related to the intervention or treatment, but they can also provide 'fundamental knowledge'. So the two types of research can reinforce each other.