

## The Logical Structure of Knowledge



**Karl Popper**

The discovery of the logical basis of scientific knowledge by the philosopher [Karl Popper](#) is one of the most important achievements in the history of mankind. Unfortunately, his work has often been [misunderstood](#), neglected, or ignored, especially in the field of cancer research. Strategies for the cure of cancer must be based on a logically sound formulation of scientific knowledge.

### **Cancer poses philosophical issues that penetrate to the very heart of science and the scientific method**

A patient with metastatic cancer can have billions of cancer cells spread throughout his or her body. It is likely that every cancer cell is unique and different. Given that it is generally not possible to examine all cancer cells in a patient, what can really be known about cancer? What can be known about cancer given the “fact” that it is an enormously diverse, stochastic, evolutionary process? How do we know what is true? How do we know what to target? How can we formulate a scientific strategy to cure cancer given these limitations?

To answer these questions requires a proper philosophical understanding of the logical basis of scientific knowledge. Addressing these philosophical issues is actually much more important to the formulation of an approach to the cure of cancer than understanding the intricacies of molecular biology.

If cancer is to be understood and cured it must be within the context of the logically sound foundations of scientific knowledge as articulated by Popper.

Since Karl Popper was so deeply concerned about the human freedom and tolerance it is appropriate to explain Popper’s monumental work with an example relevant to human rights and freedom. However, the logical principles discussed below apply to all scientific knowledge and are central to understanding the science behind the Cure Cancer Project.

## Siberia 1944

In 1944 Vice President Henry Wallace and Owen Lattimore, a respected expert on China, toured Siberia in the communist Soviet Union at the request of President Roosevelt. Both were highly impressed and described a land of vitality, populated by hardy, adventuresome, pioneering people. The following are quotes from their writings:

There has probably never been a more orderly phase of pioneering, then the opening up of the Far North under the soviet.... Gay red geraniums in the windows are almost the badge of Siberia ... We visited the gold mines operated by Dalstroi in the valley of the Kolyma,... It was interesting to find, instead of the sin, gin, and brawling of an old-time gold rush, extensive greenhouses growing tomatoes, cucumbers, and even melons, to make sure the hardy miners get enough vitamins!

... **Owen Lattimore**, in National Geographic Magazine [1]

The Kolyma gold miners are big, husky men, who came out of the Far East from European Russia...The miners in Kolyma earned a minimum of 3,000 rubles a month, compared to 800 rubles per month for mine labor in European Russia. Higher wages was the evident incentive that brought the miners into the Far East on their three-year contract... The eight-hour workday is the legal workday in Soviet Russia. Paid overtime was put in as a wartime necessity. These are the actual working conditions we found...It was restful to hear people singing as they strolled along the riverside, the youth playing guitars and accordions...There is something ageless about it, especially the spontaneous group music of the village life.

.....**Vice President, Henry A. Wallace** [2]

The horrific reality and ugly truth could not be more different. Kolyma was a Soviet concentration camp where 3 million slave laborers ultimately died from hunger, disease, abuse and execution.

I am one of the millions of slave laborers who were part of Kolyma's tragic past, and who, like so many nameless others, were slated to become historical dust and pass into oblivion in the Great Soviet Plan. I am one of those who experienced Stalin's cruel terror, through painful incarceration in Kolyma's gold mine and the hard labor camp at Magadan, in the severe arctic climate of Siberia. As one of the fortunate survivors of this insane era of Stalinism, Communism, and dehumanizing slave labor, I feel obligated to write about those who suffered and perished, and to preserve the truth of these events for future generations...

One dose of Stalin's "truth" was presented to the American Vice-President, Henry Wallace, when in 1944 he visited Kolyma. After the visit he left the country with the absolute conviction that "no such camps existed," in total agreement with the British philosopher, Bertrand Russell. Whatever was shown to the man who held one of the highest offices in the USA he accepted it as the truth and presented it in his book "Soviet Asia Mission."

The truth was that during his three-day stay the chiefs of Kolyma did their best to conceal the factual reality. The wooden watchtowers were pulled down, the prisoners were not allowed to leave their barracks and not even the least aspect of prison life was exposed to the American visitor. He was taken to the only farm in the region, 23 kilometers from Magadan, where well dressed and well fed girls, (police women disguised as swineherds), gave a false impression of the agricultural endeavor in that part of the country. He was also flown to the North, to the mine Berelakh, where he found the state mining to be an impressive enterprise. The miners, according to him, were healthy and well-clad men, and more productive than their counterparts in Alaska's Fairbanks. Being served with delicious fresh fish from Kolyma River he offered his compliments to the "presiding chef of the mining camp." The deception was total and successful. The outside world got the firsthand knowledge about Kolyma from the man who deserved his trust. Who would disbelieve or dispute information from the Vice-President of the United States of America, a force for truth and justice?

....**Stanislaw J. Kowalski** [3]

The statistics based on official Soviet archives are detailed in The Black Book of Communism:

If one includes the executions of prisoners, and the deaths in the forced-labor colonies, one can roughly calculate that there were some 600,000 deaths in the gulags in 1941-1943 alone." In the Kolyma region the annual death rate regularly reached 30%. "After a special decree of 22 April 1943, specially reinforced punishment camps were opened up, which in effect became death camps, since the prisoners were exploited in a manner that made survival unlikely.

....**Nicholas Werth** [4]

This tragic case provides a good starting point to examine the underlying logical structure of knowledge. How could two humane and highly educated men confuse a system of slave death camps for a wilderness paradise full of adventuresome pioneers? How does one know what is true and what is false? What is the logical basis of knowledge? These questions troubled philosophers and thinking men for at least two thousand years. Einstein provided a

satisfactory answer. His work was the embodiment of the solution, but it was the philosopher Karl Popper that carried the torch and fully developed the solution to this age-old problem. The answer is so simple, but the implications so profound and far reaching, that like Darwin 's Theory of Evolution's, it apparently evaded discovery and acceptance for thousands of years.

### **There is an inescapable incompleteness in any finite system of logic**

There are certain principles or axioms that cannot be shown to be true or false, that by convention must be at least tentatively accepted. These include the existence of the real world, the existence of truth and basic deductive logic. We can understand the consequences of denying these principles, but only within the context of the principles themselves. There is an inescapable incompleteness. This is true in any finite system of logic.

Mathematics is about logical relationships. In 1930, [Kurt Godel](#) proved that there were meaningful problems in math for which the answer was in principle, unknowable. Prior to that time it had been assumed that a properly formulated statement in math could always be proven true or false. Proof of the existence of problems that could never be known to be true or false, was revolutionary. It demonstrated the [incompleteness](#) of mathematical logical systems. The incompleteness was shown to apply to the consistency of the very axioms or foundations of math. It is unknowable if the axioms of math are consistent or not. [5]

For exactly the same reasons it is unknowable if the real world exists, (everything could just be a dream), if truth exists and if basic deductive logic is correct. If it were all a dream we could create in our minds a better world without cancer and the other scourges of humanity. If only it were so simple. The historical dominance of irrationality over rationality has caused untold human suffering. [6] In addition, it has been, and continues to be, one of the major obstacles to the advancement of science.

### **Within a rational context, how does one ascertain truth?**

What is the logical basis of scientific knowledge? These issues are at the very heart of science. Science is the search for truth and knowledge of the real world. The Kolyma debacle illustrates four points about the logic of knowledge:

#### **I. Authority is not a reliable source of scientific knowledge**

The voice of authority and expert opinion is not a reliable source of truth and scientific knowledge. A person who accepted the reports of Vice President Wallace and Mr. Owen Lattimore would have a grossly false view of Soviet Siberia.

#### **II. Observation is not a reliable source of scientific knowledge**

Observation is not a direct source of truth and knowledge. Wallace and Lattimore described what they observed. But they were skillfully kept from observing the horrible reality of Kolyma . Stalin had invested considerable effort to put on a good show for the Americans. (Nature is even better at hiding its secrets.)

### III. Induction is logically invalid

General conclusions cannot be made from specific observations, even repeated observations that consistently reveal the same thing. No amount of positive observation on happy life in Kolyma could have established the truth of the conclusions of Lattimore and Wallace. The notion that repeated observations (or experiments) that consistently give the same result can be generalized and extended to cases or events not actually observed is called induction. Induction is logically invalid. [i] It has no basis in reality.

### IV. Falsification and the logical basis of scientific knowledge

It would have taken just one reliable observation of the slave labor and death camps at Kolyma for Wallace and Lattimore to know that their rosy conclusions were wrong. This is an important point. No number of observations that confirmed their conclusions could prove their truth, even if in fact their conclusions were true. But, just one observation of the slave camps would have been sufficient to prove it false. The idyllic picture of geraniums, strong and well fed miners would have been shattered by one observation of the horrific slave-labor camps.

### The truth of these four points is a matter of pure deductive logic

These four points encapsulate essential elements of the logical basis of knowledge as articulated by Karl Popper. The points are deceptively simple, but profound in consequence. Popper discovered the logical basis of knowledge by analyzing the problem of induction. Historically the emergence of science coincided with attempts to explain nature on the basis of observation and experimental evidence, combined with logical argument, rather than on the basis of myth and mysticism.

### The problem of induction

The spectacular successes of the empirical, evidence-based scientific method were undeniable. Newton's publication of *The Principia* in 1687 provided a basis for the highly accurate understanding of forces and motion. For over two hundred years predictions based on Newtonian physics were consistently correct. However, the effectiveness of the scientific and empirical method posed a profound dilemma. If observation and empirical evidence were the sole sources of truth and scientific knowledge, how could one infer from the observed to the unobserved? The unobserved transcends experience. How could one ever generalize? There is an internal logical conflict or contradiction.

Yet science seemingly did this all the time. That the sun rose every morning was proof by induction that it will rise tomorrow morning. The philosopher [David Hume](#) forcibly demonstrated that induction was logically invalid and incorrect. Yet without induction, the empirical evidenced based foundations of science seemed like quicksand. The logician [Bertrand Russell](#) summed up the situation as follows:

The general principles of science, such as the belief in the reign of law, and the belief that every event must have a cause, are as completely dependent upon the inductive principle as are the beliefs of daily life. All such general principles are believed because mankind has found innumerable instances of their truth and no instances of their falsehood. But this affords no evidence for their truth in the future, unless the inductive principle is assumed.

....**Bertrand Russell** [7]

Yet Russell was quick to point out both the logical and practical falsity of induction. The logical bankruptcy of induction is illustrated by the following example: For nearly 2000 thousand years Mt. Vesuvius lay dormant. Day after day, generation after generation, people observed the beautiful mountain and saw no signs of danger. Based on past experience and inductive "logic" there was absolutely no reason for concern among the people of Pompeii. On the morning of August 24, 79 AD Mt. Vesuvius erupted with cataclysmic violence and destroyed the city of Pompeii.

**Nature does not follow or respect the rules of inductive logic, neither should people.**

Karl Popper, deeply motivated by Einstein, analyzed the logical implications of abandoning induction. In doing so Popper elucidated the logical basis of scientific knowledge. [8] [9] If we accept deductive logic, the existence of the real world, and the existence of truth, then Popper's basic formulation logically follows. It's that simple and that important. His work is the bedrock foundation of science. Many Nobel Prize winners have cited Popper's work as critical to their own scientific discoveries. However, Popper's work has frequently been taken out of context, distorted, or just wrongly criticized based on misunderstanding.

### **Popper's solution to the problem of induction is simple**

Only the falsity of a theory can be inferred from empirical evidence, and this inference is a purely deductive one.

....**Karl Popper** [10]

There is a logical asymmetry between verification and falsification. [2] No finite amount of observations can establish the truth of a theory. However, one exception that contradicts a theory can prove it false. Since all scientific knowledge must be embedded in observation and experimental data it follows that scientific theories can be proven false, but can never proven true. It follows that all scientific knowledge is provisional or conjectural. Although a theory may indeed be true, and uniformly believed to be true, it is not within the realm of logic to know with absolute certainty that it is true.

## Theories cannot be verified or proven true

The notion that scientific theories and knowledge can be verified or proven to be true by observation or experimental data is logically incorrect. It is inductive in nature and wrong. There is no logical basis for drawing conclusions about the general from observations of the specific. Nor does probability help. Observations on the specific do not make conclusions on the general more probable.

As pointed out by Popper, it is true as a matter of pure logic that falsification of a theory verifies the negation or opposite of the theory. This is true, but trivial. For what is verified lacks general applicability. This does not mean that there is essentially no difference between verification and falsification. This does not alter the logical fact that there is a major asymmetry between falsification and verification. There is a difference in logical power between falsification and verification. The universal or general theory, "*All swans are white*" can be shown to be logically false by demonstrating the existence of one swan that is not white. The demonstration of one non-white swan verifies the opposite of the theory. It verifies the narrow theory that, "*There exists a non-white swan.*" The theory that has been verified applies to the existence of a single non-white swan, has limited applicability, limited logical content and limited to no explanatory power. No finite number of observations of white swans can verify the universal theory that "*All swans are white.*" As a matter of pure logic it cannot be verified. However, it can be falsified by finding a single non-white swan.

It follows as a matter of pure deductive logic that experimental data and observation are not the source of scientific knowledge and truth. Observation can provide knowledge concerning isolated "facts." However, no number of observations can establish the truth of a scientific theory. Repeated observations are necessary to insure that the data are reliable, and not caused by artifacts like dust on the instruments, but the data derived applies only to the particular things observed. The notion that direct experimental evidence proves or validates a theory is a serious logical error. No amount of direct experimental evidence can ever provide "proof of principle." The concept of "proof of principle" is logically incorrect. The concepts of "validation," "verification" and "justification" are all logically incorrect.

## Scientific knowledge is necessarily theoretical

Always! A theory may be accepted as corroborated if it is logically consistent and is not falsified by reliable experimental and observational data. If a theory survives the severest attempts at falsification it can be provisionally accepted. However, two conditions must also apply. The theory must be falsifiable. It must be possible to come up with empirical evidence that could in principle falsify the scientific theory. If not then the theory is not within the realm of science. For example, the question of the existence of god is outside the realm of science. There is no way it could be falsified. In addition, modifications to a theory for the sole purpose of forcing agreement with conflicting evidence are not acceptable, unless the modifications can be independently subjected to empirical falsification.

To appreciate the provisional or conjectural nature of scientific knowledge it is instructive to consider an example. To a scientist who designs drugs, atoms and molecules may seem as real as bricks and mortar. Yet in reality the situation is far more complex. For how real are bricks and mortar as solid objects? Over 2400 years ago Democritus proposed the atomic theory of matter. He proposed that matter consisted of extremely small, invisible atomic

particles. The idea of atoms is now fundamental to science. The entire field of chemistry is founded on the theory of atoms. Yet, until 1908, the existence of atoms was very controversial.

The scientific community was divided on the issue. The famous and highly accomplished physicist, Ernest Mach, stated point blank that he did not believe in atoms. At the time no one had demonstrated the existence of an atom nor had anyone provided evidence that falsified the atomic theory of matter. However, it would have been difficult to explain a huge number of observations in chemistry without atoms.

The existence of atoms was finally thought to have been settled by Albert Einstein's analysis of Brownian motion, for which he received the Noble Prize. Tiny particles such as pollen suspended in water when observed under a microscope can be seen to randomly and constantly bounce around. Einstein derived a mathematical theory of Brownian motion that allowed one to count the number of molecules in a volume by measuring Brownian motion. The particle nature of atoms and molecules was finally solidly established. Or was it?

In 1929 Louis De Broglie was awarded the Noble Prize in Physics for demonstrating the wave nature of matter. Since then multiple experiments have demonstrated that atoms and even molecules as large as 60 carbon atoms can exhibit wave-like properties and can exist in more than one place at a time. [11] So atoms are actually not particles but are waves. Yet, the invention of scanning tunneling electron microscopes allowed the direct visualization of individual atoms. [12] Such is the strange world of nature. On the one hand atoms and molecules are particles and on the other hand they are waves.

Democritus, the father of atomic theory, 2400 years ago, had the last word on the subject. "But in fact, nothing do we know from having seen it; for the truth is hidden in the deep."

### **Trial and error correction**

Hypotheses or theories are put forth related to problems of interest. These are basically bold guesses. Theories are examined and discarded if found not to agree with data derived from experiment and observation. Conflict with another highly corroborated theory needs to be resolved. At least one is wrong and must go. In Popper's words:

The clash between hypothesis and reality... in this alone consists the empirical content of our knowledge... To put it another way we learn only from trial and error.

....Karl Popper [ 13]

Tests are attempted refutations. All knowledge remains fallible, conjectural. There is no justification, including, of course, no final justification of a refutation. Nevertheless we learn by refutations, i.e., by the elimination of errors, by feedback.

...Karl Popper [14]

It should be humbling to know that the only logical basis for scientific knowledge is formulating an educated guess and trial and error. And at the end of the day the only knowledge we have gained is theoretical in nature. It is always provisional and open to question. But this should not convey the message that the scientific method is impotent. It is not only the most powerful, but is the only method available to guide us in the search of truth and understanding of the real world.

**To summarize, the following statements follow as a matter of deductive logic:**

- Expert authority and opinion are not a source of scientific knowledge.
- Observation and experimental data are not direct sources of truth and knowledge.
- General conclusions cannot be made from specific observations.
- Inductive logic is invalid.
- All scientific knowledge is suspect and theoretical.
- Scientific theories can never be proven true.
- A single exception can disprove a scientific theory.
- Observation and experiment are not the logical source of scientific knowledge.
- The illusion that what we observe is truth is very powerful but false.
- Scientific knowledge comes from hypothesis, deductive logic and refutation.
- The role of empirical data is as a means of refutation.

We have hardly done justice to Popper's epoch work and its importance in these few pages. However, this introduction should provide sufficient background for us to resume our analysis of tumor cell evolution and its logical implications.

**Suggested further reading**

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## Footnotes

[i] This is not to be confused with induction in mathematics.

[ii] Verificationism is the logically unsound practice of attempting to prove a scientific theory true.

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