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THE EPISTEMIC PRIORITY OF SCIENCE

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ABSTRACT

To clearly grasp the importance of science, we need to start acknowledging the value of knowledge as constituted by two criteria: its utility and its reliability. However, there are questions concerning the interpretation of both notions. Fortunately, the problem is solvable. The meaning of utility becomes clear when we distinguish between two possible forms of utility: expected and achieved utilities. The meaning of reliability becomes clear when we recognize which form of reliability is the one that is truly achievable.

Key Words:
•*Epistemic hierarchy* •*Utility: expected-achieved* •*Reliability: weak-strong sense* •*Probability of truth.*

For long, truth has been divided into two classes only: *necessary* and *contingent* truths. Thus, the special importance of science could only be understood on the ground that it tells us something about the world that is necessarily true, i.e., the Kantian synthetic a priori judgment. In the history of philosophy, this manner of thinking has long been dominant. This dominance explains why Husserl can confidently make the claim that "we […] recognize that the Cartesian idea of a science (ultimately an allembracing science) grounded on an absolute foundation, and absolutely justified, *is none other than the idea that constantly furnishes guidance in all sciences* and in their striving toward universality whatever may be the situation with respect to a de facto actualization of that idea."[1]

Nevertheless, this long-respected belief is false. The epistemic hierarchy it gives completely misses what we aspire to from knowledge. To grasp this point, we only need to realize that necessary truth is a very strong kind of truth. It is truth where its mere possibility to be false is unthinkable, or, to put it in less psychological terms, *it could not be admitted as a true possibility*.[2] Based on this account, every sentence that is necessarily true cannot be made true by fact, since every occurrence of fact can be just a coincidence. The proof of necessity must be shown prior to the fact. This is a tremendously heavy epistemological burden while there is no clear benefit for carrying it. We can continue to rely on the laws of nature without claiming that these laws are necessarily true.

Indeed, many of us might never feel any need to possess such truth. Members of scientific communities have long embraced this pragmatic attitude. Scientists are hardly bothered by the lack of absolute certainty of their findings, as expressed by the following dictum from Henry Poincare, a prominent nineteenth century scientist. "It is far better to predict without certainty, than never to have predicted at all."[3] It is natural then for the Popperian admission of the tentative nature of sciences to be regarded by most scientists nowadays as part and parcel of scientific practice.

The old ideal of necessary truth is also dangerous. Firstly, it misleads us in understanding the value of science. It makes us consider the tentative nature of science as a sign of weakness that automatically puts scientific knowledge on par with astrology or common soothsaying. Even worse, the old manner of thinking drives us to appreciate *a mere stipulated relation of facts*, which is often made by religion, more than *a hypothesized one*, which is what science is all about, simply because the former is absolutely irrefutable by any experience. The fact that the former cannot increase our knowledge about the world, since we are simply playing with definitions (for example when a priest says that "man is a religious being and if a being is not religious, then it is not a man"), becomes unimportant.

However, albeit the mistake is known, insofar as there is no better alternative it cannot be abandoned. In this essay I develop an arrangement of our epistemic hierarchy that best fits our epistemic aspirations. The basic idea is quite simple and hardly new: the ground to rank the importance of our knowledge consists of two factors: *the degree of utility to be expected* and *the degree of reliability of the expectation*.[4] For brevities sake, I would simply call the former 'utility' and the latter 'reliability'. In this perspective, the importance of certain knowledge, including the scientific one, is determined by *the multiplication between its degree of utility and its degree of reliability*. The idea seems to be fairly simple, even though there is an enormous difficulty to understand what both notions, utility and reliability, really mean. This essay intends to provide a better interpretation of these two notions.

A note in advance: when referring to 'science' or 'scientific knowledge', I mean *the paradigmatic cases* of science, such as physics, chemistry and biology.

1. Utility

> "We want more than mere truth: what we look for is interesting truth – truth which is hard to come by [...] mere truth is not enough: what we look for are answers to our problems."[5]

For some, talking about the utility of knowledge seems to be an outrageous scandal. "It is *the* truth that we must look for," as it is passionately proclaimed. They say that *the* truth is marked by disinterestedness, since it is simply a matter of 'fitting the facts' or 'copying the reality'. However, what is missed from this is the fact that we are never satisfied by merely 'fitting the facts'. We are always looking for some general principle that could connect the experienced facts to our future possible experiences. The founder of pragmatism, William James, realized this point long time ago by asserting that 'truth' is basically a matter of *collaborating* with realities so as to bring about clearer results, and that 'knowing' is principally a matter of getting into *fruitful* relations with reality.[6]

James remarks that throughout the history of knowledge the general principle pursued can actually be categorized into two opposites. Each has its own supporter, which James calls 'the rationalist' and 'the empiricist'.[7] The first type is one who looks for general principles that can make the upcoming facts always *intelligible*. This means that the principles will always fit the facts. Rationalists do not give much care to the predictability of future events. They solely concern themselves with intelligibility. On the contrary, empiricists are only interested in principles that enable us to anticipate future events based on observable facts in the past and the present.

History clearly reveals that what we pursue is never just a copy of reality, *but always a certain way of copying the reality*. It is an act of choice that cannot be free from our interests in life. However, some people are just too fixated with old ways of using words so that an attempt to break with old habits cannot be appreciated. This is why James's remark has often been ridiculed as a self-refuting statement, since *he makes truth analyzable as utility*, which clearly denies 'truth' as disinterestedness.

To avoid the futile controversy with the language-conservatives, it is better to leave the word 'truth' altogether behind and move directly to 'utility', or, to be precise, the utility of knowledge. The utility of knowledge can simply be understood as the serviceability that we seek from knowledge. The magnitude of utility can be measured only after we have clarified the type of serviceability we actually seek. In other words, to be able to measure the degree of utility of a certain form of knowledge we must first decide what kind of utility is considered. So what kind of utility do we actually seek?

The above opposition between rationalist and empiricist shown by James helps us to realize that there are two contrasting types of utility that we may seek. The first kind of utility, which can only be served by knowledge-for-intelligibility, is constituted by *the desire to attain pure psychological bliss*. It is the pleasure of being protected from any possibility from mistakes, which creates a sense of finality in life. This explains why there are people who so willingly and stubbornly hold the statements like "everything happens because of God's will," "every existing thing has its function," or "no misdeed goes unpunished."

We cannot deduce any single fact from these statements. However, this feature is necessary, because it guarantees beforehand that there cannot be anything that can prove the falsity of these statements. My favorite example is how Pangloss, the master philosopher in Voltaire's *Candide*, can still maintain his belief that "all things have been created for the best end" and defend it vigorously in spite of all the terrible miseries that he and his friends have experienced by simply asserting that we should try harder to look beyond the misery to see the hidden benevolent purposes.

The second kind of utility, which can only be served by knowledge-for-prediction, is constituted by *the desire to master our own destiny* and to expand our power to control the reality so that our real options continuously increase.

Knowledge with this form of utility can be regarded as what W.V. Quine calls "a device for working a manageable structure into the flux of experience."[8] Our knowledge in this case is always open to the possibility of error, i.e., when the flux of experience is not flowing as our 'device' predicted. Consequently, no necessary truth can be available.

Science is clearly an enterprise to pursue the second kind of utility and, therefore, its tentative nature becomes natural. The degree of utility of any scientific knowledge or hypothesis can only be measured on that basis. Could it be done objectively? Fortunately, the measurement issue for the second type of utility faces much less difficulties than with the first one, since it simply means that we are looking for the degree of the predictive power of the considered knowledge, and the factors that determine it are basically embedded in the sentences in which knowledge is expressed. In other words, we only need to examine the sentences of the regarded hypothesis, both its syntax and semantics. As a simple example: "the sun will rise every morning" clearly has a higher degree of utility than "the sun will rise tomorrow morning" because it enables us to predict more.

Before going into a more detailed account of the determinant factors of the degree of utility, two things must be noticed when discussing 'the degree of utility'. Firstly, there is always a potential gap between *the degree of utility expected* and *the degree of utility actually received*. And secondly, what we can measure in advance is only the degree to be expected. The degree of utility actually received is solely determined by how things actually work then and hence incalculable. This gap explains the importance of 'reliability', because it is never enough just to have knowledge with a high degree of expected utility; the expectation itself must be reliable. For example, even if the degree of utility of 'every animal is black' is higher than 'every raven is black', but considering reliability, it would be irrational to value the former sentence higher than the latter, since the former is, we know, completely unreliable. The notion of reliability itself will be discussed further in the next section. For now, I would continue the discussion on the degree of utility based on the second kind of utility mentioned above.

The degree of utility of any hypothesis is determined by several factors, which are the hypothesis's level of *determinateness*, its range of *relevancy*, its range of *explanatory domain* and its level of *precision*. These factors will be elaborated below:

i. *The level of determinateness*: knowledge with the second kind of utility will always stipulate some kind of relationship among certain kinds of observable objects, although sometimes not in direct manner, but by using the medium commonly called 'theoretical object'. The relationship itself could be stipulated in various 'levels of determinateness'. The highest level of determinateness comes from the hypothesis that asserts something in the form of 'every *x* is *y*' or 'for every *x* there will be *y*', which Carl Hempel calls the hypothesis of *a universal form*. It enables us to predict the occurrence of *y* each time we observe *x*. The lower level of determinateness comes from the hypothesis that only asserts something in the form of 'for every certain number of *x* occurrence, *y* occurs in a specified percentage', which Hempel calls the hypothesis of *a probabilistic form*.[9] It only enables us to predict the amount of *y* occurrences after we have observed *x* in a certain amount of times. The lowest level would come from the hypothesis that asserts something in the form of 'whenever *x*, *y* is possible', which I call the hypothesis of *a possibilistic form*. This is the lowest one, since we could not make any prediction about the actual occurrence of *y*, no matter how many times we have observed *x*. In short, there are three level of determinateness. It is either universalistic, probabilistic or merely possibilistic.

ii. *The range of relevancy*: the range of relevancy is the extent of spatiotemporal context where the stipulated relationship by the regarded hypothesis is effective and where prediction can be deduced. Knowledge with the widest range is the one that is universally relevant, without any spatiotemporal limitation. The universally relevant hypothesis does not need to be the ones expressible in a universal sentence. A hypothesis such as "there is 90% probability that the sun rises every morning," or "there is a possibility that the sun rises every morning," is as universally relevant as "the sun will rise every morning." We also must be careful not to misunderstand what universally relevant is as something that stipulates the relationship of all the observable things in the world. This misunderstanding comes from confusing the range of relevancy with the third factor below.

iii. *The range of explanatory domain*: the totality of the kinds of observable objects that fall under the relationship stipulated by the hypothesis is the explanatory domain of that hypothesis. It must be noticed that our knowledge could have a narrow (exclusive) explanatory domain but universally relevant, or, on the contrary, a totally inclusive domain but narrowly relevant.

iv. *The level of precision of the prediction*: would the regarded knowledge enable us, at least in principle, to predict a single unique outcome (the maximum precision), or would it only enable us to predict outcomes within a limited range of variation, and how tight would the limit be?

It is true that *the weight* of each factor cannot be decided in a pure objective manner, and thus it must be admitted that comparing the degree of utility of different hypotheses cannot always be done objectively. Nevertheless, there are cases when comparison can be made in an uncontroversial manner, which is when a certain hypothesis, at least, outweighs the other at some factor, but does not lose at any other factor. Such is the case with science. Scientific knowledge shows a superior degree of utility compared to other kinds of knowledge, at least on point number ii and iii, while, in regard of the other factors, it also does not show any inferiority to the other types of knowledge.

The superiority of the scope of relevancy can be clearly seen by the fact that scientific knowledge is basically knowledge about laws, and that scientific laws always have the form of what Popper calls 'strictly universal statement', which is the statement that claims to be true for any place and any time.[10] This maximum range of relevancy explains why scientific laws can do what a mere accidental generalization cannot do, which is, as stated by Hempel, "a law […] can support subjunctive and counterfactual conditional statements about potential instances, i.e., about particular cases that might occur, or that might have occurred."[11] With regard to the explanatory domain, the wider range of scientific knowledge is demonstrated by the fact that the object referred in every sentence of basic scientific laws is never a certain individual or type of natural objects only. Instead, they are theoretical objects that cover several kinds of natural objects.

Some readers might think that by recognizing the two kinds of utility of knowledge I am indeed trying to build a model of harmonious coexistence between science, which is the superior source of the second kind of utility, and other sources of knowledge, be it religion or idealistic philosophy, which is considered as the superior source for the first kind of utility. I make no such attempt here, because coexistence is impossible. The contradictoriness of the desires that constitute each kind of utility should be quite obvious; to pursue the second kind we must have the courage to be fallible; to embrace incessantly some degree of doubt in our heart and to let go any hope for metaphysical comfort. So in the end we could only consistently pursue one of them. Which one then should it be? My answer is definitely the second one, but unfortunately to give a complete defense of my position would need a separate essay.

2. Reliability

We can simply understand reliability as the justifiable degree of belief in a hypothesis's truth. Knowledge is only reliable if it is justified to give a degree of belief that is high enough to make it as the basis of our actions, although we cannot be absolutely certain about its truth. Truth is just another name for a hypothesis with a high degree of reliability. To express this idea mathematically, we can simply say that a reliable hypothesis (hypothesis with a high degree of reliability) is the one that we are justified to hold b (belief) $>$ 0.5. The notion of reliability saves us from the temptation to make the following careless inference: if the truth of all hypotheses is not necessary, the correct degree of belief to be given to each one must be equal.

The notion has its root in the ordinary psychological fact that among the claims of which we cannot give a full degree of belief ($b=1$), since their truth is uncertain, we give a different degree of partial belief ($0<b<1$) to each claim, as could be easily seen in some gambling situations. 'Reliability' originates from our need to refine this psychological tendency. We want our degree of partial belief to be objective, and not determined by our psychological liking. It means that the degree of belief is the one that is indeed reasonable to be given, as remarked by Stephen Toulmin, "trustworthiness, reliability, these are what distinguish an 'objective' estimate of the chances of an event from a mere expression of confident belief."[12]

So far its importance seems convincing. The notion of reliability can only truly be significant if *there is clarity on the matter of applicability*. In other words, how can we actually determine the degree of reliability of the considered hypothesis? On this matter, there are many controversies. The multitude of solutions offered can generally be categorized into two conflicting perspectives. The first type is *the quantitative-probabilistic view*, which defines reliability as something determined by *truth-probability* of hypotheses, which is quantifiable rigorously from acquired evidences. Comparing the reliability of several hypotheses simply means comparing their respected values of truth-probability based on the facts observed. The highest one is the most reliable one.

It is very important to acknowledge the difference between *the truth-probability of hypotheses*, which some thinkers prefer to call the 'probability of hypotheses', and *the hypotheses of probability* or statistical hypotheses. Rudolf Carnap, who states the difference clearly for the first time, names the first concept of probability 'logical/inductive probability', and the second one 'statistical probability'.[13] The latter concept solely deals with the probability of events to occur, while the former one concerns the probability of hypotheses to be true.

The second perspective is *the qualitative view*, which understands the reliability of hypotheses as a matter of the competence of the hypothesis to fulfill *certain qualitative requirements* in its relationship to the facts. Different versions of qualitative requirements have been given, for example, by Karl Popper,[14] Ronald Giere,[15] and Hilary Putnam.[16] The important aspect to be noticed from the requirements is that they are for good reasons called 'qualitative', because they are irreducible to any quantitative concept. So it is not like 'heat', which is reducible to the Celsius or Fahrenheit scale. An example is Popper's idea of 'corroboration'. The corroboration of a hypothesis for Popper cannot be determined only by looking at the number of times the hypothesis has passed the test against facts, since we must also look at the *sincerity* of the test, and this sincerity clearly is not something that we can define quantitatively, as Popper states: "the requirement of sincerity cannot be formalized."[17]

Which alternative gives a better account of reliability? To find the answer we must first be clear about what we seek, because there is indeed room for equivocalness in 'reliability'. When we talk about "the justified degree of belief to be held," we could mean either "the degree of belief that we are obliged to hold," or merely "the degree of belief that we are permissible to hold." Because of the equivocalness, we should distinguish between the two senses of reliability: between *the strong sense*, which deals with the obligatory degree of belief, and *the weak sense*, which only deals with the permissible degree.

The more ambitious project, of course, is to pursue reliability in the strong sense. And it is our starting point. How are we able to determine the degree of belief that people *must* hold? Here, the probabilistic approach proponents have a clear advantage, since *the only credible reason to oblige people to* *hold a specific degree of belief on some hypothesis is that it reflects the hypothesis's actual probability of truth*. In other words, if we seek to be able to determine reliability in its strong sense, then we must take the probabilistic perspective as our basis, whether we like it or not.

However, being the only promising approach does not guarantee that the probabilistic-quantitative view is truly able to give a satisfactory account of reliability in its strong sense. To be hailed as satisfactory, the probabilistic approach must be able to fulfill two basic requirements. Firstly, *correctness*, which means that the truth-probability being measured is indeed regarded as crucially important for us in determining the magnitude of our degree of belief. Second, *relevance*, which means the truth-probability measurement must be applicable to all kind of hypothesis, especially the ones with a high degree of utility. Can the probabilistic approach succeed? Unfortunately, the answer is no; it cannot, as I will demonstrate below.

The first way that can be tried to measure the truth-probability of hypotheses is by using the 'frequency' interpretation of probability, as commonly used in statistics. In this interpretation, probability is regarded as a matter of determining *how often the hypothesis will be true in the total number of cases where the hypothesis is relevant* (see above on relevancy). This type of probability theory seeks to measure the frequency of cases in which a certain hypothesis will be true within the total number of cases where the hypothesis is relevant. The totality of relevant cases itself is usually called the 'reference class' of the hypothesis. Another important point is the number of cases, within the reference class, that must be distributed *randomly*. It means that we cannot identify for sure in which case, within its reference class, the hypothesis will be true.

Hence, under this interpretation, when we say that the truth-probability of the hypothesis "every raven is black" is 80%, what we mean is that the hypothesis will be true *randomly* for 80% of all ravens (the total ravens from the past, present and future). We may be tempted to think that the above sentence is identical with saying that the truth-probability of the hypothesis "80% of raven is black" is 100%. But to do that is to confuse the probability of hypotheses with the hypotheses of probability. Truth-probability only expresses the amount of support given by existing evidences.

Statistics has shown that this kind of truth-probability can be ascertained by the method of 'interval estimates'. The method enables us to infer a hypothesis with a certain limit of precision (usually called *confidence interval*), which has a certain degree of truth-frequency (commonly called *confidence level*) for its reference class, although we only observe a small part of the reference class.[18] There are indeed several cases where the statistical inference has shown to be successful, especially related to public polling. However, this success is limited to certain kinds of hypotheses alone. To see the reason, we only need to remember that the statistical inference can only be done as long the small observed part of the reference class, which is called *the sample*, is indeed representative of the class.[19]

What is needed to have the representative sample? Contrary to what some people may suppose, the size of the reference class itself does not need to be definite. Nassim Nicholas Taleb gives an eloquent formulation to the necessary requirement, which is that the reference class must be an exemplar of 'the Mediocristan world'.[20] Mediocristan world in nothing but a land of mediocrity, where we can be confident that the variety observed cannot differ much from the variety existing in the whole land. Some cases can be safely considered as Mediocristan beforehand, such as when we deal with the public opinions for yes/no questions, or with the frequency of a certain number of dice to show up after being thrown. Yet, a lot more cases in this world can only be regarded as exemplifying the opposite of Mediocristan world, which Taleb calls 'the Extremistan world'. This is the situation where, as reminded by Taleb, "one single number can disrupt all your averages."[21] Just looking at our social life, we can discern several 'extremistan' phenomena, such as wealth or book sales. This shows that the statistical inference based on the frequency interpretation fails to fulfill the requirement of relevance.

However, there is another possible form of probabilistic theory, which is based on the possibilistic interpretation of truth-probability. In this interpretation, the truth-probability of hypotheses is understood as a matter of determining *in how many possible worlds the hypothesis will be true within the totality of possible worlds given from the evidences*. Let me give an illustration to elucidate: suppose we know in the beginning that there are twenty people in the class and that John is one of them. Then, let us imagine that one particular person is called from the class. The truth-probability of the hypothesis "John is the person called from the class" will surely be 1/20 or 5%, which means that from twenty cases made possible by our initial evidence, it will only be in one of them that our hypothesis is true.

Carnap's theory of logical probability is just another name for this kind of probabilistic theory. The adjective 'logical' is suitable since the determination of the truth-probability, as we can see above, is purely a matter of logical inference. "Logical probability," as Carnap maintains, "is a logical relation somewhat similar to logical implication; indeed, I think probability may be regarded as a partial implication."[22] By partial implication, Carnap refers to the condition where the existing evidence cannot conclusively prove either the truth or the falsity of the hypothesis. It can only show the possibility for the hypothesis's truth.

The problem that comes to the fore with this type of probabilistic theory is the typical feature of every logical implication, which is that the information contained in the conclusion cannot be richer than the one contained in the premises. Consequently, it seems that this account of probability will never be able to measure scientific hypotheses because scientific laws contain more information than what can be contained in all empirical data. The problem of relevance haunts us again. Nevertheless, there have been on-going sophisticated attempts since Carnap to save the theory from that problem by modeling the relation between the evidences and the truth-probability of hypotheses as a triadic relationship, which is the relation among the evidences, the hypothesis's degree of truth-probability and our linguistic framework.

I am not interested in examining the prospect of these attempts for now, because I see the more fundamental problem of this type of theory lies elsewhere, which is in the point of *correctness*. To understand the problem we only need to pay more attention to the fact that *we do not have any good reason to say that what is more possible to happen will certainly happen more often*. When we say something is possible, we are simply saying that it can happen regardless of the frequency of its actualization. We are entitled to hold the claim of the possibility of 'X' to exist—God, for example—although the existence of God has never been actualized. Consequently, there is no guarantee that two possible things will actually happen more often than just a single possible thing.

On the other hand, when we give a high degree of a belief on a certain hypothesis, we always expect that the frequency of its truth is high. Frank Ramsey offers a good description: "suppose his degree of belief in p is m/n; then his action is such as he would choose it to be if he had to repeat it exactly n times, in m of which p was true, and in the others false."[23] Since the higher value of possibility cannot give any guarantee about the truth-frequency, its magnitude has no clear signifance to our decision in choosing our degree of belief.

The complete failure of the probabilistic-quantitative approach, while at first it seems promising, leads us to moderate our ambition, i.e. to be satisfied with the weak sense of reliability. This moderation gives us a better appreciation of the qualitative perspective, what we still can try now is to set some qualitative standard, which we find adequate, that ought to be fulfilled by any hypothesis so that it is permissible for us to hold as reliable. The adequate qualitative standard gives us the permit that not only optimally, even though not perfectly, helps us avoid falsity, but it also needs to be conducive to new discoveries of truth and thus to the improvement of human knowledge.

To formulate this kind of standard, it is important to learn from our history of knowledge, especially about how new truths are found and elaborated throughout history. We cannot pretend to know *a priori* which standard will indeed enhance our epistemic activities. Based on the historical consideration, I propose two rules that are sufficient to be adequate standards of reliability:

I. To be permissible to be held as reliable, or, in other words, to be given a high degree of reliability, a hypothesis must have not been disconfirmed in its explanatory domain.
ii. If every hypothesis, after being disconfirmed in its old explanatory domain, can still find a new domain where it is still safe from disconfirmation, then it is permissible to hold the hypothesis as reliable in its new explanatory domain.

Now, one may object to these rules because they seem too plain or generous, since, essentially, they only say that we are not justified to hold a falsified hypothesis as reliable. They permit us to rely on any hypothesis, as long it has not been proved wrong in whatever domain. I admit both the plainness and generousness, but it must be noticed that these qualities do not make the rules easier to follow. Those two rules, albeit their lenient appearance, are actually quite tough for every hypothesis, because, although we may legitimately say that we can negotiate with empirical facts, it must be noted that facts are always hard negotiators. The so-called 'social sciences', such as economics and sociology, are still struggling to find hypotheses that can survive the two rules of reliability.

Only if we go into the paradigm cases of sciences, for example physics, we can find hypotheses that still prove their mettle against facts. The epistemic priority of science has become clear then, for it is not only the best source of knowledge with a high degree of utility, but also our best source of reliable knowledge.

End Notes:

1 Edmund Husserl, *Cartesian Meditations: an Introduction to Phenomenology*, trans. Dorion Cairns (Boston: Martinus Nijhoff Publishers, 1982), 11.

2 Saul Kripke gives a similar description: "is it possible that […] the world should have been different from the way it is? If the answer is 'no,' then this fact about the world is a necessary one. If the answer is 'yes,' then this fact about the world is a contingent one." Saul Kripke, "A priori Knowledge, Necessity, and Contingency," in *Human Knowledge: Classical and Contemporary Approaches*, ed. Paul K. Moser and Arnold van der Nat, (Oxford: Oxford University Press, 2003), 347.

3 Henry Poincare, *Science and Hypothesis* (New York: Dover Publications, 1952), 144.

4 The idea can be traced back to the works of Thomas Bayes in the eighteenth century.

5 Karl Popper, *Conjectures and Refutations: The Growth of Scientific Knowledge* (London: Routledge and Kegan Paul, 1963), 229-230.

6 William James, "Humanism and Truth," in *The Meaning of Truth* (New York: Longman Green, 1911), 61, 81.

7 William James, *Pragmatism: A New Name for Some Old Ways of Thinking* (New York: Longman Green, 1907), 3-7.

8 W. V. Quine, "Two Dogmas of Empiricism," in *From a Logical Point of View* (London: Harper Torchbooks, 1961), 44.

9 The first and second form of determinateness mentioned above are inspired by the distinction made by Hempel between what he calls laws of a universal form, which is, as defined by him as "basically a statement to the effect that in all cases where conditions of kind F are realized, conditions of kind G are realized as well," and laws of a probabilistic form, which asserts "that under certain conditions, constituting the performance of a random experiment R, a certain kind of outcome will occur in a specified percentage of cases." Carl Hempel, "Laws and Their Role in Scientific Explanation," in *The Philosophy of Science*, ed. Richard Boyd, Philip Gasper and J. D. Trout (London: The MIT Press, 1997), 302.

10 Karl Popper, *The Logic of Scientific Discovery* (London: Routledge, 2002), 40-41.

11 Carl Hempel, , "Laws and Their Role in Scientific Explanation," in *The Philosophy of Science*, ed. Richard Boyd, Philip Gasper and J. D. Trout (London: The MIT Press, 1997), 306.

12 Stephen Toulmin, *The Uses of Argument* (Cambridge: Cambridge University Press, 2003), 66.

13 Rudolf Carnap, *Philosophical Foundation of Physics: An Introduction to the Philosophy of Science* (London: Basic Books, 1966), 22.

[14] Karl Popper, *Conjectures and Refutations: The Growth of Scientific Knowledge* (London: Routledge and Kegan Paul, 1963), 232-237.
[15] Ronald Giere, "Testing Theoretical Hypothesis," in *Scientific Knowledge: Basic Issues in the Philosophy of Science*, ed. Janet A. Kourany (California: Wadsworth, 1987), 220-222.
[16] Hilary Putnam, "'Degree of Confirmation' and Inductive Logic," in *The Philosophy of Rudolf Carnap*, ed. Paul Arthur Schilpp (Illinois: The Library of Living Philosophers, 1997), 770-772.
[17] Karl Popper, *The Logic of Scientific Discovery* (London: Routledge, 2002), 437.
[18] See, for example, David de Vaus, *Surveys in Social Research* (London: Routledge, 2002), 84-85, and Henry Kyburg, Jr. and Choh Man Teng, *Uncertain Inference* (Cambridge: Cambridge University Press, 2003), 186-191.
[19] References can be made to several statistics textbooks, such as William D. Crano and Marilynn B. Brewer, *Principles and Methods of Social Research* (New Jersey: Lawrence Erlbaum, 2002), 170-171, and David de Vaus, *Surveys in Social Research* (London: Routledge, 2002), 84-85.
[20] Nassim Nicholas Taleb, *The Black Swan* (London: Penguin Books, 2007), 212-252.
[21] Nassim Nicholas Taleb, 245.
[22] Rudolf Carnap, 32.
[23] Frank Ramsey, "Truth and Probability," in *The Foundations of Mathematics and other Logical Essays*, 156-198, Frank Ramsey and ed. R.B. Braithwaite (London: Kegan, Paul, Trench, Trubner, New York: Harcourt, Brace and Company, 1931), 17.

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