The Philosophy of Logical Positivism

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1 Introduction.

Also known as logical empiricism and neo-positivism, this philosophical school was born in Austria and Germany during the 1920s, and was primarily concerned with the logical analysis of scientific knowledge. Among its members were Moritz Schlick, the founder of the Vienna Circle, Rudolf Carnap, the leading exponent of logical positivism, Hans Reichenbach, the founder of the Berlin Circle, Alfred Jules Ayer, Herbert Feigl, Philipp Frank, Kurt Grelling, Hans Hahn, Carl Gustav Hempel, Victor Kraft, Otto Neurath, and Friedrich Waismann.

Logical positivists denied the soundness of metaphysics and traditional philosophy; they asserted that many philosophical problems are indeed meaningless.

During the 1930s, when Nazism gained power in Germany, the most prominent proponents of logical positivism immigrated to the United States, where they considerably influenced American philosophy. Until the 1950s, logical positivism was the leading school in the philosophy of science. Nowadays, the influence of logical positivism persists especially in the way philosophy is practiced. This influence is particularly noticeable in the attention philosophers give to the analysis of scientific thought and to the integration of results from technical research on formal logic and the theory of probability.

2 The Main Philosophical Tenets of Logical Positivism.

a. Verifiability Principle.

According to logical positivism, there are only two sources of knowledge: logical reasoning and empirical experience. The former is analytic a priori, while the latter is synthetic a posteriori; hence synthetic a priori knowledge does not exist.

> It is precisely in the rejection of the possibility of synthetic knowledge a priori that the basic thesis of modern empiricism lies. (*Wissenschaftliche Weltauffassung. Der Wiener Kreis*, 1929; English translation *The Scientific Conception of the World. The Vienna Circle*, in Sarkar, Sahotra (ed.), *The Emergence of Logical Empiricism: from 1900 to the Vienna Circle*, New York: Garland Publishing, 1996, p. 330).

Logical knowledge includes mathematics, which is claimed to be reducible to formal logic. Empirical knowledge includes physics, biology, psychology, etc. Experience is the only judge of scientific theories; however, logical positivists were aware that scientific knowledge does not exclusively rise from the experience: scientific theories are genuine hypotheses that go beyond the experience.

> It is not possible to establish a logically durable building on verifications [a verification is an observational statement about immediate perception], for they are already vanished when the building begins. If they were, with respect to time, at the beginning of the knowledge, then they would be logically useless. On the contrary, there is a great difference when they are at the end of the process: with their help the test is performed.... From a logical point of view, nothing depends on them: they are not premises but a firm end point. (M. Schlick, "Über das Fundament der Erkenntnis", in *Erkenntnis*, 4, 1934).

b. Elimination of Metaphysics.

The attitude of logical positivism towards metaphysics is well expressed by Carnap in the article *Überwindung der Metaphysik durch Logische Analyse der Sprache* in *Erkenntnis*, vol. 2, 1932 (English translation *The Elimination of Metaphysics Through Logical Analysis of Language*.) A language − says Carnap − consists of a vocabulary, i.e. a set of meaningful words, and a syntax, i.e. a set of rules governing the formation of sentences from the words of the vocabulary. Pseudo-statements, i.e. sequences of words that at first sight resemble statements but in reality have no meaning, are formed in two ways: either meaningless words occur in them, or they are formed in an invalid syntactical way. According to Carnap, pseudo-statements of both kinds occur in metaphysics.

A word W has a meaning if two conditions are satisfied. First, the mode of the occurrence of W in its elementary sentence form (i.e. the simplest sentence form in which W is capable of occurring) must be fixed. Second, if W occurs is an elementary sentence S, it is necessary to give an answer to the following questions (that are − according to Carnap − equivalent formulation of the same question):

> (1.) What sentences is S *deducible* from, and what sentences are deducible from S?
> (2.) Under what conditions is S supposed to be true, and under what conditions false?
> (3.) How S is to *verified*?
> (4.) What is the *meaning* of S?
> (R. Carnap, *The Elimination of Metaphysics Through Logical Analysis of Language* in Sarkar, Sahotra (ed.), *Logical Empiricism at its Peak: Schlick, Carnap, and Neurath*, New York: Garland Pub., 1996, p. 12)

An example offered by Carnap concerns the word "arthropode". The sentence form "the thing x is an arthropode" is an elementary sentence form that is derivable from "x is an animal", "x has a segmented body" and "x has jointed legs". Conversely, these sentences are derivable from "the thing x is an arthropode". Thus the meaning of the words "arthropode" is determined.

According to Carnap, many words of metaphysics do not fulfil these requirements and thus they are meaningless. As an example, Carnap considers the word "principle". This word has a definite meaning, if the sentence "x is the principle of y" is supposed to be equivalent to the sentences "y exists by virtue of x" or "y arises out of x". The latter sentence is perfectly clear: y arises out of x when x is invariably followed by y, and the invariable association between x and y is empirically verifiable. But − says Carnap − metaphysicians are not satisfied with this interpretation of the meaning of "principle". They assert that no empirical relations between x and y can completely explain the meaning of "x is the principle of y", because there is something that cannot be grasped by means of the experience, something for which no empirical criterion can be specified. It is the lacking of any empirical criterion − says Carnap − that deprives of meaning the word "principle" when it occurs in metaphysics. Metaphysical pseudo-statements such as "water is the principle of the world" or "the spirit is the principle of the world" are void of meaning because a meaningless word occurs in them.

There are also pseudo-statements that consist of meaningful words. An example is the word sequence "Caesar is a prime number" that has the same form of "Caesar is a general". These two sentences are well formed in English, because there is not a grammatical distinction between predicates which can be affirmed of human beings (such as "general") and predicates which can be affirmed of numbers (such as "prime number"). Although every word occurring in "Caesar is a prime number" has a definite meaning, the sequence evidently has no meaning. In a logically constructed language - says Carnap - a distinction between the different kinds of predicates is specified, and pseudo-statements as "Caesar is a prime number" could not arise. Metaphysical statements which do not contain meaningless words are indeed meaningless because they are formed in a way which is admissible in natural languages but not admissible in logically constructed languages.

What are the most frequent sources of errors from which metaphysical pseudo-statements arise? A source of mistakes is the ambiguity of the verb "to be", which is sometimes used as a copula ("I am hungry") and sometimes to designate existence ("I am"). The latter statement incorrectly suggests a predicative form, and thus it suggests that existence is a predicate. Modern logic has introduced an explicit sign to designate existence (the sign $\exists$), which occurs only in statements such as $\exists x P(x)$. Therefore modern logic has clarified that existence is not a predicate, and has revealed the logical error from which pseudo-statements such as "cogito, ergo sum" arose. Another source of mistakes is type confusion, in which a predicate is used as predicate of a different type (see the example "Caesar is a prime number").

What is the role of metaphysics? According to Carnap, although metaphysics has not theoretical content, it has a content indeed: metaphysical pseudo-statements express the attitude of a person towards life. The metaphysician, instead of using the medium of art, works with the medium of the theoretical; he confuses art with science, attitude towards life with knowledge, and thus produces an unsatisfactory and inadequate work. "Metaphysicians are musicians without musical ability" (Carnap, *The Elimination of Metaphysics*, in Sarkar, Sahotra (ed.), *Logical Empiricism at its Peak*, p. 30).

c. The Language of Science.
According to logical positivism, a scientific theory is an axiomatic system that acquires an empirical interpretation only by means of appropriate statements called rules of correspondence,

which establish a correlation between real objects (or real processes) and the abstract concepts of the theory. Without such type of statements a theory lacks of a physical interpretation and it is not verifiable, but it is an abstract formal system, whose only requirement is axioms consistency.

The language of a theory includes three kinds of terms:

1. Logical terms, which include all mathematical terms.
2. Observational terms, which denote objects or properties that can be directly observed or measured.
3. Theoretical terms, which denote objects or properties we cannot observe or measure but we can only infer from direct observations.

According to this distinction, the statements of a theory are divided in three sets:

1. Logical statements, which include only logical terms.
2. Observational statements, which include observational and logical terms.
3. Theoretical statements, which include theoretical, observational and logical terms. Theoretical statements are divided in:
   - Pure theoretical statements, which do not include observational terms.
   - Mixed theoretical statements, which include observational terms. Rules of correspondence belongs to this set of statements.

The following table represents the diverse kinds of statements.

<table>
<tr><td colspan="8">Statements</td></tr>
<tr><td rowspan="2">L-statements</td><td rowspan="2" colspan="2">O-statements</td><td colspan="5">T-statements</td></tr>
<tr><td colspan="2">Pure T-statements</td><td colspan="3">Mixed T-statements</td></tr>
<tr><td>L-terms</td><td>L-terms</td><td>O-terms</td><td>L-terms</td><td>T-terms</td><td>L-terms</td><td>O-terms</td><td>T-terms</td></tr>
</table>

With respect to the method of ascertaining their truth or falsity, the statements of a scientific theory are divided in two sets:

1. Analytic a priori statements, whose truth is based on the meaning of the terms of the language. They include logical statements, whose truth is based only on the rules of logic and mathematics.
2. Synthetic a posteriori statements, which are the not-analytic statements.

Another distinction is between:

1. Ax-true or Ax-false statements, which are either a logical consequence of the axioms of the theory or incompatible with the axioms.
2. Contingent statements, which are independent from the axioms of the theory.

The following table represents the diverse kinds of statements.

<table>
<tr><td colspan="4">True</td><td colspan="4">False</td></tr>
<tr><td colspan="3">Ax-true</td><td colspan="2">Contingent</td><td colspan="3">Ax-false</td></tr>
<tr><td colspan="2">Analytic a priori true</td><td colspan="4">Synthetic a posteriori</td><td colspan="2">Analytic a priori false</td></tr>
<tr><td>Logical true</td><td colspan="6">Possible</td><td>Logical false</td></tr>
</table>

The main points of this thesis about the structure of scientific theories are:

- The distinction between observational and theoretical terms
- The distinction between synthetic and analytic statements

- The distinction between theoretical axioms and rules of correspondence
- The deductive nature of scientific theories.

These four points are linked together. Rules of correspondence give an empirical meaning to theoretical terms and are analytic, while theoretical axioms express the empirical portion of the theory and are synthetic. A theory must be a deductive system; otherwise, a formal distinction between the various kinds of sentences and terms is impossible.

d. Observational and Theoretical Terms.
The distinction between observational and theoretical terms depends on the Verifiability Principle. A statement is meaningful only if it is verifiable; however, in scientific theories, there are many statements which are not verifiable, for example, assertions dealing with quantum particles or relativistic gravitational fields. These statements are too abstract for a direct test; strictly speaking, they are meaningless. To avoid such a consequence, different approaches were proposed. According to Schlick, the principles of a scientific theory are not statements, but rules of inference, and so the problem of their meaning does not arise ("Die Kausalität in der gegenwärtigen Physik" in *Die Naturwissenschaften*, 19, 1931). Neurath proposed another solution: the terms which belong to the abstract language of a scientific theory are explicitly definable in a restricted language whose terms describe directly observable objects ("Physikalismus" in *Scientia*, 50, 1931). So a distinction between observational and theoretical terms became crucial. Carnap realized that theoretical terms are not definable by observational ones and he proposed a partial reducibility of theoretical to observational terms ("Testability and meaning" in *Philosophy of Science*, 3, 1936 and 4, 1937). However, it became evident that theoretical terms cannot be eliminated from scientific theories neither by means of definitions nor by means of rules of correspondence.

A result of formal logic, known as Craig's Interpolation Theorem, suggested a possible way in order to eliminate theoretical terms. Let A and B be two set of statements, so that B is a logical consequence of A. Craig proved that (i) there is a set C of statements whose terms are common to A and B, (ii) C is a logical consequence of A, and (iii) B is a logical consequence of C. If A were the set of axioms of a scientific theory and B were the set of observational statements implied by A, then there would be a set C, whose terms are the observational terms which occur in the axioms, and yet C would entail B. It follows that it is possible to translate a scientific theory in an observational language without any loss of deductive power. Given a theory T, it is thus possible to build a theory T* without theoretical terms so that T and T* are equivalent with respect to observational statements; that is, every observational statement O is a logical consequence of T if and only if it is a logical consequence of T*.

Hempel ("The Theoretician's Dilemma" in *Minnesota Studies in the Philosophy of Science*, II, 1958) noted that the theory T* without theoretical terms, in spite of the equivalence (with respect to the observational language) to the original theory T, is not as useful as T. In fact, from an inductive point of view, T and T* are very different. Usually the original theory T suggests certain relations between its concepts, while in T* these concepts are forbidden. The discovery of laws is almost impossible in T*, while it is a natural consequence in T. Moreover, while the number of the axioms of T usually is finite, Craig's Theorem does not assure us of the existence of a theory T* with a finite number of axioms. So T* is almost useless. Theoretical terms are thus necessary in science.

Hempel's "The Meaning of Theoretical Terms" in *Logic, Methodology and Philosophy of Science IV*, 1973, includes a new criticism of the observational-theoretical distinction. The two main points of Hempel's analysis are:

1. Observational terms do not exist. Only a distinction between terms used in a given theory and new terms employed for the first time in a new scientific theory is possible. For example, Bohr's atomic theory includes terms like quantum numbers, quantum jump, steady

state, and explains spectra described with the help of wavelength. Now wavelength is an "old term" while quantum number is a "new term." Thus the abstract concepts of atomic theory are linked with other abstract (but already given) concepts.
2. The meaning of theoretical terms is not defined by analytic statements which are true by convention. In fact, every statement is subject to empirical tests. In a scientific theory, there is no room for "true by convention".

In *Philosophical Foundations of Physics*, 1966, Carnap proposed a slightly different approach to the observational-theoretical distinction. Now the starting-point is the difference between empirical and theoretical laws. It is possible to directly confirm (or disprove) an empirical law, while a theoretical law can be tested only through the empirical laws that are among its consequences. Moreover, an empirical law explains facts while a theoretical law explains empirical laws. Thus there are three levels:

1. Empirical facts.
2. Simple generalizations we can directly test, i.e. empirical laws. They explain facts and are employed to forecast facts.
3. General principles we can use to explain empirical laws, i.e. theoretical laws.

Empirical laws include observational terms, while theoretical terms occur in theoretical laws.

e. Synthetic and Analytic Statements.

The solution to the problem about the meaning of theoretical terms that Carnap proposed in "Beobacthungssprache und theoretische Sprache" in *Dialectica*, 12, 1958 (English translation "Observation language and theoretical language" in *Rudolf Carnap, Logical Empiricist*, 1975) was based on the analytic-synthetic distinction. Carnap's method explains the meaning of theoretical terms and their relationships with observational concepts, gives a method for separating synthetic and analytic sentences, and gives a method for dividing theoretical axioms from rules of correspondence.

Suppose the number of theoretical axioms is finite. Let T be their conjunction and let C the conjunction of all rules of correspondance; let TC the conjunction of T and C. The theory is equivalent to the single axiom TC. Carnap formulates the following problem: how can we find two statements, say A and R, so that A expresses the analytic portion of the theory (i.e., all consequences of A are analytic) while R expresses the empirical portion (i.e., all consequences of R are synthetic)? The empirical content of the theory is formulated by means of a Ramsey sentence (a discovery of the English philosopher Frank Ramsey). Carnap's solution to the problem builds a Ramsey sentence on the following instructions:

1. Replace every theoretical term in TC with a variable.
2. Add an appropriate number of existential quantifiers at the beginning of the sentence.

Look at the following example. Let $TC(O_1 \ldots O_n, T_1 \ldots T_m)$ be the conjunction of *T* and *C*; in *TC* there are observational terms O_1 ... O_n and theoretical terms T_1 ... T_m. The Ramsey sentence *R* is

$$\exists X_1 \ldots \exists X_m TC(O_1 \ldots O_n, X_1 \ldots X_m)$$

Every observational statement which is derivable from *TC* is also derivable from *R* and vice versa; thus R expresses exactly the empirical portion of the theory. Carnap proposes the statement $R \rightarrow TC$ as the only rules of correspondence; this became known as the Carnap sentence, and it is the searched sentence A expressing the analytic portion of the theory. Note that every empirical statement that can be derived from the Carnap sentence is logically true, and thus the Carnap sentence lacks empirical consequences. So, a statement is analytic if it is derivable from the Carnap sentence; otherwise the statement is synthetic. The requirements of Carnap's method can be summarized as follows: (i) non-logical axioms must be explicitly stated, (ii) the number of non-logical axioms must be finite and (iii) observational terms must be clearly distinguished from theoretical terms.

f. Probability and Inductive Logic.

There were two different theories about probability proposed by the logical positivists:

- Frequency Interpretation: the probability is the limit of a frequency.
- Logical Interpretation: the probability is the degree of confirmation a statement receives from a given set of other statements.

According to Reichenbach, the meaning of a statement such as "the probability of P given Q is *r*" is that the limit of the relative frequency of objects P in the set of objects Q is *r*. That is, in a large sample of the set Q [say *m* objects from Q, where *m* is great] there are *n* objects P, and lim (n/m) = *r*, as *m* tends to infinity. Therefore Reichenbach asserted that a statement about the probability of a *single* event is meaningless. A statement about the probability of a single event - Reichenbach asserted - is an abbreviation: it refers to a whole series of events to which the event in question is assigned.

A fundamental problem regarding probability is "Why are we justified in inferring that the observed relative frequency in a sequence of events will be preserved in a future continuation of the sequence?" (Reichenbach, *Selected Writings*, vol. 2, D. Reidel: Dordrecht, Holland, 1978, p. 339). This question - according to Reichenbach - is connected with the problem of induction. Suppose that the event B has happened *m* times among *n* events. Thus induction suggests that the probability of B is (m/n) ± δ, for a small value of δ. This conclusion is not necessarily true. Instead, induction supplies an asymptotic rule that, if the sequence has a limit of the frequency, eventually arrives at reliable predictions. Reichenbach admits that this inductive inference cannot be justified logically. However, this is not a problem, because in general probability statements are not meaningful in a two-valued logic, in which every statement is true or false. As Reichenbach said,

> we do not infer from this fact that the justification of probability statements is impossible. We merely infer that the assumption of two-valued logic alone will not help. It is not possible to justify the system of scientific statements simply on the basis of deductive logic together with observational reports; this is our epistemological result. (ibid. p. 342).

According to Reichenbach, the two truth-values, true and false, must be replaced by a continuous scale of probability. Hume's problem of induction is thus "resolved on the grounds that the demand for a justification of probability in terms of deductive logic is unreasonable" (ibid. p. 344).

Reichenbach's attitude towards induction and probability is in many respects dissimilar from the point of view of the other logical positivists, and frequently it seems in explicit opposition to Carnap's interpretation of probability. The following assertion, cited from Reichenbach's review of Carnap's *Logical Structure of the World*, is symptomatic of the differences between Carnap and Reichenbach.

> It is a puzzle to me just how logical neo-positivism proposes to include assertions of probability in its system, and I am under the impression that this is not possible without an essential violation of its basic principles (Reichenbach, *Selected Writings*, vol. 1, p. 407).

Reichenbach's interpretation of probability seems very similar to Richard von Mises' frequency interpretation, and often these two interpretations are presented together. However, when Russell presented Reichenbach's theory as a development of von Mises' theory (Russell, *Human Knowledge*, 1948), Reichenbach wrote in a letter to Russell that his theory cannot be considered a development of that of von Mises. Reichenbach asserted that his first publication on probability had a frequency interpretation and was earlier than von Mises' publications. Moreover, Reichenbach said that von Mises' theory lacks of an application to the theory of induction and it is not connected with the logical symbolism.

Reichenbach used his frequency interpretation to give a measure of the probability of a theory. Suppose that T is a scientific theory; let

$\varphi_1(x_{11}) \ldots. \varphi_1(x_{1k})$

$\varphi_2(x_{21}) \ldots. \varphi_2(x_{2m})$

$\varphi_3(x_{31}) \ldots. \varphi_3(x_{3n})$

....

$\varphi_r(x_{r1}) \ldots. \varphi_r(x_{rp})$

be an enumeration of the testable propositions that are deducible from T. For example, $\varphi_1(x_{11})$ might stand for "The Geiger counter is deflected at moment x_{11}", $\varphi_1(x_{12})$ might stand for "The Geiger counter is deflected at moment x_{12}", and so on; $\varphi_2(x_{21})$ might stand for "A flash of light occurs at point x_{21} of the screen", $\varphi_2(x_{22})$ might stand for "A flash of light occurs at point x_{22} of the screen", and so on. Every line represents a propositional sequence; thus the first line represents the propositional sequence φ_1, the second line represents the propositional sequence φ_2, and so on. The probability of a propositional sequence is the ratio of the positive outcomes to the total outcomes, that is it is the ratio between the number of testable propositions that are true and the total number of testable propositions; in other words, this probability is the relative frequency of the true testable propositions. Let $W(\varphi_i)$ be the probability of the propositional sequence φ_i; thus, according to Reichenbach, the *first-form probability* W(T) of the theory T is $W(T) = W(\varphi_1) \cdot W(\varphi_2) \cdot \ldots \cdot W(\varphi_r)$.

Reichenbach defined also a *second-form probability* for a theory T: it is the probability of the statement "The first-form probability of T is q". This distinction is analogous to the distinction between the probability of the statement "Side six shows when the die is thrown" and the probability of the statement "The probability that side six will show when the die is thrown is 1/6".

Carnap distinguished between two concepts of probability: statistical probability and logical probability. A statement about statistical probability belongs to the language of scientific theories and describes something about the facts of the nature. Hence it is an empirical statement (a synthetic statement), whose truth can be determined only by means of empirical procedures. On statistical probability Carnap agreed with Reichenbach's frequency interpretation. A statement about logical probability is an analytic statement, independent from the experience, whose truth is determined a priori.

Carnap's works on probability were mainly dedicated to an explication of the concept of logical probability. Let P(*h*,*e*) be an abbreviation for "logical probability of *h* with respect to *e*". Carnap distinguished four aspects of the meaning of P(*h*,*e*).

1. P(*h*,*e*) is the degree of the inductive support that the evidence *e* gives to a hypothesis *h*. It is determined by the semantic relation between the set of statements describing the evidence *e* and the set of statements describing the hypothesis *h*. In his late works, Carnap discarded this interpretation.
2. P(*h*,*e*) is a fair betting quotient for bets on *h*, where *e* is the total evidence. Carnap remarked that this interpretation is valid only if the risked amount is small compared to the fortune of the gambler.
3. P(*h*,*e*) is an estimate of a relative frequency. In this interpretation *e* describes the evidence, and *h* is a hypothesis assigning a property, say M, to an object which is not described by *e*.

Thus P(*h*,*e*) is an estimate of the relative frequency of M in every class of objects that are not described by *e*. This interpretation gives a link between logical and statistical probability.

4. Let X be a rational agent and let U_X be the utility function of X [i.e., for every object O, the value of U_X (O) is a measure of the utility of O for X]. Consider the following offer: "X receives an object O if and only if the event *h* occurs". The value V of this offer for X is given by the formula $V = P(h,e) \cdot U_X(O)$, where *e* is the evidence. The rational agent X must accept the offer with the higher value V. In this interpretation logical probability is linked to the theory of decision.

Waismann proposed a logical interpretation of probability in his work "Logische Analyse des Wahrscheinlichkeitsbegriffs" in *Erkenntnis*, 1, 1930. His starting-point is Wittgenstein's interpretation of probability. According to Waismann, we have to use the theory of probability when we do not know whether a proposition is true or false. In that circumstance, we can study the logical relationships between the statements that express our knowledge and we can determine their relative probability. Hence a probability is a mathematical measure of a logical relationship between propositions. What is the role of frequency in the logical interpretation? First of all, it is possible that we know so little about a physical condition that we can determine the probability only a posteriori by means of the frequency. Therefore, the relative frequency and the logical probability are obviously equal. In other circumstances, we can predict the probability through our knowledge of the relevant conditions and physical laws. In such situation, the frequency is used to verify the forecast.

g. Ethics.

A consequence of the Verifiability Principle is that statements about ethical principles are neither true nor false - they are expressions of feeling. Therefore a theory of ethics is impossible. But if ethics is meaningless, a question rises: what is the origin of ethical principles? Among logical positivists, Schlick was the most interested in ethics. He endeavored to give an account of ethics which was compatible with logical positivist philosophy. According to Schlick, ethics is a descriptive scientific theory. A person always prefers those conditions that do not produce pain or produce pleasure; good is whatever gives pleasure and no pain. Good is thus equivalent to beneficial. A person's actions are caused by a wish to benefit. So, the first ethical impulse is an egoistic one. But the motivations to act are not static - they are subjected to the natural evolution and selection. In a society, it is possible that an altruistic way of action is more beneficial than a purely egoistic one. So, there is a contrast between the very first impulse, which suggests an egoistic behavior, and the tendency to act generated by evolution, which suggests a social behavior. This is the origin of ethical principles.

3 History of Logical Positivism.

a. Before Logical Positivism.

What were the main philosophical and scientific outcomes that influenced the rise of logical positivism? First of all, the Theory of Relativity exerted a great influence the early development of logical positivism, not only because of its scientific importance, but also for the philosophical suggestions that Einstein's work contains. The first published work on the Special Theory of Relativity (Einstein's 'Elektrodynamik bewegter Körper' in *Annalen der Physik*, 17, 1905) begins with a discussion on simultaneity and length which is one of the most rigorous applications of the Verifiability Principle, about twenty years before Schlick's formulation. Moreover, one of Carnap's first works was an essay about the theory of space published in 1922. Reichenbach attended Einstein's lectures on the Theory of Relativity at Berlin in 1917 and wrote during the 1920s four books on that theory, and in 1915 and 1917 Schlock wrote two essays on the Theory of Relativity.

The development of formal logic exerted a great influence on logical positivism. Carnap attended three courses on logic under the direction of Gottlob Frege, the father of modern logic. From a philosophical point of view, Frege asserted that all arithmetic statements are analytic a priori, and thus he denied the existence of synthetic a priori statements in arithmetic (note that for Frege geometry is synthetic a priori, because it is not reducible to logic). Therefore, in Frege's opinion, analytic statements are those that are logically true. K. Gödel, the logician who proved the completeness of first order logic and the incompleteness of arithmetic, was a member of the Vienna Circle. Logical positivists had extensive contacts with the group of Polish logicians who developed several branches of contemporary logic. Polish philosophy was significantly influenced by Kazimierz Twardowski (1866-1938), who studied at Vienna and taught at Lwow. Twardowski is the founder of Polish analytic philosophy. He taught several Polish philosophers and logicians, among them were:

- Jan Lukasiewicz (1878-1956), who developed both the algebra of logic and a many-valued propositional calculus, which influenced Carnap's inductive logic and Reichenbach's interpretation of quantum physics, in which Reichenbach employed a three-valued propositional calculus.
- Stanislaw Lesniewski (1886-1939), who was interested in the logical antinomies.
- Kazimierz Ajdukiewicz (1890-1963), who taught philosophy of language, epistemology and logic.
- Tadeusz Kotarbinski (1886-1981), who asserted that many alleged philosophical problems in fact are scientific problems; that is, they are the object of empirical science and not of philosophy, which deals with logical and ethical problems only.

Lukasiewicz and Ajdukiewicz published several essays in *Erkenntnis*, the journal of logical positivism that was edited by Carnap and Reichenbach.

Alfred Tarski (1902-1983), who developed the theory of semantics for a formal language, took part to the congresses on scientific philosophy organized by the Vienna Circle and the Berlin Circle. He greatly influenced Carnap's philosophy of language.

The Italian mathematician Giuseppe Peano (1858-1932) indirectly influenced the logical research of the logical positivists. He developed a logical symbolism adopted by Russell, now widely used. He proposed five axioms as a definition of the set of natural numbers. Gödel proved the Incompleteness Theorem with respect to Peano's axiomatization.

Bertrand Russell's (1872-1970) mathematical logic exerted a major influence on logical positivism. Russell asserted the analytic character of the whole of mathematics. He endeavored to prove this assumption in his works *Principles of Mathematics*, 1903, and *Principia Mathematica*, 1910-13 (the last written with A. N. Whitehead). *Principia Mathematica* is a skilful application of logic to mathematics which gives rise to endless philosophical and technical research.

Ernst Mach (1838-1916) – the physicist and philosopher, who taught physics at the University of Prague and theory of inductive science at Vienna – is regarded as a great source of inspiration to logical positivism. The official name of the Vienna Circle was Verein Ernst Mach, that is, Ernst Mach Association. He was a radical empiricist. He criticized the absolute theory of space and time advocated by Newton and Kant; he published a philosophical and historical analysis of classical mechanics; and he formulated the principle of economy of thought, according to which scientific theories are useful tools to make predictions, but they do not reflect an objective and independent reality. Mach's influence on early logical positivism is unquestionable. However, there are many differences between Mach and logical positivism. For example, Mach never accepted the reality of physical atoms. This extreme anti-realism was not congenial to logical positivism. Schlick, at least in the first stage of his philosophical development, was a realist. He believed that science can give us a true description of an external world. He professed his admiration for Mach, but also asserted that Machian anti-realism was too extreme and did not correctly depict the real activity of scientists. It must be noted that Schlick, under the influence of Wittgestein's *Tractatus*, eventually asserted that only statements without quantifiers are meaningful and thus scientific laws are not statements, but they are rules of inference, prescriptions to make forecasts. Hence, Schlick partially rejected his realism and accepted an interpretation of scientific laws similar to Machian economy of thought.

Wittgenstein's *Tractatus Logico-Philosophicus* exerted a remarkable influence on the Vienna Circle. Many meetings were dedicated to a point-by-point analysis of that work. Not all of the logical positivists' reactions to the *Tractatus* were positive, however. According to Neurath, it was full of metaphysics. Carnap (in his autobiography published in *The Philosophy of Rudolf Carnap*) said that Wittgenstein's influence on the Vienna Circle was overestimated. Moreover, Wittgenstein did not take part in the Vienna Circle's discussions; there were separate meetings between him, Schlick, Carnap, and Waismann. Wittgenstein's influence is evident in the formulation of the Verifiability Principle (see for example proposition 4.024 of the *Tractatus*, where Wittgenstein asserts that we understand a proposition when we know what happens if it is true, and compare this with Schlick's assertion "The definition of the circumstances under which a statement is true is perfectly equivalent to the definition of its meaning"). Wittgenstein influenced also the interpretation of probability. He asserted that every statement is a truth function of its elementary statements (Note: Wittgenstein employed the term elementary statement [Elementarsatze], while the term atomic proposition was used by Russell in his introduction to Tractatus). For example, (AvB) is a statement whose truth depends on the truth of its components A and B, according to the following truth-table:

A	B	AvB
T	T	T
T	F	T
F	T	T
F	F	F

Now suppose we know (A v B) is true and we want to know whether A is true. In the first, second and third row of the truth-table (A v B) is true. In two of those rows A is true too. So there is a probability 2/3 that A is true. That is, the probability of A given (A v B) is 2/3. The probability is thus a logical relation between two statements. It is very simple to find the probability of a statement P with respect to another statement Q. First of all, we write the truth-table of Q and count the rows where Q is true, suppose they are *m*. Among them, we count the rows where P is true, say *n*. The probability of P with respect to Q is thus *n*/*m*. This theory was accepted and used by Waismann ("Logische Analyse des Wahrscheinlichkeitsbegriffs" in *Erkenntnis*, 1, 1930). Waismann's work gave rise to an intense discussion with the Berlin Circle, whose members, namely von Mises and Reichenbach, supported a frequency interpretation. Note also that this procedure is suitable only when the statements are not universal, that is to say, P and Q must be statements without quantifiers. In the *Tractatus*, Wittgenstein argued that only simple propositions without quantifiers are meaningful. This point influenced Schlick's analysis of scientific laws.

b. Early Research in Europe.

1922 was a very important year in the history of logical positivism. During that year, Schlick moved from Prague to Vienna, where he held the chair of theory of inductive science. At that time, Schlick had already published several philosophical works which heralded the new philosophical point of view: *Space and Time in Contemporary Physics*, and *General Theory of Knowledge*. In addition, Reichenbach had already published *The Theory of Relativity and A Priori Knowledge*, a philosophical analysis of the Theory of Relativity that argued against Kantian philosophy. Moreover, Hahn, Frank, and Neurath had begun their meetings on philosophy of science in 1907. Why was the coming of Schlick in Vienna so important? Schlick soon organized a discussion group and established relations with other philosophers of science, and so the Vienna Circle took shape. Schlick called Carnap to Vienna, and in 1926 Carnap became assistant professor under Schlick. The Vienna Circle joined up with the Berlin Circle (a similar group of philosophers of science that gathered round Reichenbach). The Vienna Circle took many initiatives, among them the publication of two series dedicated to the new philosophy of science, the journal *Erkenntnis*, and the organization of several congresses on epistemology and philosophy of science.

Between 1924 and 1936 (in that year Schlick was murdered), there were many philosophical outcomes that would influence the new school of logical positivism. The Verifiability Principle was formulated and metaphysics was ruled out as not verifiable. Reichenbach published extensive analyses of the Theory of Relativity. Carnap was primarily interested in logical analysis of science, and he gave the first logical formulation of the Verifiability Principle. Wittgestein's *Tractatus* was discussed in the Vienna Circle's meetings. Other philosophers were attracted by the new movement: Hempel studied with Reichenbach, Schlick, and Carnap; the Italian philosopher Geymonat went to Vienna and studied with Schlick and Carnap; American philosophers were interested in logical positivism; Morris and Quine went to Prague to meet Carnap; Polish logicians Ajdukiewicz and Lukasiewicz contributed essays to *Erkenntnis;* and Popper published his *Logik der Forschung* in the Vienna Circle's series.

In the early 1930s, logical positivism was an influential philosophical movement in the USA and Europe. Its members taught in many European universities and one of them (Feigl) in an American university. logical positivism was not only interested in pure philosophical research, but also in political and educational activity. The ideas of its members were progressive, liberal, and sometimes socialist. But in 1933, Hitler became Chancellor of Germany, and Nazism was hostile towards logical positivism. During that time, many logical positivists were forced to immigrate, and two of them (Schlick and Grelling) were murdered. The United States became the new home for Carnap, Feigl, Frank, Gödel, Hempel, and Reichenbach, while Neurath and Waismann sought refuge in England.

c. The American Period.

The spread of logical positivism in the USA occurred throughout the 1930s. In 1929 and in 1932 Schlick was a Visiting Professor at Stanford, while Feigl, who immigrated to the USA in 1930, became lecturer (1931) and professor (1933) at the University of Iowa and afterwards at the University of Minnesota (1940). In 1932, the American Philosophical Association organized a discussion on the philosophy of logical positivism. In the same years several articles about logical positivism were published in American philosophical journals; these are especially noteworthy:

- E. Nagel, "Nature and Convention" in *The Journal of Philosophy*, 26, 1929, in which Nagel discussed Reichenbach's interpretation of the Theory of Relativity.
- S. Hook, "Personal Impression of Contemporary German Philosophy" in *The Journal of Philosophy*, 27, 1930, in which Hook presented a favorable report on logical positivism.
- A. E. Blumberg and H. Feigl, "Logical Positivism: A New Movement in European Philosophy" in *The Journal of Philosophy*, 28, 1931.
- C. I. Lewis, "Experience and Meaning" in *The Philosophical Review*, 43, 1934, in which Lewis criticizes the Verifiability Principle.
- M. Schlick, "Meaning and Verification" in *The Philosophical Review*, 45, 1936, in which Schlick offers a reply to Lewis.

In 1936, Schlick was murdered by a Nazi student at the University of Vienna. Between 1936 and 1940 several German and Austrian philosophers immigrated to the USA: Carnap moved in 1936 to the University of Chicago, Reichenbach in 1938 to UCLA, Frank in 1938 (he became professor at Harvard University in 1939), Hempel in 1939 (City College of New York and in 1940 Queens College), and Gödel in 1940 (Institute for Advanced Study at Princeton).

Logical positivists found a favorable environment in the USA. They established solid relationships with American Pragmatism, particularly with Charles Morris, who took part in several logical positivist projects. One of them was the *International Encyclopedia of Unified Science*, which was primarily promoted by Neurath. Although the original comprehensive project was never fully realized, many individual works were published.

d. Influences on European Philosophy.

Some of the relations between logical positivism and Polish philosophy have already mentioned above. In the twentieth century, Polish philosophers were very interested in logical problems. Their works contributed to the development of several branches of logic, such as semantics and many-valued logic. Polish logicians analyzed logical aspects of logical positivist philosophy. Marian Przelecki's work *The Logic of Empirical Theories*, 1969, is a good example of such studies. In her work, Przelecki examined the logical structure of theories and proposed a semantic model of a formalized language suitable for a scientific theory. She used a relatively simple extension of Tarskian classical semantics. In her theory not all statements are true or false: a proposition can be indeterminate, that is, neither true nor false (but the law of the Excluded Middle is always true). Therefore, there is at least a statement, say P, so that (i) P is not true, (ii) P is not false, and (iii) $P \vee \neg P$ is true. A very interesting property of Przelecki's semantics is the following one: let Ax be the set of axioms of a scientific theory and suppose that Ax is finite, and let A be the conjunction of all statements in Ax. It is possible that A is false even if each statement in Ax is not false (that is, the conjunction of a finite number of assertions can be false even if every assertion is not false). This property is very useful in explaining a well-known situation: when a theory is proved false it is often very difficult to determine the wrong axiom. Another outcome of Przelecki's theory is a semantic characterization of the rules of correspondence. It was proved that the Carnap sentence is the weakest rule of correspondence, but it is not the only possible one. For example, suppose the following two statements are the axioms in Ax:

1. $(x)(O_1x \rightarrow T_1x)$
2. $(x)(O_2x \rightarrow \neg T_1x)$

The observational terms are O_1, O_2, and the only theoretical term is T_1. Every one of the following statements is an admissible rule of correspondence:

1. $(x)[(O_1x \vee O_2x) \rightarrow (T_1x \longleftrightarrow O_1x)]$
2. $(x)[\neg(O_1x \& O_2x) \rightarrow ((O_1x \vee O_2x) \rightarrow (T_1x \longleftrightarrow O_1x))]$
3. $(x)\neg(O_1x \& O_2x) \rightarrow (x)[(O_1x \vee O_2x) \rightarrow (T_1x \longleftrightarrow O_1x)]$

The last statement is logically equivalent to the Carnap sentence.

The English philosopher Alfred Jules Ayer (1910-1989) played an important role in spreading logical positivism. His work *Language, Truth and Logic*, 1936, was an immediate success. In that book, Ayer completely accepted both the Verifiability Principle and the distinction between analytic and synthetic statements, and so he asserted that metaphysical sentences are meaningless. A direct influence was exerted by Waismann and Neurath who immigrated to England in 1937 and 1940 respectively. Waismann taught at Cambridge and, from 1939 to 1959, at Oxford, where he taught philosophy of mathematics and philosophy of science. During this period Waismann was very interested in the philosophy of Wittgenstein.

Relations between Italian philosophy and logical positivism developed in the early stages of logical positivism. The Italian mathematician and philosopher of science Federigo Enriques (1871-1946) took part in the congresses on scientific philosophy and collaborated on the *International Encyclopedia*, and Neurath and Carnap contributed articles to the journal *Scientia* edited by Enriques. In 1934, Ludovico Geymonat (1908-1991) published a work on logical positivism: *La Nuova Filosofia della Natura in Germania*. Geymonat had the opportunity to study with Schlick, Reichenbach, Carnap, and Waismann. He later held the first chair in Italy of philosophy of science (1956). However, the interest of Italian philosophy in logical positivism was primarily directed towards historical research. Francesco Barone distinguished himself with his work *Il Neopositivismo Logico*, 1953, a detailed and up-to-date historical and philosophical analysis of logical positivism, which deserves mention because it focused attention not only on the Vienna Circle but also on the American period of logical positivism and on some forgotten philosophers (even now it is not impossible to find valuable dictionaries of philosophy that identify logical positivism with the Vienna Circle).

French philosophy was marginally interested in logical positivism. Charles E. Vouillemin translated several logical positivist works and, in 1935, published *La Logique de la Science et l'ecole de Vienne*, a book in which he examined the philosophy of the Vienna Circle. Luis Rougier (1889-1982) gave reports about logical positivism ("Une Philosophie Nouvelle: l'empirisme Logique" in *Reveu de Paris*, 63, 1935), collaborated on the International Encyclopedia of Unified Science and contributed works to *Erkenntnis*.

Scandinavian philosophers also expressed interest in logical positivism. Two of them, Swedish Ake Petzäll (1901-1957) and Finnish Eino Kaila (1890-1958), employed for the first time the expression "Logical Neo-positivism" for denoting the new philosophical movements (A. Petzäll, *Der Logistische Neupositivismus*, 1930 and E. Kaila, "Der Logistische Neupositivismus" in *Annales Universitatis Aboensis*, ser. B, 13, 1930). Petzäll was mainly influenced by the Vienna Circle and in 1930-31 he went to Vienna, where he took part in the Vienna Circle meetings. In 1935, he founded a new journal, *Theoria*, and published in Göteborg. It was the journal in which Hempel published his very first description of the paradoxes of confirmation ("Le Problème de la Vérité", 3, 1937). Eino Kaila published in 1939 a work that used the principles of logical positivism (*The Human Knowledge*, in Finnish). He taught philosophy at the University of Helsinki. Among his students was George Henrik von Wright (1916-2003) who published a study about logical positivism (*Logical Empiricism: A Principal Movement in Modern Philosophy*, 1943, in Swedish, and 1945, in Finnish). Wright contributed to the development of both modal and deontic logic. The Finnish philosopher Jaakko Hintikka (b. 1929) pursued Carnap's studies on inductive logic. Hintikka's article "A Two-Dimensional Continuum of Inductive Methods" in *Aspects of Inductive Logic*, edited by J. Hintikka and P. Suppes, and extended the methods Carnap used in *The Continuum of Inductive Methods*, 1952. Roughly speaking, Carnap defined a system of inductive logic in which there is a one-to-one correspondence between the function that gives the degree of confirmation of a statement and the function that gives the estimated relative frequency. The exact relationship between these two functions depends on only one parameter Carnap called Lambda; it can assume all real values between 0 and infinity (thus the system is a continuum of inductive methods). Every value of Lambda defines a different method for evaluating the degree of confirmation. However, the probability of a universal law is always 0. Hintikka added a second parameter he called Alfa so that the system became a two-dimensional continuum. When Alfa = infinity, Hintikka's system is identical with Carnap's one-dimensional system. Otherwise the two-dimensional system gives a reasonable degree of probability to universal laws even in an infinite universe.

The Danish philosopher Joergen Joergensen (1894-1969) actively collaborated with logical positivists. After Hanh's death (1934) he became an editor of the Vienna Circle's series *Einheitswissenchaft*, and later he collaborated on the *International Encyclopedia* to which he contributed the essay *The Development of Logical Empiricism*, 1951.

Finally, it must be noted that logical positivism played a very important role in the development of contemporary philosophy, not only for its philosophical principles, but also for its editorial and organizational activities. Popper and Kuhn published their most known and seminal works in the logical positivist series. This fact, however, does not prove that Popper and Kuhn were logical positivists, but it does show the movement's broad-mindedness, its kindly disposition, and its influence.

4 New Interpretations of Logical Positivism.

Michael Friedman’s analysis of logical positivism.
In recent years the interest of scholars in the philosophy of logical positivism is considerably grown, and new original publications has been dedicated to the d evelopment of logical positivism. New interpretations of the philosophy of logical positivism have been proposed. Of particular interest is Michael Friedman's analysis of logical positivism, according to which the "central philosophical innovation [of logical positivism] is not a new version of radical empiricism but rather a new conception of a priori knowledge and its role in empirical knowledge" (Friedman, Michael, *Reconsidering Logical Positivism*, 1999, pag. xv).

Another source of interest is the explication of the influence that Kantian philosophy exerted on the origin and development of logical positivism. According to Friedman, logical positivism, instead of adopting a purely empirical vision of science, recognized the necessity of non empirical a priori principles by means of which scientific theories can receive an empirical interpretation and therefore can be tested. Friedman calls these principles "relativized a priori principles" (Friedman, Michael, *Reconsidering Logical Positivism*, 1999, p. xv). As explained by Friedman, the necessity of such a priori principles is explicitly recognized by Hans Reichenbach in his first work on the philosophy of the theory of relativity, *Relativitätstheorie und Erkenntnis Apriori*, 1920. Reichenbach formulates the now well known distinction between axioms of connection and axioms of coordination. The former are empirical laws, formulated using concepts which are empirically well defined; the latter are non empirical principles which give an empirical interpretation to the theory. Every scientific theory requires a set of axioms of coordination. With respect to a given theory, the axioms of coordination are constitutive of the object of the theory, in the sense that without the axioms of coordination the theory has no empirical meaning. For example, in classical mechanics and in special relativity, the metric of the space-time is an axiom of coordination, that is the Euclidean structure of the geometry is assumed a priori valid. In the general relativity, on the contrary, the space-time metric is empirically verifiable, while a suitable space-time topology is assumed a priori.

The main difference between Kantian synthetic a priori and Reichenbach’s axioms of coordination is that according to Kant synthetic a priori principles are necessarily valid and unrevisable, while Reichenbach acknowledged that axioms of coordination are subjected to modifications with the evolution of scientific knowledge. For instance, Euclidean geometry is a priori relatively to Newtonian mechanics, while it is an empirical false theory in general relativity. Synthetic a priori knowledge, in Kantian philosophy, has two main features: first, it is necessarily and universally valid; second, it is constitutive of the object of knowledge (transcendental in Kantian terminology). Reichenbach accepted the presence, in scientific theories, of a priori principles which are constitutive of the empirical objects, but he denied that these principles are unrevisable.

According to Friedman, "in Carnap's Logical Syntax of Language we find a revival of the relativized a priori in something very like Reichenbach’s original sense" (Friedman, Michael, *Reconsidering Logical Positivism*, 1999, p. 68). Friedman suggests that "Carnap's L-rule or analytic sentences can be profitably viewed as a precise explication of Reichenbach's notion of the constitutive or relativized a priori" (ibid., p. 69).

5 Biographical Notes.

Rudolf Carnap.
For Rudolf Carnap (1891-1970) see Carnap (The Internet Encyclopedia of Philosophy).

Herbert Feigl.
The philosopher of science Herbert Feigl (Reichenberg, Austria, now in Czech Republic, 1902 - Minneapolis, Minn., 1988) studied physics and chemistry at the University of Munich and in 1922 moved to Vienna, where he was an early member of the Vienna Circle. At Vienna, he studied mathematics, philosophy, physics, and psychology, and received his degree in philosophy in 1927. In 1929 he met K. R. Popper whose ideas he found interesting, so he encouraged Popper to write a book which became the *Logik der Forschung*. In 1930 Feigl immigrated to the USA. His article (written with A. E. Blumberg), "Logical positivism: A New Movement in European Philosophy" in *The Journal of Philosophy*, 28, 1931, was one of the first reports on logical positivism published in the USA, which promoted the spread of logical positivism. Between 1931 and 1940 he taught at the University of Iowa and from 1940 at the University of Minnesota, where in 1953 he founded the Minnesota Center for Philosophy of Science, the oldest center for philosophy of science in the World. Between 1966 and 1973 he was president of the Institute of the Unity of Science. Feigl supported a materialistic theory of mind - the Identity Theory of mind - according to which mental events are identical with states in the brain ("The Mind-Body Problem in the Development of Logical Positivism" in *Revue International de la Philosophie*, 4, 1950; "The Mental and the Physical" in *Minnesota Studies in the Philosophy of Science*, II, 1958).

Philipp Frank.
The physicist and philosopher of science Philipp Frank (Vienna 1884 - Cambridge, Mass. 1966) studied at Gottingen with David Hilbert and Felix Klein and at Vienna, where he received (1907) his degree in physics under the direction of Ludwig Boltzmann. In the same year Hahn, Frank, and Neurath began their meetings in a Viennese café, where they discussed the new philosophy of science and epistemology. In 1912 he held the chair of theoretical physics at the German University of Prague. Frank was an editor of series *Schriften zur wissenschaftlichen Weltauffassung* and *Einheitswissenschaft*. He moved to the USA in 1938 where he taught physics and philosophy of science at Harvard University. His work *Foundations of Physics* was published in 1946 in the *International Encyclopedia of Unified Science*. From 1949 to 1966 he was president of the Institute of the Unity of Science. He wrote several essays on philosophy of physics: *Between Physics and Philosophy*, Cambridge, Mass., 1941; *Einstein: His Life and Time*, New York, 1953; *Relativity: A Richer Truth*, Boston, 1950.

Kurt Grelling.
The logician and philosopher Kurt Grelling (1886 - 1942) was a victim of Nazi persecution, and he died with his wife in Auschwitz concentration camp in September 1942. Hempel remembers that Oppenheim made every effort to allow Grelling to immigrate to the USA but, according to Hempel, immigration officials were perplexed by Grelling's alleged propensity towards Communism. Hence there was a delay that was fatal to Grelling, who was captured in France and later transferred in Auschwitz concentration camp. The episode is reported in Hempel, "Autobiografia Intellettuale" in *Oltre il Positivismo Logico*, Armando: Rome, 1988 (this essay is the text of an interview Hempel gave to Richard Noland in 1982, published for the first time in Italian translation in 1988).
Grelling was a teacher in secondary school and was interested in logical problems. A semantic paradox is named after him, the Grelling's Paradox, formulated in 1908 by Grelling and Leonard Nelson. There are some words which have the property they express, for example "short" is short.

Those words are called *autological*. The other words are called *heterological*. For example, "long" is a heterological word because it is not long. Now the question is whether "heterological" is heterological. If yes, then "heterological" is by definition an autological word and thus it is not heterological. If no, then "heterological" has the property it designates, and therefore it is heterological. Thus, "heterological" is heterological if and only if it is not heterological. This results in a semantic paradox.
Grelling collaborated with Gödel, and in 1936 he published an article in which he defended Gödel's Theorem of Incompleteness against an erroneous interpretation that implies Gödel's Theorem is a paradox like Russell's Paradox ("Gibt es eine Gödelsche Antinomie?" in *Theoria*, 3, 1936). Grelling was also interested in the analysis of scientific explanation and in the Gestalt approach in psychology.Kurt Gödel.

Kurt Gödel.
The logician, mathematician and philosopher Kurt Gödel (Brno 1906 - Princeton, NJ, 1978) studied mathematics and physics at Vienna University, and received his doctorate under Hans Hahn with a dissertation ("Die Vollständigkeit der Axiome des logischen Funktionenkalküls" in *Monatshefte für Mathematik und Physik*, 37, 1930) in which he proved the completeness of first order logic. In Künigsberg congress (1930) Gödel announced that he has proved the incompleteness of formal arithmetic; the proof was published the following year in the article "Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme" in *Monatshefte für Mathematik und Physik*, 38, 1931.
Gödel worked also on set theory and non-classical logics, such as intuitionistic and modal logic. He proved that the continuum hypothesis is consistent with the axioms of classical set theory.
He was interested in the mathematical aspects of the theory of relativity, and proved the existence of solutions of Einstein's relativistic equations in which time travels in the past are possible. These solutions describes so-called "rotating universes" with cosmological constant different from zero. "By making a round trip on a rocket ship in a sufficiently wide curve, it is possible in these worlds to travel into any region of the past, present, and future, and back again, exactly as it is possible in other worlds to travel to distant parts of space" ("A Remark About the Relationship Between Relativity Theory and Idealistic Philosophy" in *Albert Einstein. Philosopher-Scientist*, edit by P. A. Schilpp, "The Library of Living Philosopher", Evanston, Ill., 1949; quoted from Gödel, Kurt, *Collected Works*, vol.2, Oxford: Oxford University Press, 2001).
Gödel philosophic attitudes seems in contrast with those usually attributed to the other logical positivists. Of particular interest is his position on the problem of the foundations of mathematics. Gödel asserted that mathematics is not reducible to formal logic; on the contrary, the proper method of mathematics is "the intuitive grasping of ever newer axioms that are logically independent from the earlier ones" (Gödel, Kurt, "The modern development of the foundations of mathematics in the light of philosophy" in *Collected Works*, vol. 3, Oxford: Oxford University Press, 2001). The mathematician attempts to solve every clearly posed mathematical questions through the conscious extension of the axioms of mathematics; thus new axioms, which are not logically derivable from the already established axioms, become evident. This method, based on intuition and not on formal logic, "agrees in principles with the Kantian conception of mathematics" (ibid.).
Gödel defended an idealistic philosophy of time in his contributions to *Albert Einstein. Philosopher-Scientist*. In "rotating universes" there is the possibility of time travels; therefore there is no possibility to define in this universe an objective time. Thus, according to Gödel, we have to recognized that time is not an objective entity; on the contrary, we have to adopt Kantian analysis of time, and consider "change as an illusion or an appearance due to our special mode of perception" ("A Remark About the Relationship Between Relativity Theory and Idealistic Philosophy" in *Collected Works*, vol.2, Oxford: Oxford University Press, 2001).

Hans Hahn.
The mathematician and philosopher Hans Hahn (Vienna 1879 - Vienna 1934) was the co-author of the manifesto of the Vienna Circle. He received his degree in mathematics in 1902; afterwards he studied under the direction of Boltzmann in Vienna and Hilbert, Klein, Minkowski in Gottingen. In 1905 he taught mathematics at Innsbruck and in 1909 at the University of Vienna. In 1907 Hahn, Frank, and Neurath began their meetings on philosophy. After the First World War, during which he taught in Bonn, Hahn returned to the University of Vienna (1921). In 1922 Hanh, with the help of Frank, arranged to bring Schlick to the University of Vienna.
Hahn held courses on the symbolic logic, the foundations of mathematics, and Wittgenstein's *Tractatus*. One of his students was K. R. Popper, who found Hahn's lectures very interesting and of perfect clarity. Another student of Hahn's was Kurt Gödel, who wrote his dissertation, in which he proved the completeness of first order logic, under Hahn's direction. Hahn was an editor of the series *Einheitswissenschaft*.

Carl Gustav Hempel.
For Carl Gustav Hempel (1905 - 1997), see Hempel (The Internet Encyclopedia of Philosophy).

Otto Neurath.
The philosopher and sociologist Otto Neurath (Vienna 1882 - Oxford, UK, 1945) played an important role in the development of logical positivism. He took part in the meetings with Frank and Hahn from 1907, arranged to bring Schlick to the University of Vienna in 1922, was a co-author of the manifesto of the Vienna Circle (it is supposed that Neurath was indeed the principal author), planned and directed the International Encyclopedia of Unified Science, was an editor of the journal *Erkentnnis* and of the series *Einheitswissenchaft*, and founded and directed the International Foundation for Visual Education. Neurath studied economy, sociology, and philosophy at the University of Vienna and at the University of Berlin. In 1919 he was a member of the government of the socialist republic of Bavaria; he was imprisoned and prosecuted, but he managed to escape into Vienna, where he was the director of a museum from 1924 to 1934. In that year Neurath immigrated to Holland and in 1940 he moved to England, where he died in 1945.
Neurath proposed a linguistic theory of science, according to which scientific statements are not judged by means of the empirical evidence, but they are verified with respect to all other statements - truth is thus replaced with coherence. "If a statement is made, it is to be confronted with the totality of existing, statements. If it agrees with them, it is joined to them; if it does not agree, it is called 'untrue' and rejected; or the existing complex of statements of science is modified so that the new statement can be incorporated; the latter decision is mostly taken with hesitation. There can be no other concept of 'truth' for science." ("Physikalismus" in *Scientia*, 50, 1931; English translations "Physicalism" in Sarkar, Sahotra (ed.), *Logical Empiricism at its Peak: Schlick, Carnap, and Neurath*, New York: Garland Pub., 1996, p. 75).
According to Neurath, the unity of science is attainable through the unity of language. Neurath regarded the language of physics as the only legitimate and objective language, which completely avoids the problems (e.g., solipsism) generated by a phenomenalistic language (it is evidently a criticism of the methodological solipsism Carnap used in his *Der Logische Aufbau der Welte*). In the language of science there is no room for ethical terms (ethics is meaningless). But also psychological concepts are forbidden; we must substitute physical concepts for them. Neurath also proposed an international picture language, the Isotype (*International Picture Language, The First Rules of Isotype*, London, 1936; *Basic by Isotype*, London, 1937; *Modern Man in the Making*, London, 1939). This visual language was based on a combination of charts, graphics, diagrams, and maps. The original project of the *International Encyclopedia of Unified Science* included a never realized Visual Thesaurus in several volumes written in Isotype. Now we can fully appreciate the utility of a visual representation based on graphics, icons, etc., and we can also appreciate Neurath's

prophetic intuition of an international visual language.

Hans Reichenbach.
For Hans Reichenbach (1891 - 1953), see Reichenbach (The Internet Encyclopedia of Philosophy).

Moritz Schlick.
The physicist and philosopher Moritz Schlick (Berlin 1882 - Vienna 1936) studied at the University of Losanna, in Heidelberg and Vienna, where he received his degree in physics with a dissertation written under the direction of Max Planck. Between 1911 and 1917 he taught at the University of Rostock. In those years, Schlick was interested in the Theory of Relativity. He wrote "Die Philosophische Bedeutung der Relativitätsprinzip" in *Zeitschrift für Philosophie und philosophische Kritik*, 159, 1915; *Raum und Zeit in der gegenwärtingen Physik*, Berlin, 1917 (English translation: *Space and Time in Contemporary Physics*, 1920). In 1918 he published *Allgemeine Erkenntnislehre* (English translation: *General Theory of Knowledge*, 1974). With the help of Frank, Hahn, and Neurath, in 1922 Schlick moved to the University of Vienna, where he held the chair of theory of inductive science. Schlick organized a discussion group known as the Vienna Circle. He was an editor of the series published by the Vienna Circle *Schriften zur wissenschaftlichen Weltauffassung*. In 1929 and 1932 he was Visiting Professor at Stanford University and he was the herald of the philosophy of logical positivism in the USA. The American journal *Philosophical Review* hosted an interesting exchange of opinions between American philosopher C. I. Lewis and Schlick on the Verifiability Principle (C. I. Lewis, "Experience and Meaning" 1934; M. Schlick, "Meaning and Verification" 1936). In 1929, the manifesto of the Vienna Circle was written by Hahn, Neurath and Carnap. It was dedicated to Schlick, and in 1930 the first article published in the new journal *Erkenntnis* was Schlick's *Die Wende der Philosophie*. Schlick was killed in the University of Vienna by a Nazi student on June 22 1936.
Schlick can be regarded as the father of logical positivism, both for his organizational skills and for his philosophical ideas.
According to Schlick, scientific laws are not genuine statements, for they are not completely verifiable. He argued that scientific laws are rules employed to make predictions. The only criterion for justifying scientific laws is the reliability of forecasts; causal laws express nothing but the possibility of making a prediction. Quantum physics has proved, Schlick asserted, that there is a limit to such a possibility. That limitation is not due to a failure of human knowledge or to an interference of the human observer within the physical system. If quantum mechanics proves the impossibility of a simultaneous measurement of position and momentum, then, according to Schlick, simultaneous position and momentum do not exist.
Schlick criticized Neurath's linguistic theory of science. According to Schlick, science is not characterized by its internal coherence; rather, scientific statements must be tested with respect to the given experience.

Friedrich Waismann.
The philosopher Friedrich Waismann (Vienna 1896 - Oxford, UK, 1959) studied mathematics and philosophy at Vienna. In 1929, he became an assistant to Schlick. He was one of the few members of the Vienna Circle admitted to the meetings with Wittgenstein. Waismann recorded several conversations which were published posthumously in F. Waismann, *Wittgenstein und der Wiener Kreis*, 1967 (English translation *Wittgenstein and the Vienna Circle: Conversations Recorded by Friedrich Waismann*, New York: Barnes & Noble Books, 1979). Waismann proposed a logical interpretation of probability inspired by Wittgenstein in his work "Logische Analyse des Wahrscheinlichkeitsbegriffs" (*Erkenntnis*, 1, 1930). In 1936 he published his only book *Einführung in das mathematische Denken*, about the philosophy of mathematics. He immigrated to England in 1937, where he taught philosophy of mathematics and philosophy of science at Cambridge and,

from 1940, at Oxford. In England he contributed to the development of analytic philosophy. His book, *The Principles of Linguistic Philosophy*, Oxford, 1965, an exposition to the philosophy of the late Wittgenstein, was also posthumously published.

The only book he published during his life dealt with the interpretation of mathematics. Waismann criticized both Logicism and Formalism. Logicism argues that all mathematical truths are logical truths, and it is based on Frege and Russell’s definition of natural numbers, namely a natural number is the class of all equinumerable classes. According to Waismann, this definition introduces an element of contingency in mathematics, thus disturbing its a priori character. Moreover, formal logic is by no means a privileged calculus to which all mathematics is reducible. Logic itself is a part of mathematics. Waismann also rejected the formalistic interpretation, because it is not interested with the meaning of mathematical concepts. According to Formalism, a natural number is whatever fulfils the axioms of mathematics. But this approach neglects a very important problem, namely the question whether the axioms of mathematics identify the natural numbers we really employ. The solution consists in the study of the role that natural numbers play in ordinary language (note the evident analogy with Wittgenstein's assertion that meaning is use).

6 Links and Further Reading.

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