Conditions of Rationality for Scientific Research

Paul Weingartner

Abstract

The purpose of this paper is to discuss conditions of rationality for scientific research (SR) where "conditions" are understood as "necessary conditions". This will be done in the following way: First, I shall deal with the aim of SR since conditions of rationality (for SR) are to be understood as necessary means for reaching the aim (goal) of SR. Subsequently, the following necessary conditions will be discussed: Rational Communication, Methodological Rules, Ideals of Rationality and its Realistic Aspects, Methodological and Ontological Conditions (Universality, Rules for Experiments, Causality), and Metaphysical Presuppositions and Extrapolations.

Keywords: *Rationality, Scientific Research, Rational Communication, Rules of Methodology, Descartes, Leibniz, Carnap, Mendel*

I would like to dedicate this paper to Gerhard Schurz, former assistant, colleague, and friend. The work in joint seminars and the collaboration in resulting papers in the domain of relevance-logic belong to the most valuable parts of my research. I wish Gerhard many further years of putting new ideas into accurate research work, a feature that belongs to his character.

Contents

1 The Aim of Scientific Research

It seems to me to be a fact what Aristotle says in the first statement of his metaphysics: "All men by nature desire to know ..."[1] One may even weaken this claim in a twofold way to a minimal principle about mankind: One may replace 'all' by 'almost all' or 'statistically all' to allow some few extravagant exceptions caused by exceptional conditions. And one may replace 'desire to know' by 'desire to know more or better relative to that what and how they know at the present time and relative to their interests and abilities.' The minimal principle can then be stated thus:

> Almost all men (by nature) desire to increase their knowledge relative to their interests and abilities.

That what all (most of all) men desire we may call a common goal (value) of mankind. In contradistinction to the so called basic needs or basic goals (like those necessary to stay alive in any environment and those necessary to keep or regain health in a particular environment) this goal of mankind belongs specifically to mankind, i.e. to his higher faculties, viz. to his *ratio*. SR which leads to scientific knowledge is one important way in the sense of a *sufficient* condition (sufficient means) to achieve that goal. Since genuine knowledge includes truth or at least approximate truth, truth and approximate truth are included in the above mentioned goal of mankind. But truth and approximate truth cannot just be claimed. One objective way by which it can be achieved is SR for which it is a necessary condition that claims have to be testable and confirmable. Thus searching for and finding testable or confirmable truth (or approximate truth) is a property of SR which leads to scientific knowledge. For scientific knowledge one has to require the thesis: If the person a knows scientifically that p, then p is testable or confirmable true (or approximate true). In other words: For getting an adequate concept of scientific knowledge one would not allow to say that a knows that p if in fact p is neither testable nor confirmable (for a or at least for a scientific community who can inform a).[2] In addition one has to realize that the actual situation in scientific research is often such that we cannot have testable or confirmable truth as a necessary condition for scientific knowledge but only testable or confirmable approximate truth.[3]

A further necessary condition is that the truth which is approached by the scientific disciplines is informative and contentful. The search in science is not for mere tautologies or for uninteresting singular truth but for comprehensive truth expressed by law statements. Thus SR requires search for informative truth (or approximate truth) which is testable or confirmable. We may say therefore that searching for informative, contentful truth (or approximate truth) which is testable or confirmable is a necessary and sufficient condition and thus an essential characteristicum of SR. And therefore such a truth (approximate truth) is also a subordinated goal with respect to knowledge in general which is a goal of mankind.

It is a historical fact and it has been a historical experience of mankind that informative, testable and confirmable truths were the result of scientific research activity; and in most cases: of scientific research activity which was done by a scientific community who acted according to methodological rules. Today, in the twentieth century, scientific research activity shared by a community of scientists and governed by methodological rules is a necessary condition for reaching informative, testable truth (or approximate truth) and scientific knowledge. As Hempel says SR if it is rational "will have to specify certain goals of scientific inquiry as well as some methodological principles observed in their pursuit; finally, it will have to exhibit the instrumental rationality of the principles in relation to the goals."[4]

In order that scientific research activity proceeds more efficiently to reach the goals of truth and approximate truth it has to be ruled by rules and norms of methodology. Or to put it into a true conditional: If scientific research activity is not ruled by methodological rules, it does not lead efficiently to informative and testable truth and approximate truth. These rules and norms are also subject to scientific test, criticism and confirmation in order to be revised and improved permanently. A test for the validity of such a rule or norm consists mainly in an empirically testable *modus tollens* argument of the following form: if the scientific activity or research-activity does not proceed according to this or that rule, it either does not lead to truth or approximate truth (for instance, it leads to false statements), or it does not reach this goal efficiently. In this sense every scientific discipline has also the task of establishing and testing the methodological norms which are specific for that discipline.

Because of what has been said and since rules and norms are not true (false) and not approximately true but valid (invalid) or approximately valid, one has to add validity of norms if speaking more completely of the goal of SR: the goal (end, aim) of SR is testable or confirmable, informative truth and validity or approximate truth and validity.

From this consideration it follows that the aim of science and of SR is not only to find out what is the case but also what ought to be the case with respect to important goals of mankind. And it is important to notice that not only the inclusion of ethics requires that but already the scientific investigation of and reflection on the methodological norms of SR within every scientific discipline.

2 Rational Communication in a Scientific Community

A necessary condition of SR is rational communication in a scientific community. Science in its modern form is not the result of an hermit but is possible only within a scientific community and requires rational communication. If we speak of *rational* communication within a scientific community or among scientists (RCS) we mean something stronger than just human communication. The following requirements seem to be necessary conditions for RCS[5]:

2.1 *The aim of RCS is the achievement or understanding of scientific results, i.e. of true (approximate true) statements and valid (approximate valid) norms.*

2.2 *The language of RCS consists of sentences which are connected in such a way as to form a text.*

What conditions are necessary and sufficient to form a text is a controversial matter. The following condition seems to be a suitable proposal at least for an important necessary condition[6]: If a sequence of sentences (at least two) form a text then each sentence (except the first) has at least one common consequence together with at least one of its preceding sentences; where the common consequence follows either from sentences of the text alone or from them together with a sentence from the common background (which contains descriptive statements and prescriptive norms).

Example: Mr. Granger from (the university of) Aix de Provence stays this time in Santiago. He participates in the Conference on Rationality at the Universidade Catholica de Chile. Common consequences of both sentences are: Mr. Granger is not in Aix de Provence at this time. Mr. Granger is a scholar. This scholar is a male person. To draw these consequences from both sentences it is necessary to know (from the background concerning understanding language) that 'He' is an indexical referring to Mr. Granger and that 'Mr.' is used for male persons ... etc.

In order to interpret the text the persons who communicate can use further assumptions or hypotheses. This can happen in different ways but the two following cases seem important:

(1) A difficulty for a consistent or plausible interpretation of a text is overcome by inventing a hypothetical premise. Think of a criminal story which is solved (the culprit can be identified) by the invention of such a hypothesis. Logically speaking the addition of the hypothetical premise allows to draw a lot more consequences from the text.

(2) A difficulty of linking together two parts of a text or (in the simplest case) two disconnected sentences is overcome by finding a common premise for both parts. As an example take the two sentences "There is a most perfect being. Not all values are relative." In fact many philosophies and religions which assume these statements to be true accept also the following thesis of theism to be true: "There is an almighty omniscient and benevolent being who is also the highest good or value". With the help of the further assumption that what is almighty, omniscient and benevolent is also most perfect, the thesis of theism is a common and unifying premise to both disconnected sentences of the text from which both parts are derivable. More complicated examples are disconnected scientific hypotheses which become unified by a new more informative hypothesis or theory from which both are consequences.

A logician listening to these proposals would add at least the following restrictions in order to avoid trivialities:

(a) No logical tautologies as common consequences and no contradictions as common premises.

(b) No conjunctions of sentences of the text as common premises and no disjunctions of them as common consequences. Even questions can be allowed in communication and can be accepted as being part of the text. The reason is that questions together with the background presuppose certain statements from which common consequences can be drawn or for which common unifying premises can be found.

2.3 Can there be RCS about things which are inexpressible in language? This question is unprecise and has to be split into different problems.

(1) Some expression of language Ll may not be expressible in L2. For example the expressions ‘disposition’, ‘intention’ and ‘motive’ are not expressible in a behaviouristic language.

(2) The meaning of some single expression of Ll is not expressible by one single (simple) expression in L2. For example the meaning of ‘like’ has no simple expression in German.

(3) Some thing, property or fact may not be expressible in some (scientific) language. For example relativistic mass is not expressible in the language of Newton’s Principia (as it is written down; though in principle it may be expressed in it).

(4) Some thing, property or fact is not expressible (with the help of a name or description) in any language. This claim is made in some metaphysical or religious texts.[7]

In the example in (1) the respective expressions (with a more or less exact meaning) are available in the language of traditional psychology but they are excluded from the language of behaviourist psychology on purpose, i.e. in order to allow only behavioural terms. This was understood as an ideal of rationality for a program of scientific psychology. But this ideal eliminated a great part of psychology from scientific investigation thereby clashing with an essential characteristic of SR (recall ch. 1). Cases like (1), (2) and (3) often happen within the development of the scientific disciplines. In such cases RCS is certainly possible though in a more sophisticated way. If (4) would hold strictly no RCS would be possible about the respective things or objects. But applying more accuracy firstly (4) need to be formulated in some metalanguage about a class of (all) languages of a certain sort and secondly religious and metaphysical texts do in fact speak about those “unspeakable” objects in some paraphrasing, metaphorical, analogical or parabolic way. Therefore what (4) says – realistically speaking – is that some thing, property or fact is not expressible adequately in any language. With respect of this weaker version of (4) RCS may be possible if semantics is applicable to the expressions in question.

2.4 Application of Logics and Semantics.

A further requirement for having RCS is the following one:
The text has to be such that logic and semantics is applicable to it in a very basic and minimal way. This is the case (1) if the operation of logical consequence is applicable to the sentences of the text, (2) if the sentences of the text can be evaluated: the declarative sentences as true, false (in some cases maybe as indefinite) probable etc„ the normative sentences as valid, invalid (in some cases maybe as indefinite), (3) if it holds for all sentences of the text that most of the terms (name, functor, predicate) occurring in it have more definite meaning in the sense of having an extension and intension and (4) if no term occurring in any of the sentences of the text has an infinite spread of meaning, i.e. has a meaning which would encompass the extension and its complement (and therefore be contradictory).

2.5 Common basis for discussion.

The first rule here is that if the members of the scientific community disagree then they look for a common basis for discussion on which they agree. The least level or basis to which they can go back are simple logical and mathematical principles.[8] If this is not granted the communication cannot be called rational. In fact for RCS more than that is required. The members involved in RCS accept good confirmed scientific results. As an example take two philosophers A and B discussing causal influence in general and A claiming the thesis: "Everything is causally influenced by everything else in some way or other". His colleague B -being acquainted with the results of the theory of relativity – tells him that this thesis cannot be true because it contradicts good confirmed scientific results according to which the propagation of causal effects (influence) is not arbitrary, but bound to the limit-velocity of light.[9] A can react in different ways. If he says that though he believes that a good confirmed scientific result contradicts his thesis he still thinks that he is "philosophically" right then this kind of "philosophy" makes RCS impossible. On the other hand he can react in giving up his claim (then RCS is possible of course) or in giving up his claim conditionally (or provisionally) until they have investigated whether they mean the same by "causal influence" (then RCS is possible, too). In this case they go back to a lower level of common basis for discussion. Even in the case when A (out of ignorance) doubts whether B told him really a scientific result the discussion could go on provisionally (hypothetically) with the requirement on A to get more complete information about that matter. Also in this case RCS is possible. The common basis includes now to speak hypothetically about that matter. Finally also good confirmed scientific results can be rationally discussed, doubted, criticized and so on. But then the important condition for a possible RCS is again a lower or other common basis for discussion which will – besides simple logical rules of argumentation – include some other important scientific results.

3 Methodological Rules

It has been pointed out at the end of chapter I that SR in order to reach the goal of informative and testable truth (approximate truth) has to be guided by rules and norms of methodology. Such rules can be twofold: (1) General ones applied in all or most research activities. (2) Special ones applied in one discipline (say physics or psychology) or in a smaller group of disciplines (say social sciences). The general rules may be subdivided again into those (la) which, if violated violate the first goal of SR: truth (validity) or approximate truth (approximate validity); and into those (lb) which, if violated prevent SR from proceeding more efficiently to the first goal of SR. Again (la) can be further divided into those rules (laa) which if violated violate the first goal (truth, validity) as such and those (lab) which if violated violate the aspect of *informative* and *contentful* truth (validity).[10]

3.1 General Rules of Methodology

Examples for general rules of the type (la) and (laa) are: Base your hypothesis (thesis) on all scientific information available. New hypothesis (theories) should include the correct results of the old (the forerunner) hypothesis (theory) as special cases. If such rules are violated then almost certainly false statements will enter, thus a violation of such rules violates the first goal of SR.

Examples of general rules of the type of (lb): Try to create hypothesis which make new predictions (in the widest reasonable sense of the word)[11] and which make suggestions for new kinds of tests. Take the scientific tradition into account. Violating such rules prevents SR from proceeding more efficiently to its goal and from observing the aspect of testability and confirmability.

Examples for general rules of the type (lab): Explain the particular with the help of the universal. Explain the concrete with the help of the abstract. If these rules are violated the particular and concrete is explained again with the particular and concrete; i.e. there are no universal statements (laws, hypothesis) in the explanation. And this again means that the explanans does not contain enough *contentful* and *informative* truth which violates the goal of SR with respect to the underlined properties.

The last two rules have been proposed already by Greek philosophy whose ideal was: To describe and explain the visible, observable, concrete, particular, changing, material world by non-visible, non-observable, abstract, universal, non-changing and immaterial principles.

Before I shall give some examples of special rules I want to point out that every rule has to be handled with some caution: Concerning (la) there are situations where all the information available in a certain field can hardly be interpreted consistently; and further that the new theory may contain new concepts such that it is inaccurate to speak of "special cases" (even if some of the doctrines of "incommensurability" are bold exaggerations).[12] Concerning (lb) one has to avoid to ask for such new predictions or tests which trivially satisfy the respective hypothesis. Don't forget that reinterpretation of tradition belongs mainly to the history of science even if one can learn from it. Concerning (lab) we have to remember that strict universal laws are not always available and statistical laws are genuine laws too.[13] And further that searching for abstract laws does not mean rejecting application and concrete tests.

3.2 Special Rules of Methodology

Do not transfer laws from the finite to the infinite. Since many of the laws in mathematics are different for the finite and the infinite domain a violation of this rule leads usually to false results. But one should not forget interesting relations between the two domains (for example: Compactness Theorem and results of Model Theory).

All physical laws should be invariant against coordinate transformations. A violation of this norm would first of all destroy our understanding of a physical law since space-time invariance is the oldest and probably most important invariance concerning physical laws. Besides this it would weaken the requirement for content high degree of information and explanatory power. However, one should be cautious not to transmit this kind of invariance to historical or social laws, where one cannot have space-time invariance.

Try to interpret the phenomena in such a way that they have always a continuous dependence upon their causes. This rule which has as its basis the general principle of continuity and infinitesimal structure of all relations in the real world (at least for Leibniz) was successful for about 300 years. It led to the interpretation of motion by laws (differential equations) of motion.

The principle of continuity as a general one in all domains was refuted by Quantum Theory and therefore the methodological norm was shown to be invalid by the "ought-can" principle. But it is still valid and applied in a wide range of research areas.

Specify the independent variable and the dependent variable on one hand and control the contaminating variables on the other. This rule is applied in experimental tests in psychology and the social sciences. lf it is violated (assuming that variables have been defined for the experimental test) then the general rule of methodology: "Try to confirm your hypothesis by seriously testing and criticizing them" is violated too and this means a serious danger for falsity to enter.

All fundamental (formal) ethical laws should be invariant with respect to transformations in value-scales (value-systems). This rule was defended by Thomas Aquinas where he explains his formal basic principle for ethics: "The good should be done, the bad should be avoided".[14] This one is an example for being invariant with respect to different value systems. The invariance principle is analogous to the one of physics (replace space time coordinates by value coordinates). A violation would destroy our understanding of most general (formal) ethical laws.

Summarizing this chapter I want to stress once more that SR can only proceed in a rational way if it obeys methodological rules which connect the scientific research activity with intrinsic goals and values of science, i.e. with informative and testable (approximative) truth and validity. These rules themselves are confirmable and have their justification as necessary means for the goal of SR: if they are violated the goal is violated or weakened, too. But these rules can also be criticized and revised. One important example was the successful rule of looking for continuous dependencies (based on a general principle of continuity) which was restricted by Quantum Theory.

4 Ideals of Rationality and its Realistic Aspects

4.1 Traditional Ideal of Rationality (17th century)

The program for obtaining scientific knowledge proposed by Descartes and Leibniz was an ideal of rationality. It was a program to be carried out by the *ratio* in contradistinction to other human faculties. And the ideal for the program was mathematics in general and geometry in particular. How was knowledge obtained in mathematics and more specifically in Euclid's Elements? It was obtained by proof from axioms, definitions and postulates. Thus scientific knowledge is to be obtained from first principles and definitions by deductive proof. Such principles are true without exceptions for all individual objects to which they apply and are either universal like $x=x$ or particular like the Cogito ergo sum. This is already so for Aristotle if the strongest kind of scientific knowledge (episteme) is at stake but for the weaker one he accepts principles which are true in most cases (i.e. in modern terms: statistical laws). This weaker kind of knowledge was not acceptable for Descartes and Leibniz (nor for Spinoza or Christian Wolff).

The program for scientific knowledge according to the Ideal of Rationality of the 17th century can be summarized by the following six conditions:

(1) There are first evident principles which are the sources of human knowledge.

(2) There are logical and mathematical principles of deduction by which theorems (further knowledge) can be derived from these first evident principles.

(3) There is a truth-criterion by which principles of the sort (1) and (2) can be selected from other sentences.

(4) There are primitive innate ideas (concepts) which are the building blocks of the first evident principles.

(5) There are logical and mathematical principles of definition by which a reduction of complex ideas to primitive ideas is possible.

(6) There are criteria to select the primitive innate ideas from other ideas.

If we try to formulate these conditions as principles we note that the whole program is at the same time a reduction program to first evident axiomatic principles[15] (conditions 4.11-4.16) and to first primitive ideas, terms or concepts (conditions 4.17-4.19).

4.1.1 *Proposition* p *is scientifically known iff it is reducible to a first principle.* p *is reducible to a first principle iff* p *is itself a first principle or it is derivable from a first principle – or can be traced back to a first principle by logical principles of deduction and definition.*[16]

4.1.2 *First principles can be known by intuition*[17]

4.1.3 *There are first principles which are known by intuition:*

"Thus each individual can perceive by intellectual intuition that he exists, that he thinks, that a triangle is bounded by three lines only, a sphere by a single surface, and so on."[18] "The primitive truths of reason are those which I call by the general name of identicals ... Those which are affirmative are such as the following: everything is what it is, and in as many examples as we may desire, *A* is *A*, *B* is *B*."[19]

"As for the primitive truths of fact, they are immediate internal experiences of an immediacy of feeling. And it is here that the first truth of the Cartesians or of St. Augustinus occurs: 'I think, therefore I am, i.e. I am a thing which thinks' ..."[20]

4.1.4 *Everything known by intuition is known clare et distincte*[21]

4.1.5 *Descartes: Everything known clare et distincte is true.*[22]
Leibniz: Everything known clare et distincte and known to be possible (consistent) is true.[23]

From the principles stated so far it follows that for Descartes every first principle is true. For Leibniz it follows that every first principle is true provided the ideas put together in the principle are possible (consistent).

4.1.6 *Every proposition derived from true premises is true.*

The principle is intrinsic in Descartes' description of the method of deduction.[24] According to Leibniz principles of deduction belong certainly to the truths of reason. Secondly they are hypothetical truths not existential truths. The above principle is intrinsic in many passages and deduction principles he states explicitly. His examples are modes of syllogism but he also points out that there are valid principles of deduction not included in syllogism and gives principles of the logic of relations as examples.[25] The principle of the reductio ad absurdum is one other main principle of deduction.[26]

Principles of Scientific Analysis

4.1.7 Term (concept, idea) t *is scientifically analyzable iff it is reducible to primitive terms.*

t is reducible to primitive terms iff *t* is itself a primitive term or it can be traced back to primitive terms by a chain of definitions:[27]

> "Analysis is as follows: Let any given term be resolved into its formal parts, that is, let it be defined. Then let these parts be resolved into their own parts, or let definitions be given of the terms of the (first) definition, until (one reaches) simple parts or indefinable terms."[28]

> "When definition pushes analysis until it reaches primitive notions, without presupposing anything whose possibility requires an *a priori* proof, the definition is perfect or essential."[29]

As Rescher puts it "Leibnizian analysis is a logical process of a very rudimentary sort, based on the inferential procedures of *definitional replacement* and *determination* of *predicational containment* through explicit use of logical processes of inference.[30]

4.1.8 All scientific terms (concepts, ideas) which are primitive and derived from the mind are innate.

4.1.9 There are primitive terms (concepts, ideas) which come from the mind itself. Descartes uses mostly epistemical examples like knowledge, doubt, ignorance „. etc. whereas Leibniz uses either mathematical ones like square, triangle, circle or metaphysical ones like being, possibility, equality.[31]

4.1.10 To what extend is this program realistic?

(1) The program in the sense of a particular axiom system was already realized by Euclid. And this axiom system, i.e. Eucledian Geometry was one of the great ideals for this program. The method to build up some science in accordance with this ideal was called the method of *more geometrico*. From this it follows that the program is realistic with respect to an axiom system about a particular area. But the unrealistic aspect of Descartes' idea was that there is basically one axiom system for all scientific truths. Leibniz was more

modest and claimed different axiom-systems for logic, mathematics, metaphysics, physics and ethics + jurisprudence where for the first three man can find the axioms. Even if the Predicate Logic of First Order (PLl) is a good realization in Leibniz' sense there is of course not *one* axiom system for all logical systems which extend PLl and not for those which are weaker alternatives. Much more unrealistic is an axiom system for the whole of mathematics (for Set Theory see below) or for metaphysics.

(2) Descartes' idea to have just one axiom for the formal sciences and one for all factual sciences (the Cogito) is of course an extremely unrealistic exaggeration. Leibniz agrees for the formal sciences. His principle here is the law of non-contradiction – though he applies it not only as an axiom but also as a reductio ad absurdum rule. Moreover he sometimes speaks of the principle of identity as the first principle.[32] Already the Greeks have been more modest here: their goal was to explain relatively many phenomena with the help of relatively few principles. For metaphysics Leibniz seems to propose also only one axiom: the principle of Sufficient Reason. For the other areas Leibniz made weaker claims.

(3) Another unrealistic idea is that with the primitive terms according to Descartes and Leibniz. The realistic part of it is that there must be some primitive terms. But they need not to be absolute and fixed and moreover the doctrine of Descartes and Leibniz that those primitive terms which are the first building blocks of the axioms are "inborn" (whatever that may mean) is very obscure or problematic. Further the building blocks of the most important laws need not to be identical with the most primitive concepts of an area of research. Thus although mass, length and time are the most primitive concepts of physics the building blocks of the basic laws of Quantum Mechanics and General Relativity Theory are rather the constants h and c and G (Planck's constant, light velocity, gravitational constant).

(4) The strongest assumption of Rationalism of the 17th century were principles 4.14 and 4.15 from which it follows that everything known by intuition is true (Descartes) or everything known by intuition and proved to be consistent is true (Leibniz). The main point is here that intuition is at the same time justification. Now some of the modern forms of Rationalism (of the 20th century) would judge that claim as altogether wrong or as a sort of Dogmatism. But this is probably

to throw out the baby with the bathwater. I think that there is a small true kernel in the above assumption. What is it? It is the fact that such simple truths as $2 + 2 = 4$ or $x{=}x$ (without talking about existential presuppositions but assuming a non-empty universe of discourse) are transparent insights. Though they can be justified in some way, for example by building up a set of definitions like $2 =_{df} 1 + 1$ etc. as Leibniz shows[33] such kinds of justifications do not essentially add much to the insight into the simple structure. Similar examples are simple theorems of logic like $p \rightarrow p$ or what is true for all objects of a certain area is true for some etc. Also a most tolerant formulation of the principle of non-contradiction (the proposition p and its own negation non-p cannot both be true or cannot both have designated values).

My main point here is now this: The fact that intuition and a relatively high degree of justification go together in some very simple and transparent cases which are certainly basic for science does not permit to extend it to all axioms for a system of logic much less to all axioms needed in mathematics and still much less to all axioms (laws) needed in the sciences. That means that in most cases of both formal and factual sciences the axioms, laws, hypothesis, get their (partial) justification in the sense of corroboration or confirmation by investigating their consequences, their explanatory power, their role of unification further by testing their consequences with respect to consistency or with respect to their agreement with the facts. It was certainly one of the main mistakes of the Rationalism of the 17th century to hold that knowledge by intuition is always and for all cases justified knowledge. As we have seen this can be accepted only for a few most simple cases. And a second point to be made here is that these few cases do not provide a sufficient basis for building up some science.

But 'intuition' has – besides the meaning above (evident insight) – another meaning: inspiration, interesting idea, brain wave. In this latter sense intuition plays an important role in science and for SR. New hypothesis, even new theories are often invented by intuition in the sense of inspiration or brain wave. But quite clearly this *context of discovery* is not a *context of justification*, after the invention the hypothesis has to be formulated as clearly as possible and then it has to be tested.[34]

The point that new hypothesis or even theories (consisting of laws and hypothesis) are creations of the human mind and cannot be derived from experience is one of the main components of Kant's theory about how (natural) science is possible. This is important and can also be accepted in the light of our knowledge today. It is also the view of great scientists like Einstein.[35]

Kant was aroused by the correct observation of Hume that from the class of past observation statements (describing facts of the past) no future observation statement (predicting a future event like that the sun will rise) logically follows; in other words, the class of all past observation statements is logically consistent (compatible) with *any* future observation statement or its negation. Hume concluded wrongly from this correct fact that there is no objective causal connection between past and future, but only a psychological habit of expectation concerning regular future events like sun-rise. Kant understood that this cannot be true, since with the help of Newton's Theory plus past observation statements one can unambiguously predict the future sun-rise or a future eclipse of moon or sun. Therefore Kant concluded correctly from Hume's correct observation that the universal laws of Newton's Theory cannot be consequences of any class of observation statements, since then they would be compatible with any future observation: Thus they must be creations of the human mind as it has been said already. But how are they scientifically justified then? Today's view is by corroboration and confirmation via positive tests of their consequences because – according to a critical view of realism – the known laws of nature represent, even if approximately, the structure of nature. Here Kant made a similar mistake as the rationalism of the 17th century: he claimed that the laws of physics (nature) are valid because they are a priori laws of the human mind which are projected to reality. The difference is that he didn't stress the evident insight (clare et distincte ... etc.) – which seemed to him too subjectivistic – but the a priori structure of the human mind. And he added his specific point of view: Laws of nature are not representations of the structure of nature, but are representations of the structure of the human mind imposed to nature.[36]

4.2 The ideal of an embracing language of science.

There have been attempts in the philosophical tradition to construct an universal language which is a maximal precise instrument for all the sciences. One example is Leibniz.

Another is the program of the Vienna Circle, especially of Carnap to formulate the Logical Syntax of the Language of Science.

4.2.1 Leibniz: From the characteristica universalis to the calculus ratiocinator

The procedure is in several steps. First a formal language is built up from primitives. Second that language is completely mathematized. Third the mathematical language is applied to proofs such that they can be mathematically calculated. By this Leibniz hoped to have a combinatorial-mechanical method to find every truth.

(1) First step: Analyzability
According to Leibniz a scientific term has to be analyzable, i.e. it must be possible to trace it back by definitional replacement to ultimate primitive notions (which are usually inborn according to him): (cf. 4.17).

(2) Second step: Mathematization
This step has three substeps according to Leibniz:

(a) Every primitive term can be represented by a characteristic basic number.

(b) Every compound term can be represented by a characteristic number which is equal to the result of applying a certain mathematical function to basic numbers (i.e. numbers which represent primitive terms).

It follows also that every Subject-term and every Predicate-term of a categorical proposition is representable by a characteristic number.[37]

In his last and successful application to syllogistics Leibniz represented each term of a categorical proposition not by just one number but by an ordered pair of numbers of which one is positive the other negative and both have no common divisor.[38]

(c) The choice of these numbers (or pairs of numbers) is not arbitrary:
The characteristic number of the compound term has to be chosen in such a way that in addition to condition (b) the following condition is satisfied: If the predicate (P) is contained in the subset (S)[39] the number representing the predicate term (t_P) has to be contained mathematically (i.e. where 'containing' is

interpreted by a certain mathematical function F) in the number representing the subject-term (t_S).

For instance for the categorical proposition which is universal and affirmative Leibniz requires “Regulae usus characterum in propositionibus categoricis sunt sequentes: *Si propositio Universalis Affirmative est vera*, necesse est ut numerus subjecti dividi possit exacte seu sine residuo per numerum praedicati.”[40]

(3) Third step: Application to proofs (i.e. syllogistic moods)
Leibniz has given quite a number of different proposals for a mapping from the forms of the different categorical propositions to characteristic numbers.[41] The difficuIties are not only related to the categorical propositions alone but also to their role in syllogistic moods so as to be able to distinguish valid arguments from invalid ones by a method of mathematical calculation. But Leibniz's last proposal was successful. With this proposal Leibniz hoped to find a mathematical decision method for syllogistics, such that the moods can be mathematically calculated as to their validity. By this method he has found that all laws of conversion, of the square of opposition, and all the valid moods of assertoric syllogism can be proved to be valid. Moreover the method exhibits as valid Lukasiewicz' four axioms of assertion and also his axiom of rejection.[42]

There is however some difficulty which seems to have bothered also Leibniz. There are invalid syllogistic forms for which one can find numbers in such a way as to exhibit them as valid. But, on a closer look, this fact does not make Leibniz's mathematization of syllogistic incorrect. As Marshall points out correctly, the argument for rejection is as follows:

> “If invalidating instantiations can be produced, the mood is invalid; it is valid if they cannot.”[43]

(4) Extension of the Method to a Calculus Ratiocinator
Leibniz probably thought that this or a similar method of mathematization can be extended to the whole of mathematics and then also to metaphysics. In respect to physics (we may even say to empirical sciences) and to jurisprudence and ethics Leibniz was much more careful: These truths are “infinitely analytic”, i.e. an infinite number of steps would be necessary to trace them back to first evident axioms. That is man cannot demonstrate them (only God knows the connection) although also for them the principle of sufficient reason

(as a completeness-principle) holds: every truth has its proof from the respective axioms.

> "The laws of motion which actually occur in nature and which are verified by experiments are not in truth absolutely demonstrable, as a geometric proposition would be."[44]

But for logic, mathematics and metaphysics Leibniz not only thought that completeness of the respective axiomatic systems (buiIt up *more geometrico*) holds, but also, when his method of mathematization is extended, a *calculus ratiocinator*, a combinatorical-mechanical method is available to find every truth. I want to emphasize strongly that one should understand this heroic ideal of rationality in connection with his success in syllogistics and the three steps described above.

The following passage seems even to suggest that this method is available for every science although other passages (like the one above) seem to show that he makes a clear distinction between logic, mathematics and metaphysics on one side and the empirical sciences and jurisprudence and ethics on the other:

> "In Philosophy, I have found a means of accomplishing in all sciences what Descartes and others have done in Arithmetic and Geometry by Algebra and Analysis, by the *Ars Combinatoria* . ... By this all composite notions in the whole world are reduced to a few simple ones as their Alphabet; and by the combination of such an alphabet a way is made of finding, in time, by an ordered method all things with their theorems and whatever is possible to investigate concerning them."[45]

4.2.2 Carnap: Towards an all embracing Logical Syntax

The idea of a universal language for all sciences was also very strong in the Vienna Circle. But contrary to Leibniz for whom it was an aim to include metaphysics and to apply the characteristica universalis and the method of mathematization in that area in such a way as to decide upon difficult metaphysical alternatives by "calculemus" the Vienna Circle and in particular Carnap wanted to prove that metaphysics consists of "Scheinsätze":

> "The supposititious sentences of metaphysics, of the philosophy of values, of ethics (in so far as it is treated as a normative discipline and not as a psychosociological investigation of facts) are pseudo-sentences."[46]

There is also another difference: Leibniz tried to show that scientific (and philosophical) concepts (predicates) can be mapped onto certain pairs of numbers, the relations between predicates (making up a sentence) to mathematical functions and so the inferential relations between sentences. Carnaps program was to build up a general logic of science which investigates scientific concepts and sentences by logical analysis but is itself nothing else but logical syntax (where philosophy will take the role of the logic of science):

> "*Philosophy is to be replaced by the logic of science* – that is to say, by the logical analysis of the concepts and sentences of the sciences, for *the logic of science is nothing other than the logical syntax of the language of science.*"[47]

A third difference is this: Whereas Leibniz was searching for a *true* characteristica universalis (since compound terms are traced back to primitives in an absolute sense since they are inborn) and for an optimal method of mathematization Carnap tells us that the form of the universal language for the sciences is arbitrary:

> "In it [i.e. in the book "Logical Syntax"], the view will be maintained that we have in every respect complete liberty with regard to the forms of language .... For language, in its mathematical form, can be constructed according to the preferences of any one of the points of view represented; so that no question of justification arises at all, but only the question of the syntactical consequences to which one or other of the choices leads, including the question of non-contradiction."[48]

A fourth difference is this: Leibniz believed that systems of truths of reason (veritees de raison) can be built up more geometrico (as axiomatic systems) for the areas of logic, mathematics and metaphysics. And in respect to these three areas he seemed to believe that these systems are complete, i.e. that every truth has an a priori proof (from the true axioms) which is finitly analytic, that is which can be carried through in a finite number of steps. Carnap didn't believe in the completeness (except of First Order Logic) of an axiomatic system of mathematical truths in general (he knew Gödel's results) let alone metaphysics which consisted for him of pseudo-sentences. But he seemed to believe in another heroic ideal: completeness of language.

4.2.3 What are the unrealistic and what are the realistic aspects of Leibniz' and Carnap's ideals of rationality?

(1) The first step of Leibniz' analysis of concepts, i.e. reduction of concepts to primitives has been already discussed. The second step however is something special. Leibniz tries to map concepts (predicates) to numbers or to pairs of numbers, relations between concepts (predicates) to mathematical functions and relations between premises and the conclusion again to mathematical functions. As we have seen he invented a successful decision method for syllogistics with the help of that strategy (third step). This already is a proof that such a method is realizable. A realization of such a method in a much more rigorous and general way – which certainly would have pleased Leibniz – we know from the 20th century: Gödel's arithmetization of language or for short: Gödel numbering. In fact Gödel's procedure was quite analogous: First he maps logical constants like $\neg, \vee, \rightarrow, \exists, =$ etc. to natural numbers (1-10) then number variables $(x, y, z, \dots)$ to prime numbers from 11 on, then sentential variables to the squares of such prime numbers and finally predicate variables to the cubes of such prime numbers. Every sentence (in the symbolic language) can now be represented by a sequence of Gödel numbers and in order to represent every sentence by a single Gödel number Gödel took the sequence of prime numbers (beginning with 2) to the power of the respective Gödel numbers and formed the product out of it. For instance the sentence $x = x$ has the sequence of Gödel numbers 11, 5, 11 and the Gödel number of this sentence is $2^{11} \cdot 3^5 \cdot 5^{11}$. Similarly to Leibniz' third step also proofs can be represented by Gödel numbers. Proofs are sequences of sentences. Take for instance the proof: $x = x \vdash (\exists y)(y = x)$. If the Gödel number of $x = x$ is m and that of $(\exists y)(y = x)$ is n then the Gödel number of the sequence is $2^m \cdot 3^n$ or that of the respective implicational formula is $2^m \cdot 3^3 \cdot 5^n$ (forgetting additional parenthesis). This shows that every sentence and every proof can be represented by an unique Gödel number; i.e. there is a one-one correspondence between sentences (proofs) and Gödel numbers. Moreover it is not difficult to say of a number whether it is a Gödel number or not; for instance 100 cannot be any Gödel number.

However, Gödel continued to a further step which was not considered by Leibniz: by the same method also the metatheory can be arithmetized. For example the metatheoretical sentence "the variable x is a part of the sentence $x = x$" can be expressed by saying that the number 2^{11} is a factor of the number $2^{11} \cdot 3^5 \cdot 5^{11}$. Similarly one can express the metatheoretical sentence: the sequence with Gödel number so and so is a proof for the sentence so and so; for example the sequence with the Gödel number $2^m \cdot 2^n$ is a proof for the sentence with Gödel number n, where the predicate "provable" is expressed by the mathematical relation between two numbers; viz. between $2^m \cdot 2^n$ and n.

The goal of the arithmetization was to prove a sentence which says of itself (via representation by Gödel numbers) that it is unprovable but true which then proved the incompleteness of the theory of natural numbers (see below). Later on specific number theoretic sentences have been shown to be unprovable from the axiom systems of number theory.[49] Summarizing we may say that Gödel's achievements were great realizations of ideals of rationality. The first – his completeness proof of First Order Predicate Logic – realized a prediction of Leibniz that every truth (of Logic, i.e. First Order Predicate Calculus) has its proof from the axioms (of First Order Predicate Calculus).[50] The second – his arithmetization – realized Leibniz' steps two and three for the mathematization of (a formal) language. And the third – his incompleteness (and undecidability) proof put a limit to an unrealistic ideal of rationality: to the belief that there can be formal recursive proof procedures which solve every scientific or "just" every mathematical problem.

(2) Leibniz' extension of the third step to a general Calculus Ratiocinator is certainly not realizable. Gödel showed limits in the theory of natural numbers, and in general for formal systems: either the concept of provability is not recursively definable in the system or the system contains undecidable sentences, i.e. if the concept of provability is recursively definable in the formal system (which can be shown with the help of the arithmetization, i.e. Gödel numbering) then this system contains undecidable sentences. The result can be extended to many formal systems which possess a certain kind of richness, for example to Set Theory. However, caution is necessary in order not to extend the result arbitrarily to any mathematical formal system "including" natural numbers: Certain subsystems within the area of real numbers, for example the theory of real closed fields,

have been proved to be decidable.

What would be a Calculus Ratiocinator in modern terms? It would be a recursive proof procedure to decide every problem. Not just every mathematical problem as Hilbert hoped; but every logical, mathematical and metaphysical problem according to one reading of Leibniz (i.e. according to one set of passages in his works). And a method for deciding every philosophical and scientific problem according to another reading which is based on the extremely optimistic passage "In philosophy, I have found a means." (cf. 4.2.1 (4)).

(3) One of the main goals of Carnap was certainly an all embracing precise language of science. Whether the elimination of sentences of metaphysics, value theory and ethics was another one or was viewed as a consequence of the realization of the first goal is a question, which seems to be answered with Yes by at least some quotations of his *Logical Syntax* (see note 46 above).

Concerning the goal of an all embracing language of science on gets the impression from Carnap's Logical Syntax that his ideal of rationality here is an ideal of a complete language of science; i.e. that the logical syntax built up in the way he does can be made complete in the sense that every logical and (pure) mathematical predicate and relation and every scientific predicate can be expressed in it in a formal way, that is without taking into consideration the meaning of the predicates relations or respective sentences:

> "All questions in the field of logic can be formally expressed and are then resolved into syntactical questions. *Logic is syntax.*"[51]

> "The view we intend to advance here is rather that all problems of the current logic of science, as soon as they are exactly formulated, are seen to be syntactical problems."[52]

To these claims I want to make the following critical remarks:

(a) Carnap's use of the expression 'syntax' does not seem to be the one which has been used after the fifties. This is shown by the following passage of the Logical Syntax which includes truth tables into the syntax:

> "But the decisive point is the following: *in order to determine whether or not one sentence is a consequence of another, no reference need be made to the meaning of the sentences. The mere statement of the truth-values is certainly too little; but the statement of the meaning is, on the other hand, too much. It is sufficient that the syntactical design of the sentences be given.*"[53]

> "*A special logic of meaning is superfluous*; 'non-formal logic' is a *contradictio in adjecto. Logic is syntax.*"[54]

The passages cited seem to suggest a point of view influenced by the formalism of the Hilbert-school especially when Carnap emphasizes that questions of sense or meaning need not be considered beyond the form of the signs or beyond the "syntactical design". This overexaggeration was corrected later by Carnap himself when he wrote his "Meaning and Necessity". But independent of it the whole development of the model theoretic approach in Logic and the foundations of mathematics starting with Tarski's papers from the 30s is a correction of Carnap's view; even if there is also a parallel development of proof theoretical methods.

(b) It has been an experience that even a rich logical language in the sense of a Carnapian logical syntax as a logic of science is not the most suitable kind of language for sciences. The most general language which is used today in mathematics and also in different sciences including social sciences and psychology is the language of Naive Set Theory (in contradistinction to Axiomatic Set Theory). A widespread view in the 60s was that Axiomatic Set Theory will become the foundation of all (or almost all) mathematics. Instead of that there has been a shift of emphasis: not the (axiomatic) *theory* but its *language* became the general framework both for formulating mathematical proofs and for writing research papers in the sciences.

(c) Carnap's view that one could have a general Logic of Science fixed in advance to apply it everywhere in the sciences seems to be a wrong and unrealistic ideal of rationality. On the contrary it seems much better to have an open and flexible logical framework which can be corrected, revisited and extended if needed because of new problems and new results.

This point concerning revision and complementation of the underlying language (and logic) can be substantiated by the following examples.

Quantifiers: If PLl is applied to linguistics then there is a problem with the interpretation of quantifiers of natural language discourse. For example the sentence "two professors corrected six papers of three students" has in English a certain number of possible readings. By interpreting this sentence with the quantifiers of PLl one runs into the problem of nested quantifiers. The usual understanding of quantifiers in PLl does not give the same number of possible readings as ruled by correct english grammar. In some such examples logic allows more possible readings, in others logic extinguishes differences recognized by natural language.[55] Tue reason is that in natural language there are additional rules concerning the interdependence of quantifiers (depending on the position on the stress or on the selection of expressions like any or every or each). In PLl the number of distinct readings of an english sentence depends on the number of ways of linearly ordering different quantifiers. But in natural language different dependencies of quantifiers and also mutually independent quantifiers are permitted. The latter cannot be handled by the scope method in PL1.[56]

Relevance: If deduction (deriving consequences) according to PL1 is applied to areas outside logics and mathematics (from physics via different sciences to philosophy and ethics) different kinds of paradoxes come up. It can be shown that the following two properties of classical logic (PL1) are responsible for most of these paradoxes:

(a) Replaceable Parts:
Parts of the consequence α in $A \vdash \alpha$ can be replaced by arbitrary parts salva valididate of $A \vdash \alpha$. Like in $p \vdash (\neg p \rightarrow q)$, $p \vdash p \vee q$, $p \vdash (q \rightarrow p)$, $p \vdash (p \wedge q) \vee (p \wedge \neg q)$ the variable q can be replaced by any other salva valididate of the inference (in the last formula at both occurrences by the same variable).

(b) Reducible Parts:
Parts of α can be reduced to simpler (smaller) parts salva validitate of $A \vdash \alpha$. Like $p \wedge p$, $p \vee p$, $\forall x(Ax \wedge Bx)$ can

be reduced to p, $\forall x Ax$, $\forall x Bx$ as simplest consequence elements.

If the consequences do not contain replaceable or reducible parts then the following paradoxes can be avoided: Paradoxes of explanation, confirmation, law statements, quantum logic, verisimilitude, disposition predicates, deontic logic, epistemic logic, value theory.[57]

The following two criteria RC and RD are precise formulations of replaceable and reducible parts. They are put like filters on PL1 to select the set of valid relevant consequence elements out of the set of (classically) valid consequences (of a given set of premises).

RC (Replacement): α is a relevant consequence of A (symbolically: $A \vdash_{cr} \alpha$ iff the following conditions (1)-(3) are satisfied:

(1) $A \vdash \alpha$

(2) It is not the case that a predicate (including propositional variable, the identity sign) is replaceable in α on some of its occurrences by any other predicate of same arity salva validitate of $A \vdash \alpha$.

(3) There is no β such that $\beta \dashv\vdash \alpha$ and β is the result of the replacement of some occurrences of $\tau_1 = \tau_2$ by t or f.

$a \rightarrow \beta$ is relevant (symbolically: $\alpha \rightarrow_{cr} \beta$) iff $\{\alpha\} \vdash_{cr} \beta$.

RD (Reduction): let $A \vdash_{cr} \alpha$. Then α is a relevant consequence-element of A iff it is not the case that there exist mutually distinct formulas $\beta_1, \ldots, \beta_n$ $(n \geq 1)$ such that

(1) each β_i is shorter than α

(2) $\alpha \dashv \vdash \beta_i \wedge \cdots \wedge \beta_i$

(3) for each β_i, $A \vdash_{cr} \beta_i$.

By considering the conditions (1)-(3) it is easy to see that every relevant consequence α of A can be splitted up into a set of relevant consequence elements $\beta_1, \ldots, \beta_n$ $(n \geq 1)$ of A logically equivalent with the original α.

4.3 Further ideals of rationality: Logical Equivalence and Logical Closure

(1) *Logical Equivalence*

The usual opinion is that logical equivalence is a rather strong notion. This is not at all true. Experienced teachers of logic courses will know what happens when they teach students to translate a (philosophical) text into First Order Predicate Logic, make an equivalence transformation, and try to translate it back into a (the same?) philosophical text. Usually the resulting text is quite different, even if the translation is done with great care. The culprit is often: logical equivalence.[58] More formal paradoxical cases have been discussed by several authors. Concerning verisimilitude Miller[59] seems to have been the first to show that the relation "theory A is nearer to the truth than theory B" defined in one language may turn into its opposite (B is nearer to the truth than A) when defined in a language which is logically equivalent to the first one.

Thus language-invariance with respect to logical equivalence destroys reasonable properties of verisimilitude. One model to show this is as follows: It is easy to see that $A >_T B$ (A has more verisimilitude than B) cannot satisfy at the same time the following two conditions:

(a) If p and q are true, then $p \wedge \neg q >_T \neg p \wedge \neg q$

(b) $>_T$ is invariant under logically equivalent transformations of theories; i.e. if $A >_T B$ then $A* >_T B*$ where $A*$ and $B*$ are translations of A and B (of language $L_{p,q}$ into language $L_{p*,q*}$).

To see this consider the following definitions:

(i) $p \leftrightarrow (p * \wedge\, q*) \vee (\neg p * \wedge \neg q*)$ and

(ii) $q \leftrightarrow q*$. From this follows that

(iii) $p* \leftrightarrow (p \wedge q) \vee (\neg p \wedge \neg q)$ and

(iv) $q* \leftrightarrow q$.

Hence the variables of the two propositional languages $L_{p,q}$ and $L_{p*,q*}$ are interdefinable by (i)-(iv).
It holds: if $A >_T B$, then $A* >_T B*$, if $A*$ and $B*$ are translations of A and B by the above definitions. But $(p \wedge \neg q)* = ((p * \wedge\, q*) \vee (\neg p * \wedge \neg q*)) \wedge \neg q * \dashv\vdash \neg p * \wedge \neg q*$ and for $(\neg p \wedge \neg q)*$ (translation analogously): $(\neg p \wedge \neg q) * \dashv\vdash p * \wedge \neg q*$. Hence from assumption 1. and 2. it follows: $(p \wedge \neg q)* <_T (\neg p \wedge \neg q)*$, hence $>_T$ is language-dependent.[60] This shows that invariance with respect to logical equivalence is not an uncontroversial goal but sometimes a trap.

Even much stronger relations than logical equivalence, for example those of different mathematical codings, like different types of Gödel numberings show similar problems: The existence of ungrounded and paradoxical sentences (in Kripke's sense) and the number of fixed points is not invariant against the kind of Gödel numbering which is chosen if instead of the strong the weak 3-valued logic of Kleene is taken.[61]

Further examples of language-dependency are Gödel sentences (sentences expressing their own unprovability) and Henkin sentences (sentences expressing their own provability): Any two of the former are provably equivalent in Cut Free Analysis whereas for Henkin sentences this it not the case.[62]

(2) *Logical Closure*:

> "In logic, logical closures are a, if not the, principal stock-in-trade. Without exaggeration, given a question about a bunch of relations its ideal form is assumed to concern the logical closure of the given bunch."[63]

A rather drastic example of the ideal of logical closure is the usual Epistemic Logic. Because of maintaining logical closure in the usual systems of Epistemic Logic they have the (non-human) properties of deductive infallibility (i.e. one knows all the consequences of what one knows) and logical omniscience (i.e. one knows all the logically true sentences). Here logical closure leads to an ideal of rationality which is in fact not a human rationality.

The reason for those properties in (the usual) epistemic systems is that they are reconstructed out of modal systems (usually S4, S5 or some system between). The two crucial properties of such modal systems are these:

(1) They have the "necessitation rule" in the sense· that if p is logically true (a theorem in the underlying logic) then necessarily-p is also true.

(2) They have the following closure condition in respect to the operator "necessary" (which is quite adequate in modal systems): If p is necessarily true and if q necessarily follows from p then also q is necessarily true.

The main reconstruction of the epistemic system out of the modal system consists in reinterpreting the necessity-operator as a knowledge-operator. Thus whereas it is quite acceptable that all necessary consequences of logically necessary sentences are again logically necessary sentences it follows by this interpretation from (2) that also all consequences of sentences which we know are also sentences which we know (i.e. deductive infallibility). And by (1) it follows that we know all logically true (valid) sentences (i.e. logical omniscience).[64]

By containing deductive infallibility and logical omniscience the usual systems of Epistemic Logic are simply incompatible with human rationality. Why do logicians make difficult proofs of complicated theorems if they know all the logically true (valid) sentences?[65] The example shows that here *Hausverstand* was sacrificed for the ideal of Logical Closure.

It should be mentioned however that in the usual systems of Epistemic Logic the ideal of Logical Closure is intertwined with another widespread ideal: The one to have a (model theoretic) semantics by all means. Since there is (was) no (for epistemic systems) and since there was one available for modal systems one reinterpreted modal systems epistemically and had at once a semantics: Using some analogy like that of $Kp \to p$ to $\Box p \to p$ and forgetting the many differences and dis-analogies (cf. above). Analogous examples are widespread in the area called "Philosophical Logic".

5 Methodological and Ontological Conditions

5.1 Universality. Is it always rational to universalize?

The ideal of universality leads to the problem of raising universality while preserving informative content. This can be studied from different examples in the sciences: Group-structures are quite universal but still very basic for a lot of mathematical structures. Further universalization (for example semi-groups) yields diminishing return. Concerning most general physical laws it holds: raising to still higher symmetries means extinguishing interesting differences, means loss of information, means incompleteness. Charge symmetry extinguishes the difference between + and -, parity, the one between right and left ... etc.

5.2 Rationality of Methodology: Rules for experiments in biology applied by the first geneticist, Gregor Mendel.

5.2.1 Before I shall discuss Mendel's methdolological rules I shall state three more general but related points.

(1) Experienced physicists and chemists know that the concrete data never fit exactly the theoretical value. This was one of Kant's great understanding of a scientific theory like that of Newton: a scientific theory transcends essentially all the data (received from concrete application). Popper formulates some essential details of this fact in the following way:

> "Observations are always inexact, while the theory makes absolutely exact assertions ... Each observed situation is always a highly specific situation. The theory, on the other hand, claims to apply in all possible circumstances ... Observations are always concrete, while the theory is abstract ..."[66]

Moreover we may add (what Popper also stresses) that the theory may speak about entities which are at the time when it is formulated – or even more principially – unobservable.

(2) From this understanding it is clear that the following two principles are true: (i) Though it is necessary to take all the available data into account it is not necessary to use all these available data for formulating the hypothesis or theory. (ii) Although - taken prima facie - all the available data have to be taken equally serious on a closer look and after applying methodological rules it is not only not necessary but may be even irrational to take all available data equally serious; i.e. what is important is reasonable selection.

(3) From (1) and (2) it follows that a scientific theory can never be just derived (deductively) from a set of data, even if the set is very comprehensive. Therefore a successful scientific hypothesis or theory is always a great invention of the human mind (recall 4.1.10 (4)). And if it is in addition a correct or approximatively correct description of the structure of a new field in reality then it is not only a great invention but also a great discovery. This was the case with Mendel's laws govering the inheritance of individual characters.

5.2.2 Mendel's methodological rules

Mendel used severe norms of scientific methodology for his planned experiments. Those norms can be stated as follows:

R1 *The experimental plants must necessarily possess constant differing traits.*

R2 *Their hybrids must be protected from the influence of all foreign pollen during the flowering period or easily lend themselves to such a protection.*

R3 *There should be no marked disturbances in the fertility of the hybrids and their offspring in successive generations.*

Rl to R3 are Mendel's rules given in his (1866).[67] He tried to find the optimal model satisfying these rules among the Leguminosae. Preliminary experiments showed that Phaseolus and Lathyrus were not suitable because of the decreasing fertility of their hybrids. On the other hand Pisum had the best qualifications.

The following rules R4 to R6 are my own interpretations of passages of Mendel's *Experiments on Plant Hybrids* which seem to me places where Mendel describes in a more implicite way these additional important rules.

R4 *In order to make sure to satisfy Rl use prior testing of the constancy of the traits.*

The invention of this rule and the carrying out of two years prior testing was a methodological novelty introduced by Mendel for experiments in biology.[68]

R5 *In order to eliminate chance effects use a large number of plants for the experiments.*[69]

Orel[70] thinks that Mendel's understanding of R5 might have been inspired by Gärtner's monograph where he noted in the margin: one should employ a large number of observations to arrive at a standard. But it is even more obvious that Mendel learnt the properties of statistical ensembles and probability calculations from Professor Christian Doppler with whom he studied (experimental and theoretical) physics in Vienna in the years 1851 and 1852.[71]

In 1851 the second edition of Doppler's textbook on arithmetic and algebra was published which contains a theory of probability and its application to sciences.

R6 *For each experiment place a number of the potted plants in a greenhouse during the flowering period in order to serve as controls for the main experiment in the garden against possible disturbance by insects.*[72]

Also R6 is a methodological novelty as it requires a control group.

5.2.3 Fisher's Criticism

In 1936 R. A. Fisher criticized Mendel's experiments w.r.t. two main points: (a) Mendel's experimental garden (35m x 7m) was too small to grow the many plants reported in the description of the experiments. (b) Mendel's data are too good from the statistical point of view such that there seems to be an effort at "correction". To the first point (a) we can say that Fisher overlooked that Mendel placed a considerable number of pottet plants in the green house during the flowering period (see R6 above). At the start of Mendel's experiments the size of the greenhouse was 22,7m x 4,5m. Later it was enlarged.[73] To the second point (b) Thoday (1966) found out that Fisher made a questionable if not false assumption by using binominal distribution: pollen cells occur in tetrads and this may have affected seriously the results of segregation of traits. Further Weiling (1989) computerized Fisher's calculations and found out that they were based (by Fisher) on Mendel's having obtained ten plants from ten seeds; but under the supposition of a realistic 80-90% germination rate the computation of the chi-square test came out lower than Fisher's. Further Weiling (1966) computed the same test for experimental data of crossing peas experiments done by several famous biologists (like Bateson, Correns, Tschermak and others) after 1900 and found no essential difference between their data and those of Mendel.[74]

To conclude this discussion we may quote the geneticist and statistician Sewall Wright:

> "Taking everything into account, I am confident, however, that there was no deliberate effort at falsification."[75]

5.3 Causality. Is causal explanation a necessary condition for the rationality of SR?

The answer depends on the concept of causality.

(a) If causality is interpreted in the sense of Laplace's sprit – with the help of dynamical laws plus one state of the system at a given time every other state can be predicted or retrodicted – then already thermodynamics shows that such a concept of causality is too narrow (i.e. not generally applicable).

(b) If just the dynamical law without the further condition of a certain type of stability (a perturbed system relaxes) is taken as the interpretation for causal laws then also such a causality is not available in general. Dynamical chaos shows that such at type of stability is not always guaranteed.

(c) If the conception of causality presupposes as a necessary condition that any two quantities out of all ovservables can be measured simultaneously to a suitable degree of exactness then, since this condition is not satisfied in QM, such a type of causality cannot be generally accepted.

(d) Since causal propagation (in this universe) needs time an upper speed limit for signals is also a limit for causal propagation; i.e. if the speed of light is a speed limit for all signal propagation with respect to all reference frames then it is also a limit for causal propagation. Also most of the recent interpretations of new experiments concerning "Superluminarity" seem to show that the speed of light is a limit for all signal (and front) propagation although phase and group velocity in tunnelling can be greater than the speed of light.[76]

(e) From these considerations it follows that it is necessary to distinguish several different causal relations: one for Classical Mechanics and Special Relativity, another one for Thermodynamics (macro-level) and Correlation Laws, again another one for Quantum Mechanics. In the first case the causal relation is irreflexive, asymmetric and transitive, in the second it is irreflexive not-symmetric and not transitive, in the third it is irreflexive, asymmetric and not transitive.[77]

6 Metaphysical Presuppositions and Extrapolations

6.1 Newton: Absolute Space and Time

The most famous places where Newton speaks about absolute space and time are in the Scholium of the Principia (book I) and in De Gravitatione.

> "I, Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration: relative, apparent, and common time, is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true

time; such as an hour, a day, a month, a year.
II. Absolute space, in its own nature, without relation to anything external, remains always similar and immovable. Relative space is some movable dimension or measure of the absolute spaces; which our senses determine by its position to bodies, and which is commonly taken for immovable space; such is the dimension of a subterraneous, an aerial, or celestial space, determined by its position in respect of the earth."[78]

"... Moreover since we can clearly conceive extension existing without any subject, as when we may imagine spaces outside the world or places empty of body, and we believe [extension] to exist wherever we imagine there are no bodies." ... "There is no idea of nothing, nor has nothing any properties, but we have an exceptionally clear idea of extension, abstracting the dispositions and properties of a body so that there remains only the uniform and unlimited stretching out of space in length, breath and depth."[79]

"3. The parts of space are motionless. If they moved, it would have to be said either that the motion of each part is a translation from the vicinity of other contiguous parts, as Descartes defined the motion of bodies; and that this is absurd has been sufficiently shown;"[80]

"4. Space is a disposition of being qua being. No being exists or can exist which is not related to space in some way. God is everywhere, created minds are somewhere, and body is in the space that it occupies; and whatever is neither everywhere nor anywhere does not exist. And hence it follows that space is an effect arising from the first existence of being because when any being is postulated, space is postulated."[81]

"Absolute time, in astronomy, is distinguished from relative, by the equation or correction of the apparent time. For the natural days are truly unequal, though they are commonly considered as equal, and used for a measure of time; astronomers correct this inequality that they may measure the celestial motions by a more accurate time. It may be, that there is no such thing as an equable motion, whereby

> time may be accurately measured. All motions may be accelerated and retarded, but the flowing of absolute time is not liable to any change."[82]

With the concepts of absolute space and time Newton departs from Descartes but also from Copernicus and Kepler. From all the three in the sense that they have a concept of motion which is based on matter – something empirical – whereas Newton's concept is based on absolute space and absolute time, i.e., non-empirical concepts. Descartes especially relates motion to other bodies in the vicinity: motion for Descartes is a translation from the vicinity of other contiguous parts. For Newton this kind of "relativism" is untenable and absurd.

> "For unless it is conceded that there can be a single physical motion of any body, and that the rest of its changes of relation and position with respect to other bodies are so many external designations, it follows that the Earth (for example) endeavours to recede from the centre of the Sun on account of a motion relative to the fixed stars, and endeavours the less to recede on account of a lesser motion relative to Saturn and the aetherial orb in which it is caried, and still less relative to Jupiter and the swirling aether which occasions its orbit, and also less relative to Mars and its aetherical orb ... Since all these endeavours and non-endeavours cannot absolutely agree, it is rather to be said that only the motion which causes the Earth to endeavour to recede from the Sun is to be declared the Earth's natural and absolute motion. Its translations relative to external bodies are but external designations."[83]

As Barbour describes this view, Newton's passionate belief was that (for every singular body) there must be *one motion that is true, absolute and proper*.[84] And concerning time he wanted to avoid "that it may be, that there is no such thing as an equable motion, whereby time may be accurately measured" (see citation above); i.e. that there must be a more basic measurement of time than the one provided by the rotation of the earth relative to the stars or a similar periodic motion of another planet. In contradistintion to absolute space, absolute time for Newton is still in some way connected with experience: it is abstracted by the astronomers as a "correction of the apparent time" (see citation above from the Scholium). He was searching for a genuine referential basis of observable motion and for an explanation of observable motion with the help of unobservable and absolute space and time. In this respect he is in the tradition of the great aim of Greek science and philosophy: To describe and explain the visible (observable), concrete, particular, changing, material world by non-visible (non-observable) abstract, universal, non changing and immaterial principles.

Is it rational to assume such absolute concepts? Are they justified by the claim that they are needed for giving a solid basis of reference (instead of a relative one) for the measurement of motion? It has to be underlined that Newton clearly sees the differences between the two concepts of space and time:

(1) Space as an infinite immovable container, as pure extension, independent and abstracting from (the existence) of bodies in it.

(2) Space as consisting in the distances among material bodies.

(3) Time as an absolute duration independent from natural reliable clocks (like singular periodic movements of the earth or another planet).

(4) Time as a measure of the duration of a concrete motion.

Not only Descartes and Leibniz but also much earlier thinkers were opposed quite strongly against absolute space and absolute time. First of all Aristotle rejected infinite space and accepted only relative place. Thus Barbour points out correctly: "We cannot conclude this section without commenting on the remarkable similarity of the closed universes constructed by Aristotle and, more than two thousand years later, by Einstein. Both were spatially spherical and infinite in both temporal directions."[85] Concerning time Aristotle defined it as the measure of motion (or more generally: change) with respect to before and afterwards.[86] Thus he bound time to motion and change and rejected a time as duration independent of change: "Time cannot be disconnected from change; for when we experience no changes of consciousness ... no time seems to have passed .... Since, then, we are not aware of time when we do not distinguish any change."[87] But time is certainly distinguished from movement, changes may be faster or slower but time cannot have these properties. Therefore he says: "Time is neither identical with movement nor capable of being separated from it."[88]

Another important thinker who explicitly rejected both absolute space and absolute time was Thomas Aquinas. Concerning space he says that there is no place and no space before the world (universe):

"Our contention is that before the world existed there was no place nor space."[89]

According to Aquinas space is created by creating the universe consisting of material bodies. From this it is plain already that Thomas Aquinas cannot agree with Newton that postulating any being means postulating space. God as an immaterial being does not need space but creates space by creating the material and changing world or by creating material and moving bodies.

In contradistinction to Aristotle time is finite in both temporal directions and also created by creating a finite world with movement and change. He strongly agrees with Aristotle in the point that time cannot be disconnected from change as space cannot be disconnected from the material bodies and their distances in the universe. Also concerning the definition of time Aquinas agrees with Aristotle: "Time is the measure of change."[90] "Time is only the numbering of before and after in a sequence of motion".[91]

An important point made by Thomas Aquinas is that the finite age (the beginning) of the universe cannot be demonstrated by scientific proof. Since scientific proof is proof from laws. But no *hic* and *nunc*, i.e. no fixed reference point in space or in time viz. no singularity can be derived from general laws which abstract from *hic* and *nunc*.[92] This is indeed – together with the above cited passages on space and time – a genious anticipation of some essential parts of the Theory of Special Realitivity. Since a beginning of the universe cannot be proved scientifically this is accepted by faith. On the other hand he points out quite clearly that also the claim that the .world is infinite in one or both temporal directions cannot be proved scientifically (i.e. derived from laws) either; but both views are consistent with respect to the laws about the world. In other words the question whether the universe has a finite age is – according to him – not decidable with the help of laws of the universe. This is even correct today since today's estimation of the age of the universe is based on an experimental effect: the cosmic background radiation. Without this effect the known laws of nature are not sufficient to calculate the finite age (of about 15 billions of years).

We may conclude this section by saying that there is an irrational element in Newton's Principia (and other writings like De Gravitatione) concerning space and time. And moreover that important thinkers of the tradition long before Newton (expecially Aristotle and Thomas Aquinas) were much closer to the modern view of Einstein and Mach concerning these basic concepts of science.

6.2 Constants of Nature

The laws of nature are incomplete concerning a series of questions: what is the reason for the numerical values of natural constants like c, h, G and the proportion of proton and electron mass or of the fine structure constant?

The first three are the main constants for relevantistic Quantum Mechanics + Gravitation. With the help of these one can define the socalled Planck's scale (Planck length-mass and -time). What is the deeper reason for these constants, what is their interrelation to other important magnitudes? With these questions Dirac was deeply concerned and proposed his "Large Numbers Hypothesis"[93]

Dirac found a dimensionless constant which is the ratio of the electric force e^2/r^2 between electron and proton and the gravitational force $G \cdot m_p \cdot m_e/r^2$ between electron and proton: $e^2/G \cdot m_p \cdot m_e$ which is dimensionless and of the order of about 10^{40}. This number he compared with the age of the universe (T) in terms of atomic units, for example expressed in time units $t_e = r_e/c$, i.e. t_e is the time the light needs for the distance of the diameter of the electron. The age of the universe (as known today) in time units t_e is also about 10^{40}. Thus he proposed the equation $e^2/G \cdot m_e \cdot m_p = T/t_e$ as a fundamental equation expressing his socalled "Large Numbers Hypothesis". This Hypothesis states that very large numbers (numerical coefficients) cannot occur without reason in the basic law of physics:

> "It involves the fundamental assumption that these. enormous numbers are connected with each other. The assumption should be extended to assert that, whenever we have an enormous number turning up in nature, it should be connected to the epoch and should, therefore, vary as t varies. I will call this the Large Numbers Hypothesis."[94]

This hypotheses and more specifically the above mentioned equation which connects the gravitational constant with the age of the universe has severe consequences:

(1) If this equation is true then the laws of nature are not time-translation symmetric. According to Dirac $\dot{G} \neq 0$ and G should decrease with time. A further consequence would be that the law of the conservation of energy would no more hold.

(2) As Dirac points out the Big Bang Theory when developed in accordance with the Large Numbers Hypothesis implies continuous

creation of matter which violates the law of conservation of energy.

Are there empirical consequences in order to test (1) or (2)? A consequence of (1), i.e. $\dot{G} \neq 0$ would be that the moon should depart from the earth in the course of time. Very exact measurements didn't lead to a decision, they lay inside the limits of accuracy of measurement (its only some centimeters per year). Concerning the constancy of c an interesting theory which is in the spirit of Ernst Mach has been proposed by Meessen.[95]

According to this theory of space-time quantization $c = 2a \cdot E_U/h$, i.e. c is dependent on the amount of energy E_U of the whole universe (i.e. the positive energy presented by the matter of the universe) and thus c will be constant as long as the numerical value of E_U is. Here a is the ultimate limit for the smallest measurable distance – called quantum length – and not necessarily identical with Planck's length.

The discussion of the constancy of the fundamental constants of nature is a good example for questions which are not answered by the physical laws known today. And moreover such questions are in close connection with the question how we are able to separate laws from conditions which are understood as not ruled by laws (like initial conditions, boundary conditions and constants). To invent hypotheses like the Large Numbers Hypothesis in order to give an explanation or solution can certainly be called rational: The new hypotheses though they are extrapolations or though they use assumptions which go far beyond our physical knowledge and even contradict some important physical laws (like energy conservation, see (2) above) are submitted to severe empirical tests (even if some tests do not bring a decision so far).

6.3 Irrational Strategies

There are, however, also strategies used by scientists which belong to a kind of irrationality. This is not to say that rationality of SR forbids in general to fill gaps in science with metaphysical assumptions. But what is at least required is (i) that the argumentation has to be consistent internally and externally with respect to well confirmed results in the same or in other sciences; and (ii) that the arguments used are logically valid and that the metaphysical assumptions or premises are stated as clearly as possible. These requirements are not always satisfied as will become clear from the following two examples:

(1) In the last pages of his bestseller "A Brief History of Time" Hawking tries to make the beginning of the universe dependent on a

creator in order to show - with a fallacious argument - that a universe without beginning does not need one. After a critical passage concerning his proposal for a theory without boundary and with imaginary time he continues rather uncritically. The critical passage is this:

> "Like any other scientific theory, it may initially be put forward for aesthetic or metaphysical reasons, but the real test is whether it makes predictions that agree with observation."[96]

Five pages after this critical passage it is the more astonishing that Hawking claims that "the idea that space and time may form a closed surface without boundary also has profound implications for the role of God in the affairs of the universe." And further: "So long as the universe had a beginning [B], we could suppose it had a creator [C]. But if the universe is really completely self-contained, having no boundary or edge [S], it would have neither beginning nor end: it would simply be [¬B]. What place, then, for a creator?" [C? or ¬C?][97]

The letters included in the passage are mine in order to show more easily that the argument used – with ¬C as the conclusion – is fallacious. This is evident from the fact that $B \rightarrow C$, $S \rightarrow \neg B$, $S \vdash \neg C$ is a logical fallacy. From the premises $B \rightarrow C$, $S \rightarrow \neg B$ and S one cannot draw any conclusion about C (or ¬C). The conclusion ¬C would follow if we had instead of $B \rightarrow C$ the premise $C \rightarrow B$; but then – despite the question of the truth of S – this premise $C \rightarrow B$ is questionable too because a creator is compatible also with a creation which does not have a certain age or beginning.

Also a very strong claim is made at the end of the book:

> "However, if we do discover a complete theory ... then we shall ... be able to take part in the discussion of the question of why it is that we and the universe exist. If we find the answer to that, it would be the ultimate triumph of human reason - for then we would know the mind of God."[98]

This claim is entirely different from the one cited above. In fact both claims are even somewhat inconsistent in the sense that the latter presupposes a God (with mind) whereas the former does not only not presuppose one but suggests not to have a "place" for him in a universe without boundaries (forgetting the fact that in the main religions God is transcendent with respect to the universe). In spite of the above inconsistency: Thomas Aquinas might be right in saying that since the creation (the universe) is an action of God's free will and not a necessary outcome of his essence, knowing the creation (the universe) does not mean knowing his essence, which is impossible in this life (even if revealed texts accessible to religious belief tell us some aspects of his essence by analogy). Knowledge of the universe could mean then knowing him as a most powerful thinker and cause but would not reveal or exhaust the structure of his mind.

(2) In a similar way some scientists connect results of the theory of evolution and extrapolations or unproved hypothesis of this theory with atheism. It is a fact that good empirical evidence (for example fossils) is available (so far) only for the so-called microevolution (differentiation, development of species and variation where the genetic complexity is more or less the same) but not for the so called macro-evolution leading to a higher level of much more genetic complexity or especially from non living to living organisms. But independently of this fact atheism is no logical consequence of any theory of evolution. For an almighty being many ways to "create" may be open, also the way of evolution.[99] But also a creationism which denies certain good confirmed results of the theory of evolution is untenable. Both forms of argumentation are strategies of irrationality, the first because of being logically fallacious, the second because of being contrary to well established results.

Notes

1 (Met) I, 980a21.

2 Cf. the discussion in Hintikka's Knowledge and Belief, p.19 ff. and in my note on Gettier's problem (1996).

3 For a new proposal for a definition of approximate truth which avoids the well-known difficulties see Schurz-Weingartner (1987) and Schurz-Weingartner (2010).

4 Hempel (1979), p.58.

5 For a detailed discussion of conditions for rational communication see my (1983b).

6 The first version of such a proposal is due to Irena Bellert (1970).

7 Cf. the discussion of the "Unspeakable" in Bochenski's *Logic of Religion*, ch.11.

8 Cf. the discussion of a common basis concerning representatives of different religions in Thomas Aquinas S.C.G. Book I, ch.2.

9 So far investigations on Super Luminarity seem not to show a signal velocity greater than light. Even if phase velocity in tunneling can be greater. Cf. Annalen der Physik 1998.

10 For a detailed discussion of general and special methodological rules see Weingartner (1980).

11 Not only predictions in astronomy and natural science are meant here. A historical hypothesis may suggest ("predict") a place to find new historical sources or it may suggest to investigate the works of a historical person not yet considered

for the explanation of a certain epoch. Cf. the qualitative conditions for a theory being nearer to the truth than another in Popper's (1963) ch. 10,p.231 ff.

12 Cf. Weingartner (2000) pp.188–194.

13 Cf. my (1998a).

14 Thomas Aquinas (STh) I–II, 94, 2.

15 For a more detailed exposition with evidence from the works of Descartes and Leibniz see Weingartner (1983a).

16 Descartes (RD) 3, 4; Leibniz (GP) 7, p. 194 and 296.

17 Descartes (RD) 3; Leibniz (GP) *5*, p. 343, (NE) 4, 2, 1.

18 Descartes (RD) 3.

19 Leibniz (GP) *5*,p. 343; (NE) 4, 2, 1.

20 Leibniz (GP) *5*,p. 347; (NE) 4, 2, 1. Augustine formulates it as "Fallor, ergo sum" (I am mistaken, therefore I am).

21 Descartes (RD) 3; Leibniz (GP) 4, p. 423.

22 Descartes (RD) 3; (DM) 2; (DM) 4, 3.

23 Leibniz (GP) 4, p. 422; (GP) l, p. 384, (GP) 7, p. 194.

24 Descartes (RD) 3, (RD) 12, 23.

25 Leibniz (GP) 5, p. 461.

26 Leibniz (GP) 6, p. 612.

27 Descartes (RD) 4, (DM) 2, (RD) 12, 13.

28 Leibniz (GP) 4, p. 64, (De Arte Combinatoria). Cf. Kneale (1962), p.333.

29 Leibniz (GP) 4, p. 450.

30 Rescher (1979), p.22.

31 Cf. Descartes (RD) 12, 14; Leibniz (NE) 1, l, 18; 1, 3, l; 2, l, 2; (GP) 5, p. 66, 79.

32 Their relation is not always transparent. Sometimes he speaks of them as the same principle.

33 (NE) 4, 7, 10.

34 This procedure has been stressed very strongly by Popper since the appearance of his *Logik der Forschung* in 1934.

35 See his biography in the Schilpp-Volume (1949)

36 See his Prolegomena § 27-36.

37 Cf. OF p.49 and 50. This is also the opinion of Kauppi, cf. her (1960), p.146.

38 Cf. OF p. 78 and 79. Cf. Weingartner (1983a), pp.172-178.

39 Observe that according to Leibniz a categorical proposition is true iff the predicate is contained in the subject. For an interpretation cf. Weingartner (1981).

40 OF, p.42. For the exact rules concerning the four categorical propositions of syllogistics cf. my (1983a), chapter 3.1.3.1.

41 Cf. OF, p.40–84.

42 Cf. Lukasiewicz (1957), pp.126-129. Kauppi and Rescher seem not to be aware of the success of Leibniz's last proposal. They discuss only earlier proposals where Leibniz represents terms by simple numbers (not pairs). In this respect they were

correct with their doubts whether it works with all the syllogistic moods (though the simple method works for some, for example BARBARA, as they observe).

43 Marshall (1977), p.241. For the historically difficult question whether Leibniz had doubts about the correctness of his last proposal see Marshall, ibid., p.24 ff.

44 GP 3, 400. For more details see my (1983a), ch. 2.5.

45 GP 1,57.

46 Carnap (1937), par.72.

47 Ibid. Foreword, XIII (Carnap's italics).

48 Ibid. Foreword, XV.

49 Cf. Paris and Harrington (1977). For a survey of later results see Murawski (1987).

50 More accurately Gödel proved the completeness and Church complemented the proof by his undecidability result of the *First Order Predicate Calculus.*

51 Carnap (1937), p.259 (Carnap's italics).

52 Carnap (1937), p.282.

53 Carnap (1937), p.258 (Carnap's italics).

54 Carnap (1937), p.259 (Carnap's italics).

55 The theory of Barwise and Cooper (1981) cannot solve these problems if three numerical quantifiers are involved. The only theory so far which solves the problem up to three different quantifiers seems to be the one of Bellert (1989).

56 A logic with mutually independent quantifiers was developed by Jaakko Hintikka (1996).

57 For a concise formulation see Weingartner (2000a). The avoidance of the different paradoxes has been shown in the following papers: Weingartner-Schurz (1986) for most paradoxes with the help of weaker criteria; Schurz-Weingartner (1987) adn (2010) for verisimilitude, Weingartner (2009,2010) for Quantum Logic, Weingartner (2015a) for Deontic Logic.

58 Cf. Weingartner (1998b).

59 Miller (1975).

60 Miller in his 1974, p. 176 required language independency implying invariance with respect to logical equivalence and therefore had to put up with counterintuitive consequences when comparing two false theories. For another counterexample caused by logical equivalence translation see Schurz (1990) p. 316 f. and Weingartner (1994) p. 98.

61 Cf. Cain J. Damnjanovic, Z. (1991) and Weingartner (1997).

62 Cf. Kreisel and Takeuti (1974) which contains numerous other unexpected results of that sort.

63 Kreisel (1991), p.586.

64 Observe however that it is a great difference when the modal operator 'necessary' is interpreted as "provable". For instance as in the interesting interpretation "provable in arithmetic" by Solovay (1976). This successful interpretation shows once more -because of the obvious differences between 'know' and 'provable (in arithmetic)' – that an interpretation of '$\Box$' with 'know' is entirely inadequate.

65 For further critical details and for a discussion of desiderate for an Epistemic Logic which meets conditions of human rationality cf. Weingartner (1982).

66 Popper (1963), p.186. Cf. Weingartner (2017).

67 Mendel (1866), p. 5. The pages are given from the Original reprinted in Czihak (1984).

68 Cf. Mendel (1866), p.6.

69 Cf. Mendel (1866), p.10 and 13.

70 Cf. Orel (1996), p. 91.

71 Mendel studied much more physics than other subjects like zoology or plant physiology and applied for the highschool teacher examination in physics – junior and senior classes – and for zoology, botany, mineralogy, geology only for junior classes.

72 Cf. Mendel (1866), p.9.

73 Cf. Orel (1996), p.96.

74 For a detailed discussion see Orel (1996), p.199.

75 Wright S. (1966), p.175.

76 Cf. *Annalen der Physik* 7-8 (1998).

77 For a detailed theory of causality which distinguishes five types of causal relations based on a 6-valued logic, see Weingartner (2016).

78 Principia I, Scholium.

79 De Gravitatione; Hall and Hall (1978), p.132.

80 Ibid., p.136.

81 Ibid.

82 Newton, Principia I, Scholium IV.

83 Newton, De Gravitatione; Hall and Hall (1978), p.127.

84 Cf. Barbour (1989), p.614. For analogous presuppositions of Classical Physics and Classical Logics see Weingartner (2011).

85 Barbour (1989), p.92. Cf. Mittelstaedt-Weingartner (2005) ch.6.

86 Aristotle (Phys) IV, 219a.

87 Aristotle, ibid. 218b. According to Boltzmann there is no time(-flow) in a complete equilibrium.

88 Aristotle, ibid. 218b.

89 Thomas Aquinas (STh) I, 46, I ad 4. The passage in latin is: Nos autem dicimus non fuisse locum aut spatium ante mundum.

90 Thomas Aquinas (STh) I, 46, I objection 6.

91 Ibid. 53, 3.

92 Cf. Ibid. 46, 1 and 2.

93 See Dirac (1937) and later papers.

94 Dirac (1972), p.76.and (1973). For further details see Weingarter-Schurz (1996), p.74 ff., Genz-Decker (1991) p.306ff. and Mittelstaedt-Weingartner (2005) ch.8.

95 Meessen (1989).

96 Hawking (1988), p.144.

97 Hawking (1988), p.149.

98 Hawking (1988), p.185.

99 Cf. *Evolution als Schöpfung* ed. P. Weingartner (2009) and (2015b).

Paul Weingartner
University of Salzburg
Department of Philosophy (Humanities)
Franziskanergasse 1
5020 Salzburg, Austria
<paul.weingartner@sbg.ac.at>

References

[1] Aristoteles (Met): *Metaphysics*. Intr. comm. W. D. Ross, Oxford 1958.

[2] Barwise, J./Cooper, R. (1981): "Generalized Quantifiers and Natural Language". In: *Linguistics and Philosophy* 4, pp. 160-219.

[3] Barbour, J. B. (1989): Absolute or Relative Motion? *A study from a Machian point of view of the discovery and the structure of dynamical theories*. Cambridge: Cambridge University Press.

[4] Bellert, I. (1970): "On a Condition of the Coherence of Texts". In: *Semiotica* 2.

[5] Bellert, I. (1989): *Feature Systems for Quantification Structures in Natural Language*. Dordrecht: Foris Publ. Groningen –Amsterdam Studies in Semantics 10.

[6] Bochenski, J.M. (1965): *The Logic of Religion*. New York: New York University Press.

[7] Cain J./Damnjanovic, Z. (1991): "On the Weak Kleene Scheme in Kripke's Theory of Truth". In: *Journal of Symbolic Logic* 56, pp. 1452-1468.

[8] Carnap, R. (1937): *The Logical Syntayx of Language*. London.

[9] Czihak, G. (1984): *Johann Gregor Mendel* (1822-1884). Dokumentierte Biographie und Katalog zur Gedachtnisausstellung ... mit Facsimile seines Hauptwerkes: 'Versuche über Pflanzenhybriden'. University of Salzburg.

[10] Descartes (DM): *Discourse on Method*.

[11] Descartes (RD): *Rules for the Direction of the Mind*.

[12] Dirac, P.A.M. (1937): Cosmological Constants. *Nature* 139, pp.323 ff.

[13] Dirac, P.A.M. (1972): "The Fundamental Constants and Their Time Variation". In: Salam and Wigner (1972), pp.213-236.

[14] Dirac, P.A.M. (1973): "Fundamental Constants and Their Development in Time". In: Mehra, J. (ed.): *The Physicist's Conception of Nature*. Dordrecht: Reidel, pp.45-54.

[15] Fisher, R.A. (1936): "Has Mendel's work been rediscovered?" In: Stern, C./Sherwook, E. R. (1966), pp. 132-172.

[16] Genz, H. / Decker, R. (1991): *Symmetrie und Symmetriebrechung in der Physik*. Braunschweig: Vieweg.

[17] Hall, A. R./Hall, M. B. (1978): *Unpublished Scientific Papers of Isaac Newton*. Cambridge: Cambridge University Press.

[18] Hawking, St. (1988): *A Brief History of Time*. New York: Bantham Books.

[19] Hempel, C. G. (1979); "Scientific Rationality: Analytic vs. Pragmatic Perspectives". In: Geraets, Th. (ed.): *Rationality Today*. Ottawa.

[20] Hintikka, J. (1962): *Knowledge and Belief*. Cornell Univ. Press.

[21] Hintikka, J. (1996): *The Principles of Mathematics Revisited*. Cambridge: Cambridge University Press.

[22] Kauppi, R. (1960): "Uber die Leibnizsche Logik. Mit besonderer Beriicksichtigung des Problems der Intension und der Extension". In: *Acta Philosophica Fennica XII*, Helsinki.

[23] Kant, I. *Prolegomena*. I. Kant, *Werke in sechs Bändnen*. Bd.3, Darmstadt: Wissenschaftliche Buchgesellschaft, 1959.

[24] Kneale, W. and Kneale, M. (1962): *Development of Logic*. Oxford.

[25] Kreisel, G. (1991): "Suitable Descriptions for Suitable Categories". In: Schurz, G./Dorn, G. (eds.): *Advances in Scientific Philosophy. Essays in Honour of Paul Weingartner on the Occasion of the 60th Anniversary of his Birthday*. Amsterdam-Atlanta: Rodopi, pp.571-589.

[26] Kreisel, G. (Takeuti. G. (1974): "Formally self-referential propositions for cut-free classical analysis and related systems". In: *Dissertationes Mathematicae*, Vol. 118, pp. 1-50.

[27] Leibniz (GP): *Die philosophischen Schriften von G. W. Leibniz*. C. I. Gerhardt (ed.), 7 Vols., Berlin, 1875-90. Hildesheim: Georg Olms Verlag.

[28] Leibniz (OF): *Opuscules et fragments inédits de Leibniz*, L. Couturat (ed.), Paris, 1903. Hildesheim: Georg Olms Verlag.

[29] Leibniz (NE): *Nouveaux essays sur l'entendement humain*. Darmstadt: Wissenschaftliche Buchgesellschaft. 1959, 1961.

[30] Lukasiewicz, J. (1957): *Aristotle's Syllogistic from the Standpoint of Moden Formal Logic*. London: Oxford UP.

[31] Marshall, D. Jr. (1977): "Lukasiewicz, Leibniz and the Arithmatization of the Syllogism". In: *Notre Dame Journal of Formal Logic* 18, pp. 235-242.

[32] Meessen, A. (1989): "Is it Logically Possible to Generalize Physics Through Space Time Quantization?" In: Weingartner, P./Schurz, G. (eds.): *Philosophy of Natural Sciences. Proceedings of the 13th Wittgenstein Symposium*, *Vienna 1989*, pp.19-47.

[33] Mendel, G. (1866): "Versuche iiber Pflanzen-Hybriden." In: Czihak, G. (1984), pp.65-111 (which agrees with page 1-47 of the original pagination).

[34] Miller, D. (1974): "Popper's Qualitative Theory of Verisimilitude". In: *British Journal for the Philosophy of Science* 25, pp. 166-177.

[35] Miller, D. (1975): "The Accuracy of Prediction". In: *Synthese* 30, pp. 159-191.

[36] Mittelstaedt P. and Weingartner P. (2005): Laws of Nature, Springer

[37] Murawski, R. (1987): "On the Incompleteness of Arithmetic Once More". In: Perzanowski, J. (ed.): *Essays on Philosophy and Logic*. Cracow: Jagiellonian University Press, pp.93-106.

[38] Newton, I. (PMP): *Principia Mathematica Philosophiae Naturalis* (Engl. transl. by A. Motte, revised by F. Cajori, Vol. I, Berkeley 1962).

[39] Orel, V. (1996): *Gregor Mendel. The First Geneticist.*

[40] Paris and Harrington (1977): "A Mathematical Incompleteness in Peano Arithmetic". In: J. Barwise (ed.): *Handbook of Mathematical Logic*. Amsterdam: North Holland 1977.

[41] Popper, K. R. (1934): *Logik der Forschung*. Wien: Springer.

[42] Popper, K. R. (1963): *Conjectures and Refutations*. London: Routledge.

[43] Rescher, N. (1979): *Leibniz. An Introduction to his Philosophy.* Oxford: Blackwell.

[44] Salam, A/Wigner, E. P. (eds.) (1972): *Aspects of Quantum Theory*. Cambridge UP.

[45] Schilpp, P. A. (ed.) (1949): Albert Einstein: *Philosopher - Scientist*. Autobiographical Notes. pp.2-94.

[46] Schurz, G. (1990): "Sprachabhiingigkeit der Erkenntnis". In: Born, R./Wohlgenannt, R. (eds.): *Reflexion und Wirklichkeit*. Vienna: VWGO, pp. 309-327.

[47] Schurz, G., Weingartner, P. (1987): "Verisimilitude Defined by Relevant Consequence Elements. A new Reconstruction of Popper's Original Idea". In: Kuipers, Th. (ed.): *What is Closer-to-the-Truth*? Amsterdam: Rodopi, pp. 47-77.

[48] Schurz, G., Weingartner, P. (2010): *Zwart and Franssen's impossibility theorem holds for possible-world-accounts but not for consequence-accounts to verisimilitude*. Synthese, pp.415-436.

[49] Solovay, R. (1976): "Provability Interpretations of Modal Logic". In: *Israel Journal of Mathematics* 25, pp. 287-304.

[50] Stern, D./Sherwood, E. R. (1966): *The Origin of Genetics. A Mendel Source Book*. San Francisco: W. H. Freeman and Company. (Contains an English Translation of Mendel's famous work: Experiments on Plant Hybrids.)

[51] Thoday, J.M. (1966): "Mendel's work as an introduction to genetics." In: *Advancement of Science* 23, pp. 120-124.

[52] Thomas Aquinas (S.C.G.): *Summa contra Gentiles*, ed. G. Pera et al., Marietti-Rom 1961.

[53] Thomas Aquinas (STh): *Summa Theologica*. Transl. by Fathers of the English Dominican Province. Vol.I–V. Westminster (USA): Christian Classics 1981.

[54] Weiling, F. (1966): "Hat Mendel bei seinen Versuchen zu genau gearbeitet? Der x^2 Test und seine Bedeutung für die Beurteilung genetischer Spaltungsverhältnisse". In: *Der Züchter* 36, pp. 359-365.

[55] Weiling, F. (1989): "Which points are incorrect in R. A. Fisher's statistical conclusion: Mendel's experimental data agree too closely with his expectation?". In: *Angewandte Botanik* 63, pp.129-143.

[56] Weingartner, P. (1976): "On the Introduction of Intensions into Set Theory". In: Przelecki, M./Szaniawski, K./Wojcicki, R. (eds.): *Formal Methods in the Methodology of Empirical Sciences*. Wroclaw: Ossolineum, pp. 287-296.

[57] Weingartner, P. (1980): "Normative Characteristics of Scientific Activity". In: Hilpinen, R. (ed.): *Rationality in Science*. Studies in the Foundations of Science and Ethics. Dordrecht: Reidel, pp.209-230.

[58] Weingartner, P. (1981): "A New Theory of Intension". In: Agassi, E./Cohen, R.S. (eds.): *Scientific Philosophy Today. Essays in Honor of Mario Bunge*. Dordrecht: Reidel, pp. 439-464.

[59] Weingartner, P. (1982): "Conditions of Rationality for the Concepts Belief, Knowledge and Assumption". In: *Dialectica* 36 (1982), pp. 243-263.

[60] Weingartner, P. (1983a): "The Ideal of Mathematization of All Sciences and of 'More Geometrico' in Descartes and Leibniz". In: Shea, W.R. (ed.): *Nature Mathematized.* Dordrecht: Reidel, pp. 151-195.

[61] Weingartner, P. (1983b): "Normative Principles of Rational Communication". In: *Erkenntnis* 19, pp. 405-416.

[62] Weingartner, P. (1993): "A Logic for *QM* Based on Classical Logic. In: Maria de la Luiz Garcia Alonso/Moutsopoulos, E./Seel, G. (eds.): *L'art, la science et la métaphysique.* Bern: Peter Lang, pp. 439-458

[63] Weingartner, P. (1994): "Can there be Reasons for Putting Limitations on Classical Logic?" In: Humphries, P. (ed.): *Patrick Suppes, Scientific Philosopher, Vol 3.* Dordrecht: Kluwer, pp.89-124.

[64] Weingartner, P. (1996): "A Note on Gettier's Problem". In: Heinzmann, G. (ed.): *La Science et l'hypothèse.* Nancy, pp. 221-231.

[65] Weingartner, P. (1997): "Language and Coding Dependences of Results in Logic and Mathematics". In: Agazzi, E./György Darvas (eds.): *Philosophy of Mathematics Today.* Dordrecht: Kluwer, pp. 73-87.

[66] Weingartner, P. (1998a): "Are Statistical Laws Genuine Laws? A Concern of Poincare and Boltzmann". In: *Philosophia Scientia* 3(2), 1998–1999, pp.215-236.

[67] Weingartner, P. (1998b): "The Weakness of Logical Equivalence". In: *Bulletin of the Section of Logic* 27, Nr. 1/2, pp. 46-49.

[68] Weingartner, P. (1998c): Causality in the Natural Sciences". In: *Annalen der Physik* 7-8 (1998), pp.737-747.

[69] Weingartner, P. (2000a): "Reasons for Filtering Classical Logic". In: Batens, D. et al. (eds.): *Frontiers in Paraconsistent Logics. Proceedings of the First World Congress on Paraconsistency, Gent 1997.* London: Research Studies Press 2000, pp.315-327.

[70] Weingartner, P. (2000b): *Basic Questions on Truth.* Dordrecht: Kluwer.

[71] Weingartner, P. (ed.) (2001): *Evolution als Schöpfung.* Stuttgart: Kohlhammer.

[72] Weingartner, P. (2009): "Matrix-Based Logic for Application in Physics". Review of Symbolic Logic 2,1; pp. 132-163.

[73] Weingartner, P. (2010): "Basic Logic for Application in Physics and its Intuitionistic Alternative". *Foundations of Physics* 40, pp.1478-1596.

[74] Weingartner, P. (2011): "Presuppositions of Classical Logic, Presuppositions of Classical Physics". *Studia Philosophiae Christianae* 4, pp.85-102.

[75] Weingartner, P. (2015a): "A 6-Valued Calculus which Avoids the Paradoxes of Deontic Logic". In: Beziau, I.V. et al. (eds.): *Conceptual Classifications. Tributes to Patrick Suppes (1922–2014).* College Publications 2015, pp.87-105.

[76] Weingartner, P. (2015b): *Nature's Teleological Order and God's Providence. Are they Compatible with Chance, Free Will and Evil?* Berlin: De Gruyter.

[77] Weingartner, P. (2016): "The Need for Pluralism of Causality". Logic and Logical Philosophy 25,4; pp. 461-498.

[78] Weingartner, P. (2017): "Observability and Unobservability". In: C. Limbeck-Lilienau, F. Stadler (eds.): *The Philosophy of Perception and Observation. Contributions to the 40th Intern. Wittgenstein Symposium.* Kirchberg 2017, pp.277-279.

[79] Weingartner, P./Schurz G. (1986): "Paradoxes Solved by Simple Relevance Criteria". In: *Logique et Analyse 113*, pp. 3-40.

[80] Weingartner, P./Schurz G. (eds.) (1996): *Law and Prediction in the Light of Chaos Research.* Lecture Notes in Physics 473. Berlin: Springer.

[81] Wright, S. (1966): "Mendel's Ratios." In: Stern, C./Sherwood, E. R. (1966), pp. 173-175.