SCIENCE AND THE LEBENSWELT
ON HUSSERL'S PHILOSOPHY OF SCIENCE

Jairo José da Silva
Centre of Philosophy – University of Lisbon
CNPq and CLE-Unicamp

I present and discuss in this paper Husserl's investigation of the genesis of the modern conception of empirical reality as carried out in his last work *The Crisis of European Sciences and Transcendental Phenomenology*. The goal of Husserl's genetic investigation was to uncover the many layers of constitution that from the life-world (the *Lebenswelt*) the modern scientific conception of Nature was originated and to point out the need to ground the scientific project of modernity in the life-world so as to overcome the "alienation" that, for him, characterized the "crisis" of European science. I, however, approach his analyses from a different perspective. The problem that interests me here is the applicability of mathematics in the empirical science. My aim is to assess Husserl's treatment of this question in order to see whether it can be sustained from a strictly scientific perspective. My conclusion is that it cannot. What Husserl takes for the "crisis" of science is inherent to the best scientific methodology. Nonetheless, Husserl's analyses offer important insights that I incorporate in what I believe to be a more satisfactory treatment of the problem concerning the role of mathematics in the empirical science.

The world where we live our ordinary lives and the world as conceived by science are not, for Husserl, completely alien to one another. The latter, he believes, is a refinement of the former. Experimentation and the testing of scientific hypotheses and theories, for example, to the extent that they ultimately rest on sensorial perception, either naked or instrumentally enhanced, are not essentially different from prosaic activities of the life-world

such as feeling the texture of a fabric or checking a piece of information. But although perception pertains to the life-world, the *scientific interpretation* of perception does not. Experimental data, which are never *mathematically* precise (no one will *ever* actually read the value, say, π on a scale) are for scientific purposes often interpreted as *approximations* to the "real" values of the physical magnitudes being measured, those values the *theory* tells us to expect (for example, π).

All sorts of vicissitudes are thought to stand in the way of exactness, the deficiencies of human attention, the inaccuracy of sensorial perception, unforeseeable local fluctuations of relevant parameters; in short, "errors" of all sorts. The experimental scientist, then, inhabits two different worlds, the life-world and the world of science; he perceives as a man of the world but interprets his perceptions with the idealized scientific picture of empirical reality firmly rooted in his mind. He is convinced that, despite his efforts, empirical reality will *never* disclose itself adequately to the senses; no matter how much his sensibility is enhanced by scientific instruments or how careful he carries out his measurements. *Le tourbillon de la vie* will always interfere.

The life-world is the world of the "*a peu près*", but exactness prevails in the purified, pristine world of science. In science, a cannonball follows a trajectory *perfectly* parabolic, space is filled by an electromagnetic field *precisely* determined at each point, the metric of space-time is *exactly* given by some differential form, etc, etc. Behind the stage where life happens there lies, or so science presupposes, a hidden structure of mathematical precision. But science is interested in the hidden structure, not in the drama happening on the stage. From the perspective of science, the reality accessible to the senses is a more or less deceptive manifestation of the true reality that will remain forever hidden to the senses. It follows by necessity that, as a matter of *principle*, not mere fact, the senses are impotent to reach real reality in an adequate and apodictic manner.

Husserl saw a problem here. It is a basic tenet of empiricism, to which science pledges allegiance, that scientific theorizing must be confronted with experience and that in experience alone it can be validated. But scientific experimentation, no matter how refined, is basically and ultimately touching, seeing, smelling, tasting and hearing; the scientist must eventually use his eyes to check to which number in a numerical scale the pointer is pointing (or better, within which more or less fuzzy range of the scale the pointer is located). But if sensorial perception is a priori disqualified as a provider of adequate knowledge, isn't science a priori undervaluing the validation it seeks? What is the *point* of empirical testing? Moreover, by alienating the world as man experiences it isn't science ipso facto alienating man? Husserl

answers both questions affirmatively. He concluded that modern science is, and has from its beginning been immersed in a "crisis" characterized by the alienation of man and all that makes sense to him. This "crisis", as Husserl saw it, poses problems for philosophy and culture in general, including, as we'll see, the comprehension of the scientific project itself.

I'll be more explicit below; at this point I only want to indicate in which direction Husserl believed a way out of this critical situation (which is in fact a crisis of man) can be found. It is important to keep clear in mind, however, that, for Husserl, the crisis of science is not a crisis *internal* to science. Scientific methodology is a scientific affair; philosophy has nothing *scientifically* relevant to say about it. Philosophy's job is not "to fix" science, but to understand it, disclose its true nature and clarify its methods (which include the mathematical methods that characterizes modern science since the times of Galileo).[1] Phenomenological clarification is, for Husserl, the first step into solving the crisis of science.

To accomplish this, Husserl embarked on a journey in search of the origins of modern science. This meant first and foremost the investigation of the intentional genesis of the scientific conception of empirical reality, "unpacking" its many layers of sedimented meaning so as to bring its true nature to light. What was finally revealed is that the empirical world as conceived by science is not *transcendently real* but, rather, an intentional elaboration of the sole true reality – perceptual reality – devised for methodological purposes. For Husserl, the modern mathematical science of nature deals with reality as perceived, the *only* true reality, by dealing with a symbolic-mathematical surrogate of it.

Husserl also detected a tendency to "forget" that goes along with the bestowing and sedimentation of intentional meaning, which tends to obliterate intentional constitution by taking as given what is only a construct. Eventually, a reversal of ontological and epistemological priorities takes place; the *originally given* empirical reality, that which is experienced with the senses, loses its status of true reality, being substituted by a mathematically purified surrogate. A mathematical representation of reality, one that man cannot adequately grasp with his senses, ends up being enthroned as the real reality. Thus science "naïvely" embraces Platonism as its "official" philosophy.

Husserl believed that the right order of priority had to be reestablished for the crisis of science to be solved; the mathematical world of science had to be "unmasked" as a product of intentional action devised for methodological purposes and the world experienced with the senses restored to the dignity

[1] This is also true in the philosophy of mathematics, whose task is to clarify not rectify.

of the true real world.[2] This required, in particular, that the idealizations and presuppositions that go into the intentional constitution of the world of science be brought to light, a task carried out in full in the first sections of *Crisis*.

The world, however, is not only what we (or a generic I) *have* actually experienced, it also contains what we *can* in principle experience. The horizon of possible experiences beyond experienced reality, however, or so Husserl thinks, is not a closed totality already completely determined in itself. To take it as such *is a presupposition of science, not of the man of the world*.[3] But, and this is, I believe, very important, it is *only* by presupposing this that science can accomplish the task it imposed upon itself of *anticipating* experience beyond the rough possibilities of anticipation available in the life-world.

One aspect of Husserl's clarification interests me particularly. By revealing the true nature of empirical reality as conceived by science, Husserl rendered comprehensible the apparent "mystery" involving the applicability of mathematics in the empirical science. He has clearly shown *how* such a thing is *possible* (but not so much the mechanisms by which it operates). The empirical science of nature can be mathematized, we conclude, *because* empirical reality *as conceived by science* is already mathematical. The real reality experienced with the senses is not intrinsically mathematical (not at least to the extent required by modern science), but the scientific representation of reality, an abstract, idealized and mathematically improved version of perceptual reality is.

Galileo told us that the book of nature is written in mathematical characters and cannot be understood by those who are not conversant with mathematics. This remains strictly true. What Husserl has shown is that this book does not display *snapshots of* empirical reality, but an *abstract representation* of it. It tells a somewhat fictitious, or partially fictitious tale from which we can, nonetheless, infer important things about the world *as experienced*. This

[2] In connection with this it is illuminating to hear what the 1952 Nobel Prize winner Felix Bloch (Bloch 1976) had to tell about a conversation he had with Werner Heisenberg, of whom he had been the first doctorate student: "We were on a walk and somehow began to talk about space. I had just read Weyl's book *Space, Time and Matter*, and under its influence was proud to declare that space was simply the field of linear operations. "Nonsense," said Heisenberg, "space is blue and birds fly through it." This may sound naive, but I knew him well enough by that time to fully understand the rebuke. What he meant was that it was dangerous for a physicist to describe Nature in terms of idealized abstractions too far removed from the evidence of actual observation. In fact, it was just by avoiding this danger in the previous description of atomic phenomena that he was able to arrive at his great creation of quantum mechanics." Husserl would certainly take side with Heisenberg.

[3] It is by presupposing this that science can make unrestricted use of classical logic, the principle of bivalence (tertium non datur or excluded-middle) in particular (see da Silva 2013).

imposes upon the philosopher of science the task of investigating why and how this book, which rigorously speaking does not concern itself with perceptual reality, can all the same tell something about the reality that we experience with our senses. More importantly, it befalls on the philosopher the task of explaining why it is so *efficient* at that.

The transcendental history of empirical science is the history of its intentional constitution. This is a job for phenomenology (to which the initial part of *Crisis*, essentially chapter II, particularly §9, is dedicated), but cannot be done without the assistance of factual history (which, however, Husserl barely touches).[4] Science has to do with sense-formations and sense-formations have a (transcendental) history that requires phenomenological clarification. As already mentioned, Husserl's strategy for clarifying the sense-formation "empirical nature" consisted in going through layers of sedimented meaning, "desedimenting" them so as to bring to light the intentional action that went into their constitution, revealing eventually the source from where sense originally emanates. At the end of the journey Husserl finds the life-world, which, reversing scientific ontological priorities, he reestablishes as the original reality and the primary source of meaning. Thus, he thinks, the epistemological dignity of experience is reinstalled and coherence in the empiricist allegiances of science restored.

The crisis of science, Husserl believed, was not confined to science; it spread to philosophy and psychology, blocking the way to a truly philosophical universal science whose foundations, Husserl insisted, must be firmly rooted in the life-world. Descartes, the philosopher who took mathematical extension as the essence of the physical body, who borrowed from mathematics the criterion of truth, who advocated a mathematical methodology for reasoning, and, more importantly, conceived the idea of a *mathematical scientia universalis,* is a perfect example of the new philosophical *Zeitgeist* that "contaminated" modern philosophy. Descartes' philosophy and that of those who followed him, Husserl claimed, would be impossible without Galileo's conception of reality as a closed mathematical manifold, a "rational unified system" (*Crisis* §11). To overcome the critical situation of alienation in which

[4] The transcendental history of modern physics is intertwined with that of mathematics, which plays such a pivotal role in it. Modern physics, with its characteristic sense, could not have been constituted independently of the shift of sense that accompanied the creation of Greek geometry. An investigation of the intentional genesis of geometry and its objects was carried out by Husserl in his essay "The Origins of Geometry", which appears as an appendix in W. Biemel's edition of *Crisis*. Jacob Klein (Klein 1992) has argued that the task would not be complete without a similar investigation concerning the concept of number (about this see Hopkins 2011).

science, philosophy and man are immersed Husserl proposed a return to the life-world, the source from where sense originally flows.

But, again, the search for the origins of modern science, the careful investigation of the intentional constitution of scientific sense-formations, the clarification of scientific methods, and the reestablishment of the ontological and epistemological dignity of the life-world is not to be carried out *against* science, for nothing is *wrong* with it or its methodological strategies. Nonetheless, if the ties of science with the life-world are not repaired, Husserl believed, science risks being incomprehensible, even absurd. Only by reestablishing *"de jure"* ontological and epistemological priorities, he thought, science could make sense, its methods and fundamental hypotheses clarified and circumscribed, and its criteria of validation firmly secured. So, although the development of a fully articulated philosophy of science was not its primary goal, *Crisis* contains the most articulate reflection on scientific issues on the part of Husserl (at least as far as the physical sciences are concerned). I here want to examine it more attentively, to verify the extent to which it clarifies the nature of science and its methods, but also its shortcomings, the extent to which Husserl's struggle to safeguarding man from alienation can jeopardize the effectiveness of science and the accomplishment of the task science imposed upon itself.

Crisis begins with a detailed historical account of the genesis of modern (17^{th} century) physical science, whose characteristic trait is the use of mathematics (for representational, predictive and, even, heuristic purposes). For Husserl, the spirit of the new science was born in ancient Greece, where eastern geometry, essentially a technology pertaining to the life-world, was completely redefined as the science of an idealized rational domain of *becoming* – the notion of *construction* occupied the forestage in Greek geometry. Galileo promoted the same radical shift of sense with respect to empirical reality, pushing it a little further. Besides conceiving empirical reality as an idealized and mathematized domain of *being* (not *becoming*) he also posited it as a domain existing and completely determined *in itself*. Thus, Husserl thought, the germ of crisis was instilled in science. The consequences are many: perception is downgraded as the privileged means of accessing empirical reality, symbolization and symbolic manipulations carried out sometimes in complete disregard for what the symbols meant (which is a extreme version of what Husserl called "technization") take the place of direct access to intuitable contents, certain perceptual aspects of things are dismissed as subjective features of things (colors, for example, are no longer seen as objective aspects of bodies, but subjective impressions caused by light

reflecting on bodies and falling on our retinas, with no *objective* reality), in short, the alienation of man from his living experience and all that makes sense to him.

Husserl clearly saw that the distinctive trait of modern science is the extensive use of mathematics; the modern science of empirical nature is *essentially* mathematical. Concerning this, two questions immediately impose themselves: 1) how is it possible that mathematics has *anything* to say about empirical reality? 2) How is it possible that mathematics is scientifically so *effective*? We can easily extract from Husserl's considerations a *correct* answer to (1), but, unfortunately, he does not have anything to say about (2). Rather than welcoming the intromission of mathematics in science, Husserl *worried* about it, particularly if purely *symbolic* mathematics is involved. Mathematization, he thought, opened the way to alienation. His goal was to ground science in the pre-scientific world where man lives, not to investigate the scientific usefulness of mathematics, although his recipe for avoiding the alienation of man also serves the purpose of restricting the amount of technization allowed in science – at a price though, for the "blind" use of meaningless symbols has important explanatory, predictive and heuristic roles in science. For Husserl, in order for science to be meaningful for man, the sense sedimented in routine scientific practices, concepts and methods must be reactivated and reoriented towards where meaning originally sprang, the life-world. This poses limits to the amount, and type, of symbolization that science can lawfully admit.

Husserl also believed that there is a science of the life-world, which, however, is not and cannot be mathematical. So, he opposed mathematization being taken as the distinctive trait of scientificity in general. This induced in him a somewhat critical disposition concerning the role of mathematics even in the empirical science. Since the life-world is the real world and the world of science is only a construct devised for methodological purposes, mathematical methods must be carefully circumscribed so as to prevent science from alienating itself, and man, from reality. The question I want to raise is whether this caveat is, *from a strictly scientific perspective*, desirable. I believe that it is not, that Husserl's recipe for re-installing the life-world as the sole source of meaning in science imposes crippling conditions on the mathematical methods of science. It also has consequences for the strategies of validation of scientific theories since it seems to require that *each* scientific proposition must *individually* express the content of an idealized experience. This requirement does not correspond to the methodological practices of science and would, if enforced, seriously jeopardize their effectiveness. Science *must* alienate the

living reality of man so as to accomplish its task.[5] I'll come back to this later; for now let's spend some time in Husserl's company.

For him, as I have already noted, although the crisis of science was intensified with the creation of the modern mathematical science of nature from the 17th century on, its origins can be traced back to the ancient Greeks. However, Husserl claimed, despite the idealization and systematization (i.e. axiomatization) that geometry knew in the hands of the Greeks (from Tales to Euclid), they never conceived the idea of the geometrical domain as a closed domain of entities completely determined in itself where the facts subsist *sub specie aeternitatis*, waiting only to be revealed; a domain in which "everything that ideally 'exists' in the geometrical space is from the start already univocally decided in all its determinations. Our apodictic thinking only 'discovers', in its infinite progression, stepwise, according to concepts, principles, reasoning and proofs, what from the start, in itself, truly already is" (*Crisis* §8). For the Greek geometers, geometry had to do with ideal possibilities of constructions; becoming, not being (despite Plato's criticism of the constructive language of geometry).

Modern geometry, contrary to ancient geometry, however, conceives its domain as a "rational infinite domain of being systematically mastered by a rational science" (*Crisis* §8), "an infinite world, closed in itself, of ideal objectivities presenting itself as a field of investigation" (*Crisis* §9). How such a conception came about, the idealizations and presuppositions it harbors, is the theme of Husserl's essay *The Origins of Geometry*, which sets a model for similar "genetic" investigations (i.e. for transcendental history).

The distinctive trait of Galilean physics is the mathematization (rather, geometrization) of empirical reality, and its most basic presupposition is that empirical nature is a mathematical *Universum* in the geometrical sense, i.e. an infinite realm of mathematical idealities closed and completely determined

[5] To make clear what I have in mind, let me give an example. The complex-valued wave function of quantum mechanics does not correspond to anything directly experienceable in the world. According to the standard Copenhagen interpretation, only the square of the modulus of the wave function has some physical meaning, namely, a probability density, which, by the way, is hardly a purely physical entity. In a sense, the wave function "codifies" in mathematical form all the relevant information about a physical system, information we can "extract" whenever we want. As the great mathematician and physicist (and part time philosopher) Hermann Weyl claimed, physical theories, together with their heavy mathematical apparatus, are symbolic constructions that touch reality only at few points, but that must, then, "check". If they do not, the *entire* theory, together with its mathematics (and maybe even its underlying logic), must be reexamined and fixed. The relations of science with reality are more subtle and, we could say, more superficial than Husserl believed necessary to rescue man from the situation of alienation with respect to his world that science imposed on him.

in itself into which mathematics only has access (Galileo's famous "the book of nature is written in geometrical characters..."). Nature is geometric and only geometry has adequate access to the secrets of nature. In this *Universum*, moreover, all co-beings are submitted to the omnipresent legality of a universal causal regulation.[6] To the question "how is it possible 'to know the world philosophically', that is, in a seriously scientific manner, [building] systematically, in some way a priori, the world, the infinity of its causalities, from a meager stock of what is possible to establish in direct and relative experience?" (*Crisis* §9)

Mathematics seems to provide the answer. By conceiving empirical reality as a geometrical *Universum*, modern science treats nature like, but not *exactly* like geometry treats the geometrical domain. The difference, which Husserl is careful to point out, is that whereas geometry can uncover the subjacent legality of the geometric realm a priori and once for all, science can only rely on the meager stock of experience and so can never touch the mathematical legality that supposedly lies within the core of empirical reality in a completely satisfactory manner. Why is it so difficult to extract from nature its mathematical structure? Why can't we have access to it as we have access to the structure of the geometrical realm? I'll come back to this later, but I can advance here what I think Husserl's answer was: in fact, mathematics is *not* in nature (that is, *perceptual* nature), not at least to the extent that science presupposes, *only* in our scientific *representation* of nature. But our representation of nature must be erected on our perception of nature, not a priori and definitely not once for all, since the field of perception has an open horizon.[7]

Husserl's search for the sources of science, as I mentioned before, involves uncovering hidden presuppositions which, by remaining hidden, make it difficult, if not impossible, to correctly understand scientific methodology and draw its limits of applicability. Let's consider one of them, related to the mathematization of secondary qualities, color, texture, etc. Modern

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[6] Has the collapse of the "classical" conception of causality brought about by quantum mechanics changed in some way this picture? According to Husserl, it did not. In quantum mechanics nature is still "mathematical in itself, given in formulas and interpretable only in formulas" (*Crisis* §9). Moreover, causality is not completely eliminated in quantum mechanics, since the "state" of a system at any given point in time still depends strictly on its state at any previous instant, the "state evolution" being mathematically regulated.

[7] Mathematical domains are subsumed to *concepts*, and it is by inquiring *the intentional meaning* of mathematical concepts that mathematics can theoretically master the domains which they subsume a priori and once for all. But whereas mathematics can adequately grasp the meaning of mathematical concepts, empirical science must be content with an *extensional* approach to empirical concepts.

science is well-known for "subjectifying" them, which can only be recovered objectively by indirect means. *As such,* secondary qualities belong to the realm of the subjective-relative of no concern for science, but can be recovered *as something else* in the objective-absolute (that is, valid for all) realm of science. For example, the subjective sensation of color can, for scientific purposes, be replaced by the wave-length (or frequency) of the radiation that "produces" the color sensation. This, however, Husserl says, requires the presupposition that "the specifically sensible qualities (the 'content') experienceable in the bodies given to intuition *be intimately connected* [one to another] *according to a rule* and, in a very particular way, to *forms* that belong to them according to their essence" (*Crisis* §9). The mathematization of secondary qualities, then, requires that sensible, intuitive "contents" be related with strict legality not only to one another but also to mathematical forms which act as objective substitutes of them. But this, Husserl observes, does not go by itself. Despite the evidences that the Pythagoreans had already brought to light, this is a *presupposition*, a *hypothesis*, justifiable only by the Galilean belief in a *Universum oú tout se tient* and whose internal connections can only be explicitly rendered mathematically.

Once intuitable contents are replaced by mathematical entities (numbers and the like), the variance of intuitable contents *experienced* in the life-world can, under the hypothesis of strict underlying legality, be mathematically expressed in *formulae* involving only the mathematical representatives of experienceable contents. These formulae are mathematical expressions of *natural laws* on whose basis *intuitions* can be anticipated, *but exclusively with regard to their mathematical form*. Mathematics now *controls* the life-world. Says Husserl, "the indirect mathematization of the world, which expresses itself as a methodic objectification of the world of intuition, produces general numerical formulae which, once found, can serve in applications to accomplish the objectification of singular cases subjected to them. The formulae express general causal connections, 'laws of nature', laws of real dependence, under the form of 'functional' dependence among numbers" (*Crisis* §9).

What sort of hypothesis is this, that nature is subjected to strict and mathematically expressible legality? Is the *fact* of science and its unquestionable success a confirmation of this "Galilean" hypothesis? As Husserl says, this is "a very surprising hypothesis indeed. Our empirical science, which has for centuries been its confirmation, is thus a confirmation of a very surprising nature. *The surprising is that the hypothesis remains, despite its confirmation, always and ever a hypothesis.* Its confirmation (the only conceivable for it) is an infinite succession of confirmations" (*Crisis* §9). Galilean science is

founded on a "hypothesis" that cannot be definitively confirmed, which makes it a rather peculiar hypothesis. This demands explanation.

Can't the "hypotheses" that nature is a completely determined domain existing in itself and submitted to strict legality that only mathematics can adequately express be given a "positivist" reading, such as that the Church of Rome in the XVI century gave the Copernican heliocentric "hypothesis", namely, a mathematical scheme "to save the phenomena" with no consequence for reality as it *really* is?[8] Could Husserl be ranged with the "positivists"? Was mathematization, for Husserl, only a *convenient* way of structuring our *experience* of reality; reality *itself* remaining inaccessible?

This way of seeing is, I believe, completely alien to Husserl's thought. It would require a distinction between noumenal and phenomenal realities, with phenomenal reality, and it alone, being given, for reasons of convenience, a mathematical structure. This mixture of Kantianism with pragmatism has no place in Husserl's philosophy. The relevant distinction, as Husserl saw it, is not between phenomenal and noumenal realities, but between *reality* and what science *takes for* reality. Husserl objects to the view that real reality is transcendent and mathematical and that the immanent reality amenable to direct experience is only a distorted projection of true reality Our experience of reality *is* reality and it is definitively *not* mathematical, or at least not mathematical to the extent that the scientific representation of reality is mathematical. Reality, the real one, can only be mathematized by being idealized, that is, by being put out of the reach of experience, the only way we have of accessing reality directly. There are enough gambits here to keep a philosopher busy. For Husserl, there is no distinction between reality itself and experienced reality: the reality we experience *is* reality itself. Of course, misperception of reality is likely to happen, but they can in principle be corrected by experience. Mathematized reality is only an ideal model of *experienceable* reality devised for methodological purposes. To take mathematized reality as only a convenient way of organizing phenomenal reality, with no consequence for real transcendent reality is, then, something Husserl cannot do.

Although science depends on the presupposition that nature is submitted to laws, natural laws do not follow by necessity, or at least not completely, from the scientific *concept* of nature; laws must in large measure be inferred

[8] The Church tried to press this view on Galileo, but Galileo refused it. According to historians of science, such as Koyré and Crombie, Galileo was definitely not a "positivist"; mathematics was not, for him, an instrument for conveniently structuring the *phenomena*. Galileo believed that mathematics is built in the structure of nature *itself*.

from *direct experience*. The realm of experience, however, is constantly open to new experiences. Unlike mathematical domains, capable of being completely surveyed a priori, those of empirical science cannot. Empirical science, then, must always be ready to be shaken by what new experiences may bring in; the *actual* legality reigning in nature is constantly *sub judice,* although the *hypothesis* of natural legality is not. In fact, it is by maintaining this hypothesis against the failure of *particular* systems of scientific law that science can ever again reform its theories. The openness of the realms of science (in contrast to the closeness of mathematical domains) implies that the foundational "hypothesis" of science cannot ever be definitively confirmed. It is, however, by maintaining it that science is *never* defeated by its failures. The falsification of a particular purported natural law never counts as the falsification of the hypothesis of natural legality. The conclusion is that the hypothesis of intrinsic legality of reality is not an *empirical* hypothesis regarding experienceable reality, but a *transcendental* hypothesis regarding the scientific representation of reality.[9]

But there is more, the experimental scientist, whose task is to test scientific hypotheses and theories and who has business only with experienceable reality, has nonetheless in his mind the idealized construct science substitutes for reality. He plays the same game of the theoretical scientist; he too orients himself by "ideal poles"; he too presupposes strict legality. Numerical magnitudes and general formulae are always at the center of interest, theoretical or experimental. Scientific hypotheses, suggested by "experimentally verifiable facts", are from the start expressed in formulae, involving ideal relations. So, the experimental physicist cannot challenge the idealized world vision of the theoretical physicist and the "hypotheses" at its core. "Hence, the science of nature is subjected to a mutation of sense and a covering of sense that has more than one level. The interplay between experimental and theoretical physics [...] has a horizon of sense that has suffered a mutation".

For Husserl, then, the "mathematizing objectivism [...] attributes to the world itself a mathematical rational essence" (*Crisis* §24). "[T]he substitution by which the mathematical world of idealities, which is a substruction [...] is taken as the only real world, that which is truly perceivable, the world of real or possible experiences: in short, our daily life-world" (*Crisis* §9).

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[9] In case you are not counting, we have already met two transcendental hypotheses in the constitution of the scientific representation of empirical reality; 1) it is a domain of *being* existing and completely determined *in itself*, 2) it is a domain subjected to *strict legality*, which can be mathematically expressed (and only thus can be adequately expressed).

Husserl deplores that Galileo did not question "the original sense bestowing act, that which, as idealization, acts on a primitive soil of all theoretical and practical life – the soil of the immediately perceived world" that lies at the basis of his method. But, for Husserl, it is the life-world that interests us; it is in this world that we live; it is this world that we want to know inductively from experience. But in this world "we do not meet geometric idealities, nor geometric space, nor mathematical time with all its forms" (*Crisis* §9).

What, then, is the purpose of science? It is, Husserl answers, "to correct in an infinite progression, by '*scientific*' anticipations, the *rough* anticipations that are originally the only possible within the effectively (actual or possible) experienced in the life-world" (*Crisis* §9). In other words, the point of science is to *anticipate* experience more effectively than it is possible in the life-world. This is done, however, it is important to stress, only by revealing *formal* aspects of *ideal* counterparts of experiences of the life-word. The mathematical science of nature, as Weyl has observed, can only touch the formal surface of reality, and even though, only at a highly idealized level. Science set *ideals* for our actual experience of the world; it directs our efforts into improving our experience of reality. The mathematical science of nature anticipates experience, but *only* by anticipating the *mathematical form* of experience. The *material* content of experience can only be anticipated by having contentual meaning somehow attributed to the mathematical symbolism, which in any case is *not* a concern of mathematics. In short, under the presupposition that nature obeys laws whose *form* admits mathematical expression, formulas are devised to express "natural laws", which are then used to predetermine the *mathematical form* of future experience. I'll come back to this soon.

The historical accuracy of Husserl's considerations can be put to test by comparing his views with those of an expert historian of science (Koyré 1973, 83 the English version is mine):

"The way Galileo conceives a scientific method implies a predominance of reason over mere experience, the substitution of ideal (mathematical) models for empirically known reality, the primacy of theory over facts. It was only thus that the limitations of Aristotelian empiricism could be surmounted and a truly *experimental* method could be elaborated, a method in which the mathematical theory determines the very structure of experimental investigation, or, in Galileo's own words, a method that uses mathematical (geometrical) language to formulate its questions to nature and interpret nature's answers, which, by substituting the rational universe of precision for the imprecise world empirically known, incorporates measurement as the fundamental and most important experimental principle."

Husserl's conclusions concerning the main traits of modern science are all summarized in this quote, namely, the reification of a methodological construct, the mathematical substruction of empirical reality, the downgrading of the life-world (the imprecise world of empirical experience, of the morphological, not the geometric) as a source of knowledge, the theoretical, mathematical predetermination of experience. Even though Husserl was not involved with factual history he certainly hit the nail on the head concerning the factual development of physics.

I want now to consider the problem of the applicability of mathematics in natural science more carefully. This question was raised in *Crisis*, where Husserl offered the key to understand how this is possible, but did not pursue the issue much further. The problem is that Husserl was suspicious of the intromission of symbolic mathematics in science; so, instead of trying to understand the phenomenon in its full extension he chose to criticize the "irresponsible" use of it. The primacy of the life-world and perceptual experience demanded, or so Husserl thought, that symbolization in science be kept under strict surveillance. Husserl allowed it only in the following cases: 1) when symbols have denotations that refer, via idealizations, to the life-world, i.e. when symbolic calculi are meaningful, or else, 2) if symbols are void of content, when they allow practical but essentially dispensable extensions of meaningful calculi. Purely symbolic theories are tolerable only as consistent extensions of *definite* contentual theories, i.e., theories that, first, can be "decoded" in terms of direct perceptions and, second, are syntactically complete.[10] This way of avoiding the dangers of "technization", however, has two major shortcomings. One is that definite theories, although allowed to stand as *ideals*, are not in general, due to Gödel's theorem, available; another is that symbolic mathematics has a much wider range of applicability in science than Husserl allowed it to have. Is there, then, a better way of dealing with this problem? I want to propose one here that takes inspiration from Husserl's analyses of the genesis of modern science and his account of the *possibility* of applying mathematics in science, but refuses his conservatism as to the range and scope of this application.

The *scientific* inadequacy of Husserl's views on the mathematization of science derives from his belief that mathematical methods must be kept under strict control so as to avoid alienating man from his *Lebenswelt*. From the

[10] A definite or complete theory was, for Husserl, one that is syntactically complete, that is, a theory capable of settling any question that can be expressed in its language – Husserl obviously thought that this was an attainable ideal.

perspective of scientific methodology, however, formal mathematical methods are not only effective, but essential, even when mathematical symbols and concepts cannot, even in principle, even approximately, be interpreted in terms of direct experiences. Moving to ever higher levels of mathematical abstraction and indulging into purely symbolic reasoning can grant the theorizing scientist access to ever more powerful mathematical tools of *formal* investigation, leading to formal-symbolic theories that nonetheless yield *empirically testable* consequences, despite the fact that most of its assertions do not correspond to anything in principle *perceivable* or testable.

For Husserl, however, algebra and other forms of symbolic reasoning, although often harmless when symbols stand for "real" entities, can become *problematic* when they stand instead for "imaginary" ones ("empty" symbols). According to him, "[t]he powerful elaboration of signs and the modes of algebraic thinking, a decisive moment that has in a certain sense been rich in future consequences but, in another, disturbing for our destiny" (*Crisis* §9). The situation becomes critical, he thought, when symbols do not correspond to intuitable contents, since assertions involving these symbols do not correspond to possible experiences. The use of *meaningful* symbolic mathematics is not in itself, for Husserl, a very serious problem, for it can be epistemologically justified. But like some people, who believe that the use of light drugs can lead to the abuse of heavier ones, Husserl thought that the use of meaningful symbols can quickly lead to the abuse of meaningless ones. In fact, Husserl claimed, it is a short ride from the invention of algebra and its use in science and geometry (Descartes, Fermat) to the creation of purely formal, intuitively empty mathematics and the complete "technization" (and alienation) to which it leads.

The problem of the *epistemological* justification of the *scientific* use of symbolic mathematics was not raised in *Crisis* but it was approached in a different context, involving the *mathematical* applicability of symbolic mathematics. The *Philosophy of Arithmetic* of 1891 is a case in point; Husserl presents in this work a detailed justification of the symbolic technology of arithmetic. He probably did not see any reason for dealing with the problem afresh in connection with the *scientific* applicability of mathematics, for this is not essentially different from the applicability of mathematics in mathematics itself. As he showed in *Crisis*, science represents empirical reality as a *mathematical* realm; so, to apply mathematics in science is to apply mathematics in mathematics itself. As I claimed before, this insight is the key to understand why mathematics can have scientific utility: for scientific purposes, empirical reality is a mathematically idealized representation of

perceptual reality; we can apply mathematics in the investigation of reality *because* we have turned reality into a mathematical realm.

Nevertheless, even the use of *meaningful* symbols, those that correspond through a series of idealizations to experienceable contents, despite its justifiability, also counts as symbolization and a form of technization, although a less alienating one. For instance, analytic geometry already implies, or so Husserl thought, a "debilitation" of the sense of geometry, for it no longer is space, but a mathematical "image" of space that commands our interest. But this is not, by a long far, the only case of symbolization in science. Algebra gave origin to purely formal mathematical theories, which, as Husserl claimed, when considered *in themselves*, are perfectly legitimate *formal ontological* theories, that is, theories of formal manifolds (among which the *definite* manifolds given by "complete systems of axioms" stand out). But extending contentual mathematical theories, and in particular the mathematical theories of nature, into purely formal theories can lead to loss of meaning and "alienation". "[T]he original thinking", says Husserl, "which gives sense to this technique and its true results (even if it is the 'formal truth' proper to the mathesis universalis) is here [*i.e. in purely formal mathematics JJS*] put out of circuit". This passage from the "mathematics of real domains to formal mathematics" is correct and necessary, but "can and must be a method understood and utilized with full consciousness". That is, we must be careful that "dangerous shifts of meaning" do not occur; i.e., that "the original donation of sense of the method, from where it takes its sense as the realization of the knowledge of the world, be always at our disposal".

The question that bothered Husserl can be formulated thus: how can the use of symbolic mathematics in science be *philosophically* justified from the point of view of a philosophy that puts direct experiences as the ultimate ground of justification?[11] Let's consider first the use of algebra in physical geometry, the mathematical theory of physical space. Physical geometry is a science based on *geometric* intuition, which is a refinement, or better, an *exactification* of perceptual intuition. According to its *original* sense, the validation of geometric propositions depends on *geometric constructions*. These constructions aim at displaying geometric truth directly to the mind's eyes, often via a sequence of constructions based on axiomatically valid elementary constructions and elementary facts (there is here a constant interplay between sense perception and its exactification, geometric intuition). Now, in using algebra in geometry –

[11] My point here, in a nutshell, is that Husserl's answer to *this* question cannot count as a good answer to *another* question, namely: how can the use of symbolic mathematics in science be *scientifically* justified?

analytic, as opposed to synthetic geometry – Descartes and Fermat transferred the burden of validation to algebraic, i.e. symbolic manipulations, *no longer intuitive constructions*. Despite the shift of sense introduced by analytic methods in geometry, symbols still correspond to geometric entities (which correspond, as their exactification, to things that either are or can be given in spatial perception); algebraic manipulations can still be "decoded" into geometric constructions (which represent, via idealizations, experiences in perceptual space). Technization is still, so to speak, under control; the original sense of geometry can be recovered.

Formal mathematics, where symbols do not correspond to anything intuitable however, or so Husserl thought, more than technization for practical purposes introduces something more disturbing, *alienation*: purely symbolic manipulations have no ties with experienceable reality. How, then, can they be *justified*?

Based on Husserl's treatment of "imaginaries" in mathematics, as presented in the double lectures delivered in 1901 in Göttingen, we may *guess* what his answer would be: formal mathematics can only be justifiably used in science if it is a consistent extension of *definite*, logically complete "meaningful" theories, i.e. theories of idealizations of formal-abstract aspects of experiences in principle available in the life-world. Unfortunately, this will not do; such a requirement would cripple scientific methodology (see da Silva 2008, 2013).

But there is an even more fundamental problem that Husserl did not address in *Crisis*, but that had already been dealt with in much earlier works: how, after all, is it possible to obtain knowledge of entities of a type, belonging, for instance, to the geometric or empirical domain, by manipulating symbols, for example, algebraic symbols, referring to entities of a *different* type (numbers, in the case of algebra)? Part of the answer is available in his *Philosophy of Arithmetic*: if the system of entities we want to know is *formally identical* with the systems of entities our symbols denote, then whatever is true in one is necessarily true in the other.

Let me explain what Husserl had in mind. Let A be our domain of primary interest and B an *isomorphic* copy of it. It does not matter what the elements of B are, I only suppose that B is more easily accessible to direct experience than A (whatever type of intuitive experience the direct inspection of A and B requires, perceptual or any other). Whatever is true in B, provided it involves only relations and concepts for which there are isomorphic correspondents in A, is also, upon reinterpretation, truth in A. Truth is preserved under isomorphism. This is how Descartes' analytic geometry works, points are given numerical representatives in such a way that geometric properties are

represented analytically and geometric constructions replaced by algebraic manipulations *isomorphically*. B may also be a purely formal domain, defined by a formal theory, for which truth has only a formal sense.

Once our perception of empirical reality is mathematized, the applicability of mathematics in the empirical science depends on the existence of relevant formal-mathematical connections between *mathematical* realms. This is how it goes. By retaining from perceptual experience objective *form* instead of subjective (*material*) *content*, formal structure can be abstracted from experience. From a mathematical perspective, perceptual structure is still very "rough"; proto-mathematical instead of fully mathematical. But it can be idealized into a mathematical structure proper. Thus an *ideal* mathematical mold is *imposed* on experience, making "exact" the "rough" structuring displayed in experience. From this point on the applicability of mathematics in science is only a particular case of the applicability of mathematics in mathematics itself. If, for example, we can find a domain B isomorphic to the domain A, the mathematically idealized form of experience, the theory of B, provided it is expressed conveniently, i.e., in the language of A, is also true in A. But in general the first-level mathematization of experience, our A, is still mathematically too poor to have interesting isomorphic copies with well-developed theories and can profit from being mathematically enriched into a domain C (we can think of this as *immerging* A into C by a convenient monomorphism). If this embedding is short of being a full isomorphism, the language of the theory of C may have symbols that are "imaginary" from the perspective of A, that is, symbols that have no interpretation in A. In this case, for Husserl, or so I claim, the theory of C can only be utilized for dealing with A if the theory of A is a definite, i.e., a syntactically complete theory.

In short, by abstraction and idealization we pass from the life-word into the world of mathematics. If this mathematical substitute corresponds to the life-world in such a way that mathematical symbols correspond to contents of the life-world isomorphically, similarly to what happens in analytic geometry, in which numbers and numerical variables stand for geometric entities and variables over the geometric domain in such a way so as to preserve the latter's structural form, technization (i.e. the substitution of the intuitable by the symbolic) can be justified along the same lines algebra is justified vis-à-vis physical geometry. But when mathematical symbols have no representational value in the life-world, i.e. when mathematics is purely symbolic, the ties with the life-word are severed. Scientific theories with "imaginary" symbols are no longer, strictly speaking, theories of an ideal version of formal-abstract aspects of experienceable reality, but of an *imaginary extension* of it, a *symbolic*

reconstruction of perceptual reality, in the words of Weyl. How, then, can they be epistemologically justified in a way that takes experience into account?

Given that Husserl's answer, or what I take for it, is unacceptable, is there a better one? There is one that imposes itself, I think: theories which incorporate "imaginaries" can only be tested as *wholes* by means of their *meaningful* (i.e. testable) consequences; isolated propositions cannot in general be empirically verified. This perspective can be called *scientific holism*. The theory of C is scientifically justified provided any assertion that can be interpreted in A, but whose justification involves in some way the theory of C, is *verifiably* true in A. Of course, the effectiveness of the theory of C in dealing with A can never be definitively justified once for all, because a consequence may be derived that is false in A. This, by the way, is how Weyl solved the epistemological problem posed by purely symbolic manipulations in science (see da Silva 2014).

As I see it, Husserl may have been aware of this possibility; the problem is that it does not offer comfort for the alienation of man; rather, it embraces it. "Blind" symbolic manipulations *do* alienate man, his life-world, his experiences, and the testimony of the senses. But science cannot do otherwise if it is to remain efficient. But holism does not turn the back to the life-world, it too gives man's perceptions a fundamental role in the justification of scientific theories, no matter how symbolically "contaminated" they may be (though more globally than locally, as Husserl's "intuitionism" seems to require).

There is an interesting point that I want to consider now, the radical difference Husserl detected between pure and applied mathematics. For him, "a feeling emerges, little by little, with a sensation of malaise, of the obscurity inherent to the relation between the mathematics of nature and the mathematics of the space-temporal form [...]" (*Crisis* §9). Whereas pure mathematics can be known a priori and apodictically "the concrete universal legality of nature", despite being also mathematical, is only accessible a posteriori and inductively. Whereas the relation of reason to consequence dominates pure mathematics, applied mathematics must abide by that of cause to effect. So, applied mathematics cannot detach itself completely from experience.

Mathematical structuring is *imposed* on experience not on the basis of what experience *gives*, but on the basis of what it *suggests*, however meagerly. But since experience is never exhaustive, science must turn to it again and again in search of new hints. The mathematical structuring of experience takes notice of the facts of experience, but it is not *extracted* fully dressed and fully armed from experience. So is the *inductive* and *a posteriori* character of applied mathematics. Mathematics, *as utilized by science*, is not a given of experience; rather, it comes from outside as a methodological devise.

That experience, nonetheless, has already some mathematical or proto-mathematical structuring comes out clearly in Husserl account of the constitution of perceptual space (experience *too* is in part an intentional construct).[12] Perceptual space, although not strictly speaking geometrical, is nonetheless proto-geometrical; it has some structure on the basis of which, by idealization, a geometric manifold (*physical* space) is constituted. Idealization, after all, is not a creation ex nihilo; as a process of exactification it requires something that is not "exact" to begin with; in this case, perceptual space and its *perceivable* structure. But not even *this* structure is only a matter of *actual* perception. Perceptual space also betrays a constitution; it is not simply given but a *product* of intentional psycho-physical systems whose task is to "process" raw sensorial impressions. The constitution of perceptual space – a structured system of "positions" (or points) and relations among them, such as: point A is *closer* to point B than to point C, A is *between* B and C, etc. – is a joint contribution of the senses and built-in psycho-physical intentional systems. These relations are perceptually accessible and are more qualitative than quantitative. Perceptual space, however, is for Husserl *real* space.

This can be easily generalized. Our ordinary, pre-scientific experience of empirical reality has also, inevitably, some structure. The experience of the world is not a chaotic mess, but a structured system of perceptions. And who says structure says mathematics. Any structuring is mathematical and structuring relations, such as order, proximity, contiguity, and gradation of different types, are essentially mathematical and so prone to mathematical treatment. The structure discernible in experience is an aspect of the experience itself. Science may and does enrich it, idealizing it, "polishing" it, so to speak, introducing new objects and relations in it, but it does not create it ex nihilo. Now we have some inkling on why mathematization works as a *method*: it is a way of extracting by more refined mathematical methods information regarding the *structure* of experienceable reality. But it cannot, *by itself*, independently of semantic content being somehow instilled into the symbols, tell us anything about the *material* content of experience (the *whats* instead of the *hows*).

Husserl admitted this much, namely, that experienceable reality is to some extent already mathematical; he only denied that it is mathematical to the extent science presupposes. The life-world is not mathematics-free, and Husserl knew it. What Husserl maybe failed to see – at least he did not emphasize

[12] The fact that the structure of experience is, to some extent, *already* mathematical or proto-mathematical indicates that the intentional action that molds crude data of sensation into *perceptions* involves a certain amount of mathematization, which, however, emanates from constituting subjectivity, not the given of the senses.

it – was, first, that the *objectification* of experience demands that its *material* content be relinquished in favor of its *formal* content, for form only can be objectified through language – indeed, no linguistic rendering of experience, being as they are, out of necessity, invariant under isomorphisms (true in all isomorphic copies of any domain where they are true) can singularize material content. And, secondly, since science is necessarily formal in the sense above, that it can benefit from purely formal-symbolic mathematics devoid of any material content. For Husserl, the project of science requires that subjective content (colors, sounds, etc) has correspondents in the objective realm of form (respectively, frequency of light radiation and longitudinal waves in the air of determinate frequency and amplitude, etc). But this is not, as Husserl seems to believe, a presupposition of Galilean science only, but of any *objective* science whatsoever.

By admitting a proto-mathematical structure to experience, Husserl in a way "humanizes" Platonism. Instead of a strictly mathematical reality out of perceptual reach, a proto or quasi-mathematical reality within human reach that can, for methodological purposes, be represented by an idealized, often structurally enriched mathematical pseudo-reality. However – and this is important –, the entire process has only to do with the *form* of empirical reality. As long as material contents – *themselves, not their symbolic "representatives"* – are brought in, mathematical methods of investigation loose completely their relevance (Goethe's theory of colors, to give an example, is refractory to mathematical treatment). If Husserl had seen this he would, I believe, be less concerned with preserving the possibility of recovering perception from its formal aspects alone. Maybe he would then accept that scientific theories, no matter the amount of mathematics that goes into them, are *always*, considered in themselves, independently of *external* donation of material meaning to symbols (i.e. by associating content of experience to symbols), purely formal, and that this is why they can be so efficiently extended by purely formal means, no other way existing for the contour conditions imposed by perception to be taken into account than by submitting theories to test *as wholes* by means of the formal consequences we extract from them and into which we manage to instill some material content.

Roughly speaking, the structure of a domain is the system of relations that the elements of this domain establish among themselves abstractly considered, i.e., regardless of *what* the elements or the relations among them are. Hence, the structure of any domain is an *abstract* aspect of this domain that can be reified (as an *ideal* object, or Form, to use Platonic jargon) which can be indifferently instantiated in any domain of a family of isomorphic domains (in Platonic language, all isomorphic domains *partake* in the same ideal Form). Although

the structure of two different, but isomorphic domains are *equal*, they are not *identical*, for they are aspects of *different* domains. But both are instances of the *same* ideal structure; we can say that the same identical ideal structure *projects* itself in equal, but non-identical structures of different isomorphic domains.

Mathematics is solely concerned with structures, be they given as abstract aspects of specific domains of objects (for example, the ω-structure of the domain of natural numbers) or ideal structures characterized by their properties (for example, the ω-structure as given by second-order Dedekind-Peano axioms). Mathematical theories are always structural descriptions, either *in concreto*, as contentual theories, such as arithmetic seen as the description of the structure of the domain of natural numbers) or *in abstracto*, as formal theories, such as formal second-order arithmetic.

Let's consider an example. Let's postulate a domain (no matter which or even whether there *really* is such a domain; this postulation is a *free* act of imagination) whose elements (no matter what they are) are ordered (by no matter which binary relation) in a discrete linear order such that there is a first element but no last, each element has another element – but only one – immediately following it and each element can be reached from the first in a finite number of steps (*just like* the natural numbers ordered by the successor relation). Regardless of the nature of the objects or the relation that orders them, the above description concerns only *how* the objects of the domain are ordered and is a typical example of a structural description *in abstracto*. An ideal structure is thus posited. But in making this structural description, we may also have a particular, previously existing domain of entities under the eyes (or the "mind's eyes"); for example, the natural numbers ordered by the successor relation; the description, in this case, would be one *in concreto*, describing the abstract structural aspect of a *particular* domain.

Any contentual mathematical theory can, by formal abstraction, be made into a formal theory. In case this is a categorical theory (all models are isomorphic) it is no longer a description in concreto of the abstract structure of a particular domain but a description in abstracto of an ideal structure. Non-categorical theories cannot completely characterize a structure; they are incomplete characterizations. But mathematics is often more interested in families of similar structures (for example, groups), than in single structures of this family (for example, the group *S5*). Any description (any theory) is capable of characterizing a family of similar structures, those of all the domains that correspond to this description (all the models of the theory).

By keeping in mind that mathematics can *only* provide structural descriptions, we can see how it can be of help when we are interested precisely in the purely structural aspect of our experience of the world. Let's consider

again an example. We may notice in our immediate experience that bodies that are exposed to the sun feel warmer to the touch, some more than others. Our curiosity is stimulated and we consequently put ourselves in a *scientific* state of mind. We are no longer content in *describing* our experience; we want to *explain* it, to bring out the "hidden rationality" of the phenomenon. We, then, maybe not always consciously, formulate the "Galilean" hypothesis: there is a hidden legality connecting the period of time bodies are exposed to the sun and the increase of intensity in the feeling of warmth they cause when touched (and, if we are slightly more scientifically sophisticate, that this relation may depend on the *type* of body in question). We have isolated a particular structural aspect of empirical reality we happen to be interested in. To bring it out, so to speak, we resort to the "Galilean" strategy: we objectify the sensation of warmth, *substituting* it by the objective (scientific) notion of temperature, and different "degrees of warmth", actually or only potentially perceivable, by numbers (this depends of the relation of temperature to, for example, the length of a thin column of mercury). Now, based on the observable correlation between two series of numbers, one series measuring the time of exposure of the body to the sun, another the temperature change of this body due to the exposure, idealizing and generalizing inductively, we may be able to arrive at a numerical formula, expressing an idealization of the correlation we want to bring to light. Now, all the questions we want to pose about our immediate experience (for example, how much warmer a piece of iron would feel after being exposed to the midday sun for the period of time of my lunch?) can be posed about its mathematical substitute (what the temperature rise of a piece of iron exposed to the midday sun for an hour would be?). Once our formula is available, and the initial conditions checked, the answer is only a matter of arithmetical calculation. The mathematical substruction of experience is, in this particular case, complete.

One aspect of the Galilean hypothesis in particular is worth noting. It is presupposed that the mathematical "translation" is *adequate*, that is, that the mathematical relation does really bring out something that was hidden in the world. In other words, that experienceable reality admits a hidden structure that is mathematically expressed. This, as Husserl emphasizes, is a *hypothesis*, and a very peculiar one. Our experience can neither confirm nor disconfirm it. The hypothesis is put out of reach of empirical testing. If the *real* world is, as Husserl wants, the experienceable world, then its *real* structure is the one we can experience. It can be mathematical in a certain sense; for example, in our example, we can *experience* that short periods of exposure can cause only small changes in the feeling of warmth, i.e. that the continuum of periods of exposure is related to the continuum of increases in the warmth feeling

in a *continuous* manner.13 This is a *topological* property of experience, and as such mathematical. Its *metrical* translation, however, embodied in the formula relating temperature changes with periods of exposure (which expresses analytically the intuitive properties of continuous correlations), is an idealization that is not capable in principle of direct experience. The Galilean hypothesis consists in taking it as an *adequate* translation of the topological property, *even though it involves more than what meets or can meet the senses*. The *philosophical* error (which, however, is not a *scientific* error) lies in taking the hypothesis for a *fact*. Some aspects of experience can be mathematical, but not always in the same sense their mathematical translations are.

ABSTRACT

I present and discuss in this paper Husserl's investigation of the genesis of the modern conception of empirical reality as carried out in his last work The Crisis of European Sciences and Transcendental Phenomenology. The goal of Husserl's genetic investigation was to uncover the many layers of constitution that from the life-world (the Lebenswelt) the modern scientific conception of Nature was originated and to point out the need to ground the scientific project of modernity in the life-world so as to overcome the "alienation" that, for him, characterized the "crisis" of European science. I, however, approach his analyses from a different perspective. The problem that interests me here is the applicability of mathematics in the empirical science. My aim is to assess Husserl's treatment of this question in order to see whether it can be sustained from a strictly scientific perspective. My conclusion is that it cannot. What Husserl takes for the "crisis" of science is inherent to the best scientific methodology. Nonetheless, Husserl's analyses offer important insights that I incorporate in what I believe to be a more satisfactory treatment of the problem concerning the role of mathematics in the empirical science.

Bibliography

Bloch, F.: *Heisenberg and the Early Days of Quantum Mechanics*. In: Physics Today 29(12)/ 1976, 23-27.

da Silva, J.: *Husserl and the Principle of Bivalence*. In: Hill and da Silva, 285-298.

______: "Husserl and Weyl, the Elusiveness of Influence". To appear, 2014.

[13] Perception can also display *quantitative* aspects of experienceable reality (*longer* periods of exposure entail *larger* increases in the sensation of warmth change) which, however, remain at the level of the morphological (as opposed to the exact). The formula gives these aspects an exact translation, which, although not corresponding to anything *hidden* in the real world, can be translated *back* in terms of elements of the experienceable world. Mathematics provides a *representation*, not a faithful *picture*; its methodological value consists in this.

Hill, C. O./ da Silva, J. J.: *The Road Not Taken, On Husserl's Philosophy of Logic and Mathematics*. London 2013.

Hopkins, B. C.: *The Origins of the Logic of Symbolic Mathematics*. Bloomington 2011.

Husserl, E. *Philosophie der Arithmetik*, Halle: Pfeffer, 1891; also published in Husserliana Bd. XII (The Hague 1970); English translation: *Philosophy of Arithmetic, Psychological and Logical Investigations with Supplementary Texts from 1887-1901*, trans. D. Willard, Dordrecht 2003.

________. *Die Krisis der europäischen Wissenschaften und die transzendentale Phänomenologie. Eine Einleitung in die phänomenologische Philosophie*. In: Husserliana. Bd. VI ed. W. Biemel, Husserliana (The Hague 1954); English translation: *The Crisis of European Sciences and Transcendental Phenomenology*; trans. David Carr, Evanston, Ill 1970.

Klein, J.: *Greek Mathematical Thought and the Origin of Algebra*. Trans. by Eva Brann, Cambridge, Mass. 1969; reprint: New York 1992. Orig. *Die griechische Logistik und die Entstehung der Algebra*, in Quellen und Studien zur Geschichte der Mathematik, Astronomie und Physik, Abteilung B, 3(1)/1934, 18-105 (Part I), and 3(2)/1936, 122-235 (Part II).

Koyré, A. : *Les origines de la science moderne*. Diogène 16/1956, 14-42, reprinted in Études d´histoire de la pensaée scientifique, Paris 1973/ 61-86.