Phenomenology and Physics

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Physics has a long and venerable history of overthrowing deeply entrenched assumptions about the fundamental structures of empirical reality. Its revolutionary potential was once again on full display when two ground-breaking paradigms made their first appearance during the first decades of the 20th century. In Relativity Theory and Quantum Mechanics, physics offered a view of reality that was radically different from many of the orthodoxies that had prevailed during the preceding centuries. Rather unsurprisingly, the need to revise fundamental concepts such as space, time or causality also left its mark on philosophy: It is no overstatement to say that the early 20th century revolutions in physics were a decisive factor in the institutional downfall of Neo-Kantianism, in the development of Logical Empiricism and Critical Rationalism, and thus in the formation of what later became the dominant analytic orientation in contemporary philosophy (of science).

Given the impact physics had on the philosophical landscape during the early decades of the 20th century, one might wonder what the role of phenomenology was in all this. On a first impression, an answer to this question will be disappointing. The fact that the formative years of the phenomenological movement were also marked by profound revolutions in mathematics and physics have, for the most part,[1] received little attention in the writings of the first wave of classical phenomenologists. Husserl is no exception to this: For instance, the name "Einstein" is, to the best of my knowledge, mentioned less than ten times in all 42 volumes of the *Husserliana* edition (cf. Husserl 1970, 4, 125-26, 295; Husserl 1973b, 229; Husserl 2002, 297). Given this, and given the fact that Husserl's most noteworthy engagement with physics is a rather general analysis of the early modern mechanics of Galileo Galilei (Husserl 1970, §9; cf. also Wiltsche 2017), it seems safe to assume that Husserlian phenomenology is not particularly illuminating when it comes to understanding contemporary physics. Yet, the aim of this chapter is to argue that such a conclusion would be premature. To be sure, my claim is not that Husserl was a philosopher of physics in the present-day sense of the term.[2] My strategy will rather be an indirect one: I will focus on some motifs in Hermann Weyl's oeuvre in order to show how the Husserlian mind influenced the thinking of one of the most prolific mathematicians and theoretical physicists of the 20th century.[3]

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[1] To be sure, there are exceptions, such as Moritz Geiger's lecture on Relativity Theory that was held at the University of Munich in 1921 and appeared in print in the same year. Yet, in light of how sophisticated the philosophical discussion about Einstein's new theory already was at the time (cf. Ryckman 2018), it seems like a stretch to claim that Geiger offers an original and genuinely phenomenological take on Relativity Theory.

[2] For a more general overview of Husserl's, Martin Heidegger's and Maurice Merleau-Ponty's contributions to a phenomenological analysis of the physical sciences, cf. Berghofer & Wiltsche forthcoming. Some of the key texts in phenomenological philosophy of science are collected in Kockelmans & Kisiel 1970.

[3] Although not too well known in philosophical circles, Weyl is a towering figure in 20th century mathematics and science. Since an exhaustive list of his achievement would exceed the scope of this chapter, I will restrict myself to just a few of Weyl's most salient contributions. In pure mathematics, Weyl's premier achievement is probably his general theory of the representations and invariants of the classical Lie groups, which was later applied to quantum mechanics. Weyl also contributed to the foundations of mathematics, where he first defended a form of predicativism and then an intuitionistic view similar to that of L.E.J. Brouwer. In theoretical physics, one of Weyl's most enduring achievements grew out of the attempt to unify electromagnetism and general relativity. Although Weyl's unified field theory was rejected by most of his contemporaries—and by Einstein in particular—it contained the notion of gauge invariance, which (in the form of non-Abelian gauge fields) is still at the very core of the Standard Model of contemporary particle physics of which the most recent triumph is the experimental detection of the Higgs boson at CERN in 2012. Furthermore, in the fifth German edition of *Space-Time-Matter* Weyl predicted the cosmological redshift, six years before the effect was empirically established by Edwin Hubble. Finally, it was on the basis of his analysis of mass in terms of electromagnetic field energy that

Before turning to philosophical issues, let me provide some biographical information (cf., for more detailed presentations, Ryckman 2005, 111-15; Pesic 2009, 2012): After completing his doctoral studies in mathematics and physics under the supervision of David Hilbert, Hermann Weyl (1885-1955) accepted the position as *Privatdozent* at the University of Göttingen in 1908 and stayed there until 1913. It was also in Göttingen that Weyl became acquainted with phenomenology—Weyl's later wife Helene Joseph (1893-1948) was a student of Husserl, and although it isn't unlikely that Weyl had already heard of phenomenology through his colleagues in mathematics and physics, it was primarily Helene who sparked his interest in Husserl's philosophy. Weyl himself never left any doubt as to how important phenomenology was for the development of his philosophical and scientific thinking. Apart from Weyl's explicit recollection that "it was […] Husserl […] who led me out of positivism […] to a freer outlook upon the world" (Weyl 2009, 209), there are countless implicit and explicit references to Husserlian phenomenology both in Weyl's scientific and in his philosophical writings.[4] To one such reference we shall now turn.

One of the most fundamental insights in all of Husserl's phenomenology can be summarized as follows:

> Object, objective being and consciousness belong *a priori* and inseparably together; and if we can attribute to each consciousness a consciousness-Ego, an Ego belongs to this essential correlation as well. A possible Ego and a specifically determined possible consciousness are ascribed to each and every possible objective being. (Husserl 2003, 73; my translation)

What Husserl expresses here is the so-called "universal a priori of correlation between experienced object and manners of givenness" (Husserl 1970, 166). As long as we remain within the natural attitude, there is always the temptation to objectify reality as something that is "simply out there", that exists in complete independence from consciousness. The very point of performing the epoché and the transcendental reduction is to liberate us from this naïve realist assumption and to make us aware of the subject's sense-giving contribution that always already underlies all encounters with reality. Phenomenologically construed, every object that presents itself to us in scientific or extra-scientific contexts is not only to be understood as existing "in itself" but also in relation to the subjective accomplishments through which it is disclosed. As a consequence, every objectivist (i.e. transcendentally unclarified) thematization of reality must necessarily remain incomplete because it ignores the process of sense-bestowal without which no objective world would appear to consciousness in the first place.

Although the mature Husserl became increasingly clear that neither side of the correlation can be analyzed in complete separation from the other—that, for instance, conceiving of the sense-bestowing subject as an outerworldly, disembodied and solitary monad is not significantly better than a purely objectivist interpretation of reality—, there are several passages in which the consequences of the universal correlation are put in rather extreme terms. Probably the most notorious of these passages is contained in section 49 of *Ideas 1* in which Husserl argues that even the complete "annihilation of the world" would leave the "residuum" of "pure" or "absolute" consciousness untouched (cf. Husserl 1983, §49). On a first reading, one might be tempted to take this as an argument

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Weyl proposed the topological idea of "wormholes" or "Schläuche von eindimensional unendlicher Erstreckung", as he initially called them (Weyl 1921, 557).

[4] To get an idea of how strong the influence of phenomenology was, consider, for instance, the following passage from *Space-Time-Matter*, one of the first textbooks on General Relativity Theory that went through five editions in the first six years: "In perception I see this chair, I am directed towards it. I 'have' the perception, but it is only when I make this perception in turn the intentional object of a new inner perception (a free act of reflection enables me to do this) that I 'know' something regarding it (and not only regarding the chair alone) [...]. In this second act the intentional object is immanent, i.e. like the act itself, it is a real component of my stream of experiences, whereas in the primary act of perception the object is transcendent, i.e. it is given in an experience of consciousness, but is not a real component of it." (Weyl 1952, 4; translation modified)

in favor of metaphysical idealism, i.e. the view that consciousness is exhaustive of reality, and that, consequently, the physical world is ontologically parasitic on the constructing powers of the Ego. However, in what follows I will suggest an interpretation of the annihilation of the world thought experiment that is more in line with the basic tenets of phenomenological philosophy. Although there is, I believe, no point in denying that phenomenology is indeed committed to idealism, it is crucial to acknowledge the specific nature of Husserl's transcendental-idealistic stance. It is important to get clear on this because a genuinely phenomenological brand of transcendental idealism is also operative in the background of Hermann Weyl's analysis of the nature of scientific cognition.

In order to get a clearer view of the annihilation of the world thought experiment, it is advisable to remind oneself of phenomenology's acknowledgment of the first-person perspective as a crucial element and indeed the starting point of any rigorous inquiry into the nature of sense-bestowal. If there is any hope of understanding fundamental notions such as truth, knowledge or objectivity, then, phenomenologically construed, analysis must proceed from an unbiased description of the *phenomena*, i.e. of the things as they appear to us in conscious experience. Take perception as a model: Although we are intentionally directed towards a three-dimensional thing in space, all that is ever sensuously given is two-dimensional appearances, i.e. profiles of the thing, as it appears from one particular perspective. To be sure, unlike in the case of memories or imaginings, it is characteristic of perceptual experiences to present their objects "in the flesh", "as actually present" or as "self-given" (Husserl 1997, 12). However, as perceptual illusions show, the instantaneous "presentationality" of particular two-dimensional appearances is not a sufficient ground for establishing a truly robust sense of reality. The sense of objectivity that is characteristic for successful encounters with physical things is rather constituted over time, and more concretely on the basis of structures that remain invariant across an entire series of perspectival views. For instance, its squareness is experienced as an objective feature of a building because the angular relations between the experiencing subject and each side of the building remain invariant, no matter from where the building is seen. And what is true of particular objects is no less true of the world as a whole, for "things and their occurrences do not arbitrarily appear and run their course but are *bound* a priori by [an invariant general] style, by the invariant form of the intuitable world" (Husserl 1970, 31). It is this invariant form which is responsible for the genuine sense of objectivity that is characteristic for how the world presents itself to us.

The key to a sensible interpretation of the annihilation of the world thought experiment is to realize that the term "world", phenomenologically understood, does not denote the set of all actually existing objects. "World" rather denotes the ultimate horizon of sense in which everything that can become a possible object of investigation must be localizable, and whose mode of givenness is essentially characterized by the aforementioned invariant form. The point of the annihilation of the world thought experiment, then, is not to ponder over a hypothetical scenario in which the world as we know it ceases to exist because, say, our sun goes supernova. The point is rather to stipulate that "certain ordered concatenations of experience and therefore certain complexes of theorizing reason oriented according to those concatenations would be excluded" (Husserl 1983, 110). This is to say that the hypothetical scenario we are asked to imagine is one in which the world—phenomenologically understood as the ultimate horizon of all horizons—ceases to exhibit any kind of structuredness at all. Even if this was the case—even if no invariances whatsoever were to arise from a purely chaotic tumult of contingencies—, consciousness would, as Husserl argues, still display the same familiar eagerness to latch onto any invariance that might offer itself to the sense-bestowing Ego. Of course, since, by stipulation, there is nothing to latch onto under such extreme conditions, consciousness would be severely modified. According to Husserl, however, this does not change the fact that, even if the ultimate horizon of sense dissolved into pure and utter chaos, it would still be chaos *for an Ego*, which would continue to desperately seek for structures that remain invariant over time.

No matter what one's views of the annihilation of the world thought experiment,[5] the point Husserl seeks to make is that there is a fundamental asymmetry between the pre-structuredness of the world on the one hand and the sense-bestowing activities of transcendental consciousness on the other: Since only the former can be imaginatively abstracted away, we come to realize that even the most extreme variation of the world—a blooming, buzzing confusion that hardly deserves to be called "world" at all—would still be an intentional object *for an Ego*. This insight has far-reaching consequences: According to metaphysical realism, it is meaningful to speak of a world, the objects it contains as well as their properties and the relations between them in complete independence from consciousness. The annihilation of the world thought experiment is supposed to undermine this view by emphasizing that no matter how distorted we imagine the world to be, it must still be imaged as something that remains experienceable for an Ego.[6] This, and only this, is what Husserl seeks to express when he refers to "absolute consciousness as the residuum after the annihilation of the world" (Husserl 1983, 109; translation modified).

Husserl's rejection of metaphysical realism has always been something of a hot potato among commentators, and I suspect that part of the reason has to do with the worry that the commitment to a specific form of transcendental idealism puts phenomenology on a direct collision course with science. An argument to this effect could proceed as follows: As we have seen earlier, perceptual objectivity is constituted on the basis of structures that remain invariant across an entire series of perspectival views. The reason is, supposedly, that experience combines subjective as well as objective features, and that the only way to separate the former from the latter is to search for invariances. Think, for example, of color: Although we may agree that color is essential to how physical objects appear to us, we also know that the ways in which specific color-qualities are experienced do not depend on the perceived object alone. Color reports can vary significantly because it seems impossible to disentangle a perceived color-quality from contingent factors such as one's position, one's physiological make-up, the illumination or the medium between object and observer. Matters are different in the case of other properties, however: Although the perceived shape of a rectangular building will also vary from point to point, the lawful angular relations between one's momentary position and each of the building's sides remain invariant over all varying shape-appearances. It is invariances of this kind on which the constitution of perceptual objectivity is ultimately founded: Unlike in the case of specific color-qualities, we are more confident that a specific shape is an objective property of a thing because the angular relations between the thing's sides remain invariantly the same—for anyone, at any time, and at any position in space.

As the previous discussion shows, the ability to identify invariances plays a crucial role in our basic perceptual capacities and thus in our everyday encounters with reality. Building on this insight, one could go a step further and add that the very point of physics is to refine this ability and to amplify it to its limit: In everyday contexts, the notion of spatial invariance is essentially tied to an infinite manifold of possible locations of real or imaginary embodied observers, and to their in-principle capacity to move from any of these locations to any other. Invariance is then attributed to those properties which remain unaltered when embodied observers vary their spatial positions through auto-motion. Now, what seems to happen in physics is that, first, embodied observers are replaced by abstract reference frames (or coordinate systems), and that, second, the bodily capacity for auto-motion is replaced by mathematical transformation rules that specify the relationship between two quadruples of coordinates of a set of events, as measured from within two inertial frames. Physical significance is only granted to those properties whose values remain invariant under a given group of

[5] Although it would lead me too far afield to enter a detailed discussion here, it should be noted that there are good reasons to view the didactic value of the annihilation thought experiment with some caution. For a more detailed discussion, cf., e.g., Rinofner-Kreidl 2000, 699-708; Zahavi 2008, 2010.

[6] It should be clear that the annihilation of the world thought experiment will only convince those who are already willing to make major concessions to Husserl's position. Those who aren't will be quick to respond that, for instance, the thought experiment crucially relies on a very peculiar understanding of the notion "world"—an understanding which arguably begs the question against the metaphysical realist.

transformations. The functional relationship between these properties is then quantitatively determined by laws, and objectivity is finally linked to the requirement that the laws must transform covariantly, i.e. that their mathematical form must be preserved under transformation from one frame to the other (cf. Cassirer 1953; Kosso 2003). In light of this, it might not only be reasonable to conclude that physics is indeed an amplification of abilities that are already operative in our everyday perceptual encounters with reality. It might even be reasonable to argue that the way in which mathematics is put to work here enhances these abilities to a point where all traces of subjectivity are indeed removed from the scientific representation of reality. On this view, then, replacing embodied observers and their capacity for auto-motion with abstract coordinate systems and mathematical transformation rules is a successful strategy for doing away with the vagaries of subjectivity and thus for fulfilling the aim of a completely dehumanized *view from nowhere*.

Given the influence Husserlian phenomenology has on his thinking, it is natural to assume that Hermann Weyl does not concur with this realist line of interpretation. Although this is undoubtedly true, it is nevertheless interesting to examine Weyl's argument in detail. This is because Weyl does not just reject metaphysical realism on some principled philosophical grounds. The reason for his dismissive attitude has rather to do with the claim that an objectivist interpretation of scientific cognition misconstrues the very nature of mathematical representation. Or, to put it more concretely, a realist interpretation of mathematized physics is doomed to failure because it ignores the fact that whenever we seek to represent empirical reality mathematically, "*the coordinate system remains as the necessary residuum of the ego-annihilation*" (Weyl 1949, 75; translation modified and emphasis added). As the wording indicates, Weyl directly refers to Husserl's annihilation of the world thought experiment here (Sieroka 2019, 113; Ryckman 2005a, 128-36). However, since the exact nature of Weyl's allusion might not be entirely clear, I will spend the next few paragraphs inquiring into the details of the relation between Husserl's and Weyl's respective views.

Following Weyl's remarks in *Philosophy of Mathematics and the Natural Science* (Weyl 1949, 110-13) and elsewhere (cf., e.g., Weyl 1952, 3-4), the driving force behind modern physics is indeed the attempt to objectify reality through a methodologically regimented exclusion of everything subjective. Historically, the first steps into this direction were made when pioneers of the scientific revolution such as Galileo Galilei claimed that "tastes, odors, colors, etc., […] are nothing but empty names [that] inhere only in the sensitive body" and that, consequently, "if one takes away ears, tongues, and noses, there [remain] the shapes, numbers, and motions, but not the odors, tastes, or sounds" (Galilei 2008, 185, 187). Hence was born the distinction between primary and secondary qualities according to which mathematizability is the main criterion for what can count as objectively real. Following this distinction, only primary qualities belong to the inventory of objective reality because secondary qualities like color, odor or taste resist mathematization and quantification because of their subjective character. Yet, as Weyl also points out, the distinction between primary and secondary qualities was only an intermediate stage in the process of systematically excluding everything subjective from the scientific description of the world. Ultimately, the development of physics culminated in a purely symbolic representation of reality where everything that can be granted physical significance must find its expression in mathematical symbols.

In light of this historical narrative, it is hard to deny that the aforementioned objectivist interpretation of physical theorizing contains at least a grain of truth: What is undeniably true is that the systematic exclusion of everything subjective functions as a regulative idea and thus as a prescriptive telos that gives physical research its normative direction. However, Weyl's point is that, as with all regulative ideas, the focal point towards which the movement of symbolization strives will never be fully realizable. An argument to this effect is given in the following passage from *Philosophy of Mathematics and the Natural Science*:

> How is it possible to assign to the point of a point-field marks or labels which could serve for their identification or distinction? The labels are supposed to be self-created, distinctive and always reproducible symbols […]. Only after this has been accomplished can one think of representing the spectacle of the actually given world by construction in a field of symbols. All

> knowledge, while it starts with intuitive description, tends toward symbolic construction. No serious difficulty is encountered as long as one deals with a domain consisting of a finite number of points only […]. The problem becomes a serious one when the point-field is infinite, in particular when it is a continuum. A conceptual fixation of points by labels of the above-described nature that would enable one to reconstruct any point when it has been lost, is here possible only in relation to a *coordinate system*, or frame of reference, that has to be exhibited by an individual demonstrative act. The objectivation, by elimination of the ego and its immediate life of intuition, does not fully succeed, *and the coordinate system remains as the necessary residuum of the annihilation of the ego*. (Weyl 1949, 75; translation modified and final emphasis added)

The background of this passage can be illuminated by taking a closer look at the constitution of space both in scientific and pre-scientific contexts. Following Husserl detailed analyses in, for instance, *Thing and Space* or *Ideas 2*, our pre-scientific sense of lived space is constituted on several different levels which correspond to different kinesthetic systems. While the idea of pure homogeneous space is correlated with the limiting case of an observer at absolute rest, ocular movements add a quadridirectional widening of the visual field, which is again extended by cephalomotoric movements and finally by the capacity of locomotion (cf. Drummond 1983). Yet, what is true of all of these layers of constitution is that "we find ourselves to be centers of reference" (Husserl 1997, 2), and that, consequently, the very sense of spatiality must be understood in "reference to the spatial Ego-center as the relational center of all spatial orientations and all possible presentations" (Husserl 1997, 109). Yet, whereas the perspective of the embodied Ego, which always and necessarily functions as a center of orientation, is essential for the constitution of pre-scientific space, things are quite different with respect to the notion of space that underlies contemporary physics. Ever since the works of Albert Einstein and Hermann Minkowski, we are used to the ideas that space and time are, first, not conceived as separate and separable things but as one unified four-dimensional space, that, second, space-time is represented mathematically by a *manifold* and hence by a continuum of points labeled by four coordinates, and that, third, space-time is assumed to be homogeneous and isotropic, or—to put it more loosely—that in our scientific representations of space-time no particular location or direction ought to be picked out as somehow special. What this means is that, unlike in the case of pre-scientific space where the position occupied by the experiencing Ego always and necessarily stands out, there is no a priori reason why any particular point of the space-time manifold should enjoy a privileged status over any other.

In light of the earlier discussions about the roles of invariances in perception and physics, one could see in the transition from pre-scientific to scientific space(-time) yet another example of the methodologically regimented exclusion of everything subjective from the scientific description of reality: It may be true that the sense of pre-scientific space is essentially tied to the privileged position of the embodied Ego. Yet, one could argue that what makes the modern mathematization of space(-time) so successful is precisely the abandonment of this anthropomorphic assumption. According to Weyl, however, there is something utterly wrong about this view. The issue, in a nutshell, is this: Since, as mentioned earlier, no point of the space-time manifold is privileged over any other, we face a problem of identification whenever we seek to establish a link between the mathematical formalism on the one hand and the empirical data on the other. In order to carry out measurements, for instance, it is necessary to "single out conceptually a single arbitrary object *P* from the continuously extended domain of objects" (Weyl 1952, 9), and this can only be done by introducing a coordinate system. Now, while there are quite a few things about this act of implementation that are arbitrary—such as the choice of the particular type of coordinate system or the unit of measure—, the act itself is not. This, together with the fact that a point of origin is an essential feature of any kind of coordinate system, strongly suggests the following line of interpretation: Although the aim of a completely dehumanized depiction of the world indeed functions as an overarching telos and thus gives physics its normative direction, it is the unavoidable implementation of a coordinate system that will always reintroduce transcendental subjectivity into the purely symbolic representation of reality. This is because, from a

Weylean perspective, the origin of the coordinate system is the most formal representation of the physicist's lived body, her "zero-point of orientation" (Husserl 1989, 166); the axes of the coordinate system, on the other hand, represent the physicist's orientation in space. On this view, then, the perspectivity and subject-relativity of every symbolic representation of reality is not just an artifact of interpretation, it is indeed mandated by physics itself: Whenever we seek to establish a link between the mathematical formalism and reality, a coordinate system must be introduced. Yet, whenever a coordinate system is introduced, transcendental subjectivity seeps back into our purely symbolic representation of the world. This is what Weyl means when he refers to the "*coordinate system* […] *as the necessary residuum of the annihilation of the ego*". (Weyl 1949, 75; translation modified and emphasis added)

While there is no point in denying that "Weyl's expression here is surely mimicked on Husserl's" (Sieroka 2019, 113), one could still wonder where exactly the parallels lie. My view is that Weyl's analysis should not only be seen as a self-standing phenomenological take on the nature of mathematical representation in general and the coordinate system in particular, but also as a logical continuation of Husserl's original argument in section 49 of *Ideas 1*. As I have pointed out earlier, Husserl's annihilation of the world thought experiment is supposed to show that there is a certain sense in which the transcendental Ego can indeed be said to have primacy over the objective world: While we may imaginatively vary the objective pole of the intentional relation to a point where it loses any sense of structuredness and hence its status as a coherently experienceable world, not even the most chaotic stream of unrelated impressions could be imagined as anything other than the intentional object for some experiencing Ego. It is precisely in this way that Husserl utilizes the imagined scenario of the annihilation of the world to highlight the indispensability of transcendental consciousness for establishing any kind of intentional relation to any kind of transcendence. Now, although, on my view, Weyl seeks to make the same point, he does so in an almost inverse manner. Instead of annihilating the objective pole of the intentional relation by depriving it of all structuredness and coherence, Weyl considers physics as the most elaborate attempt to construct a representation of the world as it would appear if all traces of subjectivity were eliminated. This line of reasoning leads Weyl to the same conclusion Husserl had reached before him: In a similar sense in which a purely chaotic stream of experiences would still be chaos *for an Ego*, a purely dehumanized conception of the world remains incomplete and devoid of meaning unless it is animated by the "original constitutive act [of the] [i]mposition of a local coordinate system" (Ryckman 2003, 77).

Coming back to Weyl's phenomenological analysis of the coordinate system, there is one last aspect I would like to mention. Although there can be no doubt that section 49 of *Ideas 1* and hence the annihilation of the world thought experiment is the most obvious link between Husserl's transcendental phenomenology and Weyl's views on the nature of mathematical representation, it is interesting to note that there are also other possible sources of influence which, to the best of my knowledge, have so far been overlooked. Consider, for instance, the following passage:

> Each Ego [originarily] finds itself as the center, as the *origin of the coordinate system* so to speak [(it is the primordial coordinate system through which all coordinate systems receive their meaning)], from which the Ego perceives, classifies and identifies all worldly things, both identified or unidentified. Yet, each Ego finds this center as something relative; the Ego changes its position in space, for instance, and while it keeps uttering "here", it knows that "the Here" is actually somewhere else. Each Ego distinguishes objective space as a system of objective positions in space (places) from the phenomenon of space as the way in which space appears to me "here and there", "ahead and behind", "right and left". And the same regarding time. (Husserl 1973a, 116-17; my translation and emphasis added)

There are several things to say about this passage. To begin with, I take it to be beyond dispute that Husserl's point here connects with Weyl's remarks on the nature and origin of the coordinate system. For, according to Husserl as well, the origin of the coordinate system must be interpreted as the most formal representation of the Ego's embodied perspective which is, as we have seen, the necessary condition of the constitution of pre-scientific space. Yet, by referring to the Ego as “the primordial coordinate system through which all coordinate systems receive their meaning”, Husserl also hints at another issue that is brought into prominence mainly in his last major work, the *Crisis*: The success of modern mathematized science is intimately connected to the methodologically regimented application of idealities such as frictionless planes, point masses or rigid rods. As the late Husserl is at pains to show (cf., e.g., Wiltsche 2017, 2019, 352-56), however, the meaning of such idealities essentially depends on basic life-world experiences out of which these abstract objects are constructed in the first place. In order for the meaning of, say, a frictionless plane to be originally constituted, there must be a basic acquaintance with real surfaces and with technical procedures to make real surfaces flatter. Yet, what can be said about more obvious examples such as frictionless planes or point masses is no less true of coordinate systems. Their meaning also originates in the life-world of pre-scientific experience, namely in our most primordial acquaintance with the experience of taking up an embodied perspective through which the sense of spatiality and temporality is ultimately achieved.[7]

I come now to my concluding remarks. The aim of this chapter was to give the reader an idea of how the Husserlian mind had at least an indirect impact on contemporary physics by influencing the thinking of Hermann Weyl, one of the most prolific mathematicians and theoretical physicists of the 20th century. To be sure, space constraints prevent me from offering a more exhaustive treatment which would, for instance, include a discussion of the phenomenological background of one of Weyl’s signature accomplishments, his discovery of the gauge principle.[8] Nevertheless, I hope to have convincingly shown that investigations into the relation between Husserl and Weyl should not be viewed merely as a matter of exegetical interest. Although there are growing doubts about its philosophical significance, the analytic/continental-split continues to shape the face of professional philosophy. In many areas the reality is still that philosophers who associate themselves with one tradition tend to ignore the other. This state of mutual ignorance is particularly noticeable in philosophy of physics, where influences from outside the well-established canon of analytic philosophy are even scarcer than in other fields such as ethics or philosophy of mind. Now, when looking at his philosophical writings from a contemporary perspective, one can easily agree with the observation that Weyl “wrote more like a ‘continental’ than an ‘analytic’ about mathematics and science” (Ryckman 2012, 28). It is for this reason that the Weylean oeuvre—apart from being enormously valuable in itself—offers an intriguing glimpse of how a phenomenologically informed, anti-naturalistic and transcendental-idealistic alternative to the current mainstream in philosophy of physics could look like.

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[7] On a more historical note, it is also worth mentioning that the afore-quoted passage is taken from a lecture course entitled “Basic Problems of Phenomenology” which Husserl gave during the winter semester of 1910/11 and hence at a time when he and Weyl were still colleagues at the University of Göttingen. It is of course hard to decide with certainty whether Weyl was actually present during these lectures. However, given his newly sparked interest in phenomenology, and given the fact that the lecture course covers several topics that must have been of utmost interest to Weyl—Husserl discusses the reduction, intersubjectivity, the charge of solipsism, Evidenz, the ontology of nature, the constitution of space, and the relation between phenomenology and the physical sciences—, it may not seem entirely implausible to suppose that *Logical Investigations* and *Ideas 1* were by no means the only phenomenological sources of influence for Weyl’s views on the nature of mathematical representation. Highlighting less well-known textual sources also adds further ammunition against those commentators who typically downplay Husserl’s impact on Weyl’s philosophical thinking (cf., e.g., Bell 2004; Sieroka 2010; Toader 2013).

[8] This episode is told in a masterful way by Tom Ryckman (2005a). Cf., for a less technical summary, Ryckman 2005b.

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