



# Husserl's Theory of Scientific Explanation: A Bolzanian Inspired Unificationist Account

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## Abstract

Husserl's early picture of explanation in the sciences has never been completely provided. This lack represents an oversight, which we here redress. In contrast to currently accepted interpretations, we demonstrate that Husserl does not adhere to the much maligned deductive-nomological (DN) model of scientific explanation. Instead, via a close reading of early Husserlian texts, we reveal that he presents a unificationist account of scientific explanation. By doing so, we disclose that Husserl's philosophy of scientific explanation is no mere anachronism. It is, instead, tenable and relevant. We discuss how Husserl and other contemporary thinkers draw theoretical inspiration from the same source—namely, Bernard Bolzano. Husserl's theory of scientific explanation shares a common language and discusses the same themes as, for example, Phillip Kitcher and Kit Fine. To advance our novel reading, we discuss Husserl's investigations of grounding, inter-lawful explanation, intra-mathematical explanation, and scientific unification.

## 1 Introduction<sup>1</sup>

As any introductory textbook on the philosophy of science will mention, science does more than merely offer a collection of descriptive statements: it provides explanations. Accordingly, insight into the inner workings of science involves grasping how scientific explanations function. While serious ongoing debate concerning

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the nature of scientific explanation has been going on for at least the last seventy years in analytic philosophy of science, little rigorous discussion regarding scientific explanation has occurred in contemporary Husserlian scholarship.<sup>2</sup>

This is for two prominent reasons. First, studies of Husserl's philosophy of science have often focused on his later work, particularly *The Crisis of the European Sciences* (Hua VI/1970a—henceforth, *Crisis*) (see for example Gurwitsch, 1979; Heelan, 1987). More recent investigations focus on questions concerning whether Husserl is an instrumentalist or a scientific realist (Hardy, 2014, 2020; Wiltsche, 2012), only tangentially discussing scientific explanation. Discussions centered on the *Prolegomena* (Hua XVIII/1970b), on the other hand, tend to focus on the central themes of psychologism and pure logic. In adopting these foci, one can overlook the theory of explanation contained in Husserl's early works.

Second, even in those cases when Husserl's views on scientific explanation are briefly discussed, an inaccurate interpretation is often put forward; certain scholars are led to the plausible conclusion that Husserl subscribes to something like the deductive-nomological (DN) model (Hardy, 2014, p. 29). Because the DN model is now widely rejected due to a variety of fatal objections, Husserl's theory of scientific explanation might be taken to be a mere anachronism with no valuable contribution to make contemporarily.

In contrast to that train of thought, this essay focuses on Husserl's early works to reveal that he does not accept a standard DN model of explanation, but instead adopts a sophisticated version of it; what will later be called a unificationist account of scientific explanation. Unificationists, such as Husserl, Bolzano, Friedman, and Kitcher, subscribe to the thesis that the local structure of explanation is indeed deductive, but that, globally, explanatory systems must exhibit patterns of unification.

We develop our original interpretation by drawing extensively from the *Prolegomena*, *Logical Investigations* (Hua XIX/1970b) and *Logic and General Theory of Science* (Hua XXX/2019).<sup>3</sup> Our discussion of these texts demonstrates that Husserl's theory of scientific explanation not only avoids the pitfalls of the classical DN model, as it is much more sophisticated than has yet been recognized. Rather, we also show that Husserl's account can contribute to the debates in the philosophy of science today, because it presents a coherent and innovative picture of explanation. As we reveal, Husserl is particularly well poised to contribute to ongoing discussions, because he and many contemporary scholars, such as Philip Kitcher and Kit Fine, have developed their theories by working from the insights of Bernard Bolzano.<sup>4</sup> Germane themes for contemporary audiences which emerge from this shared heritage include discussions of grounding, intra-mathematical explanation,

<sup>2</sup> We focus in this essay on the type of explanation offered by non-human sciences. For discussions on Husserl's account of psychological explanation, see Williams (2020a, 2020b).

<sup>3</sup> Hua XXX/Husserl (2019) presents an elaboration of many of the ideas found in the *Prolegomena*.

<sup>4</sup> In the Husserlian literature, it is well known that Bolzano had a significant impact on Husserl's theory of science and logic. For example, see Casari, 2017; Rollinger, 1999, 69–82; Sebestik, 2003, 64–80.

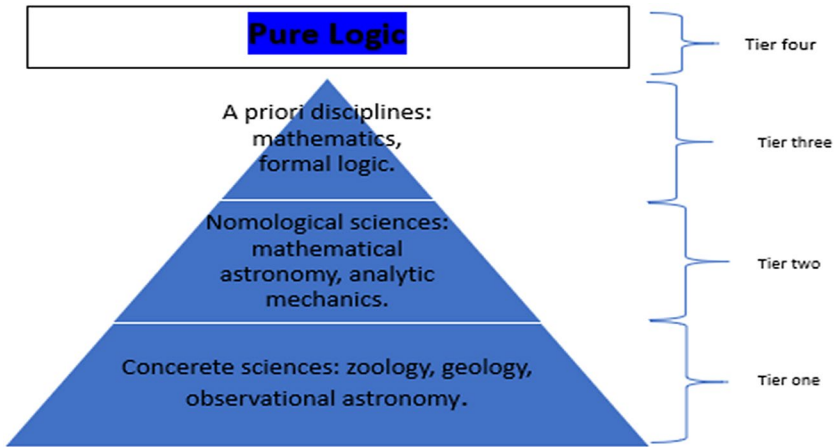


Fig. 1 The hierarchical structure of science

and unification and, on these topics, we thus seek to add explanation to the list of items that Husserl studies makes substantial contributions to.

Our paper is divided, very broadly, into three sections. First, in section two, we discuss Husserl’s understanding of the local DN structure of explanations; a relation that is established initially between propositions contained in the nomological and concrete sciences. Section three discusses explanation within the a priori sciences such as mathematics. Our final section elaborates Husserl’s understanding of the global instantiation of explanatory unification. More details on the exact contents are provided at the outset of each section. Understanding Husserl’s theory of scientific explanation is predicated on some knowledge of certain themes within his philosophy of science. And so, it is with a broad overview of Husserl’s philosophy of science that we begin in section two.

## 2 Explanations Within the Concrete and Nomological Sciences

Husserl’s theory of scientific explanation emerges from his understanding of the structure of the scientific field. Simply stated, Husserl concludes that there are four hierarchically structured and interrelated tiers or strata to the scientific field. As a general sketch, the different tiers of science can be charted as follows (Fig. 1):

For the remainder of section two, we investigate the relationship between tiers one and two from our chart. In section three, we outline Husserl’s portrayal of the third tier. Accordingly, section two and section three together cover what we will call “standard” science.<sup>5</sup>

<sup>5</sup> For clarity and brevity, we do not discuss the fourth tier—the theory of science as realized by a pure logic—in this essay. See Fiset (2003).

Regarding the precise details of the contents of Sect. 2, during our discussion in Sect. 2.1 of Husserl's understanding of the relationship between tier one and two, we introduce the topic of *unity* and provide an initial account of Husserl's understanding of the explanatory function of the sciences. We also show that, locally at least, Husserl is certainly operating with a DN theory of explanation, but a DN theory that uniquely emphasizes a hierarchical interrelation between first and second-tier sciences. In Sect. 2.2, we introduce the topic of *ground* (*Grund*), which is central to Husserl's account of scientific explanation. Finally, in Sect. 2.3, we provide an example of Husserl's system of explanation in action. To close section two, we observe that Husserl—over 100 years ago—foresaw that the natural laws which frequently feature in DN explanations are mathematically idealized.

## 2.1 Explanation and Unity of Science

Two of the more important concepts of Husserl's discussion of science in the *Prolegomena* are “unity” and “explanation.” Regarding unity, a foundational tenet of Husserl's analysis is that science is not a chaotic amalgamation of random facts. Instead, sciences are organized and unified sets of propositions that possess systematic unity (Hua XVIII, pp. 30–31/1970b, 18). These propositions are expressively spoken in lectures or written in articles by scientists. One notable feature of these sets of propositions is that they must form a coherent body, such that they can be recognized as individual sciences distinguishable from each other (Hua XVIII, pp. 22–23/1970b, 13) and from pseudoscience (Hua XVIII, p. 39/1970b, 24).

We begin to clarify Husserl's insights about unity, by noting that his philosophy of science—as it is presented in the *Prolegomena*—seeks to clarify how *many* propositions can be organized to form *one* unified science (Hua XVIII, pp. 230–238/1970b, 144–47). Importantly, Husserl claims that sciences are differently organized depending upon tier. The goal of those sciences found on the first tier, that is, the concrete sciences, is “the description of individual and typical individuations of earthly and heavenly existence” (Hua XXX, p. 338/2019, 356). Regarding unity, these concrete sciences are organized around specific sets of phenomena, which are taken as belonging together. Zoology studies the objects that belong together as animals, geography investigates states of affairs that concern the structure and substance of the physical earth, and so on (Hua XXX, p. 338/2019, 356; Hua XVIII, pp. 237/1970b, 148). In contrast, the second tier of the science—which Husserl refers to variously as the “abstract,” “nomological,” or “explanatory” sciences (Hua XVIII pp. 237–238/1970a, 147–148)—are sets of laws, which are organized according to the unification provided by the structure of the web of scientific explanation (this unification is discussed more in section four).

Regarding the second important concept, that is, explanation, it is evident that in the *Prolegomena*, Husserl thinks that the propositions of the concrete sciences require the propositions of the nomological sciences to carry out the essential scientific function of providing explanations.

Explanations, for Husserl, are a form of deductive argument,<sup>6</sup> which minimally has three parts: two premises and one conclusion. The prototype of a deductive argument (even an unexplanatory one) involves a major or universal premise (the example which introductory logic books used to provide is “all men are mortal”) and a minor, existential premise (“Socrates is a man”), and a conclusion which follows deductively from these two premises.

For Husserl, for the relevant kinds of explanation, the laws of the nomological sciences serve as the major premise. One then assumes certain “presupposed” or “pertinent circumstances” (Hua XVIII, p. 234/1970b, 146) as antecedent conditions that serve as the minor premise. This is, of course, a standard account of “what scientific explanation amounts to” (Hardy, 2014, 17), according at least to the DN model as it was first articulated by Hempel and Oppenheim (1948). As the latter put it, any “explanans falls into two subclasses; one of these contains certain sentences ... which state specific antecedent conditions,” that is, Husserl’s presupposed or pertinent circumstances, “the other is a set of sentences ... which represent general laws” (Hempel & Oppenheim, 1948, 137). Husserl’s thesis is that the contingent facts of the concrete sciences can be explained when they can be deduced as a consequence of a deductive argument, where these two subclasses of explanantia serve as premises (Hua XVIII, p. 234/1970b, 146).

A unique aspect of Husserl’s theory of explanation is his understanding of the relationship between the hierarchy of the sciences. He concludes that first-tier sciences offer the explanandum whilst second-tier sciences provide the key explanantia: laws. Otherwise stated, the nomological sciences of the second tier articulate laws, which explain the facts about the things that are the subject matter of the descriptions of the concrete sciences. Husserl writes that every natural empirical thing, or “every individual-concrete thing falls under what is universal, and the universality everywhere leads to conformity to laws” (Hua XXX, p. 337/2019, 355). This allows us, in science, to aim “ultimately to bring the particular under the law-concepts of what are called the abstract sciences precisely for purposes of explanation” (Hua XXX, p. 338/2019, 356).

Even though it is the abstract sciences that articulate the laws that feature in DN explanations, Husserl concludes that the concrete sciences carry out the type of pertinent explanations by “borrowing” those laws and applying them. He writes:

Concrete sciences like geology, mineralogy, and so on, first aim at the description of individual and typical individuations of earthly and heavenly existence. *In them [the concrete sciences]*, however, the goal is ultimately to bring the particular under the law-concepts of what are called the abstract sciences precisely for purposes of explanation. (Hua XXX, p. 338/2019, 356, emphasis ours)

Each concrete science “corresponds” with certain nomological disciplines that provide the requisite resources to explain the facts about its field. For example, concrete

<sup>6</sup> “[E]xplanatory theory” is, for Husserl, “*deductively explanatory*” (2019, 355). He claims, in “the explanatory sciences, deducing ... plays a leading role” (2019, 272).

biological sciences, such as zoology or botany can borrow the lawful resources from the corresponding nomological disciplines of biochemistry, cell theory, or genetics. The empirical or concrete sciences thus “set themselves the goal of not only describing concrete individuations of a field, let us say of some natural sphere, but of explaining them as necessarily being so through subsumption under the laws of a corresponding nomological discipline” (Hua XXX, p. 256/2019, 255). Tier one concrete sciences “reach up” to a corresponding discipline above them in tier two and use the nomological resources they find there to explain the facts they have described.

## 2.2 Grounding as Explaining

As stated, Husserl believes that sciences explain and more specifically, that the laws of the nomological sciences explain the facts of the concrete sciences. Yet, by simply stating that the former explains the latter, Husserl has by no means clarified the explanatory function of science. He must respond to the question; how exactly do those laws explain concrete facts? Husserl begins to develop his answer by asserting that the laws, which play the role of the major premise in a DN explanation, can explain by serving as *ground* (*Grund*). He writes, “To see a state of affairs as a matter of law ... and to have knowledge of the ground [*Grund*] of the state of affairs or of its truth ... are equivalent expressions” (Hua XVIII, p. 233–234/1970b, 146).<sup>7</sup> Husserl claims that science is made possible due to lawful grounding explanations (Hua XVIII, p. 256/1970b, 160). He even goes so far to write that “each actual advance in science is performed in an act of grounding [*Begründung*]” (Hua XVIII, p. 39/1970b, 24; translation modified).<sup>8</sup>

In the *Prolegomena*, Husserl’s thinking around grounding is influenced by Bernard Bolzano’s use of the term *Abfolge* (“grounding”<sup>9</sup> or “consecutivity”<sup>10</sup>) in his *Wissenschaftslehre* (1972).<sup>11</sup> As Stefan Roski elucidates, Bolzano thinks of ground

as an explanatory consequence relation. Bolzano takes grounding to be a sense of “following from”—a relation that obtains between premises and conclusions of certain proofs or arguments ... However, if some proposition follows from another one in this sense, then the latter does not only guarantee the truth

<sup>7</sup> Concerning Husserl’s theory of grounding and evidence, see Plotka 2019.

<sup>8</sup> When reading the *Prolegomena*, English speaking audiences may wish to make note of the fact that Findlay often translates *Begründung* as “validations.”

<sup>9</sup> Roski’s (2017) translation of *Abfolge*.

<sup>10</sup> Centrone’s (2010) translation of *Abfolge*.

<sup>11</sup> The concept of “ground” was key to Bolzano’s work and he is the premier theorist on the nature of grounding some 150 years before the concept was revived in the context of the contemporary theory of explanation. See Correia & Schnieder (2012). A detailed discussion of Husserl’s indebtedness to Bolzano on the concept of “ground” can be found in Centrone (2010).

of the former, it also accounts for why it is true: grounding under lies proofs that are not merely valid, but also explanatory. (Roski, 2017, 2)<sup>12</sup>

Husserl too thinks that deductive entailment is necessary, yet insufficient to establish grounds:

every explanatory [*erklärende*] interconnection is a deductive one, but not every deductive interconnection is an explanatory one. All grounds [*Gründe*] are premises, but not all premises are grounds. Every deduction is necessary, i.e., falls under laws, but the fact that the conclusions follow according to laws (inferential laws) does not mean that they follow from those laws and are “founded” [*“gründen”*] in them in the precise sense. (HUA XVIII, p. 235/1970b, 147, translation modified)

Accordingly, for Husserl, an explanation is a type of deductive argument, where the conclusion follows not merely because it is valid according to one of the laws of inference, but also because the conclusion is grounded in one of the premises; that is, when at least one such premise, which features as a constituent of the actual argument itself and ergo leads deductively to the conclusion, is a law. As we shall see in Sect. 4 below, Husserl also accepts Bolzano’s thesis that the explanatory function of ground arises due to the unification provided by the global structure of the scientific field.

It is worth noting that the concept of “ground” has garnered much attention in the recent literature on explanation (see for example the collection in Correia & Schnieder, 2012; an overview in Raven, 2015). In this contemporary scholarship, it is generally thought that “ground” is a relation which obtains when one phenomenon is built out of, or one fact holds in virtue of, another. It is an asymmetric, irreflexive, transitive, and non-monotonic relation, which establishes an order amongst facts (Raven, 2015).<sup>13</sup> Moreover, ground is currently taken to be both a *semantic* relation that holds amongst facts or propositions and a “metaphysical”<sup>14</sup> relation that holds amongst real things in the world. Ground “is metaphysical because it concerns the phenomena in the world itself, but also explanatory because it concerns how some phenomena hold in virtue of others” (Raven, 2015, 325). Similarly, Husserl’s use of the term “ground” reflects an inseparable a priori correlation between

<sup>12</sup> While we will continue to develop this idea throughout the paper, it is important to now initially outline Bolzano’s account of scientific explanation. Bolzano concludes that in any scientific context, one cannot be satisfied with a simple truth, but must require explanations of facts. He more specifically describes these scientific explanations, by stating that they do not appeal to the epistemic reasons for believing something, but rather concern the reasons why a proposition is true. In other words, for Bolzano, explanations answer so-called “explanation-seeking why questions.” Furthermore, Bolzano claims that this notion of explanation is prior to the division between causal and non-causal relationships, such that it applies equally well to both (Bolzano, 1972; see Roski, 2017: 8). On that basis, Bolzano claims that non-causal/mathematical facts of the formal sciences and causal/empirical facts of the empirical sciences must be accounted for via such explanations.

<sup>13</sup> This ordering amongst facts is further elucidated in Sect. 4 below.

<sup>14</sup> The term “metaphysical” is here being used in the contemporary analytic sense, that is, as concerned with the fundamental structure of the world. It should not be thought of as Husserl often understood the term, that is, in the context of the debate over idealism vs naturalism.

the “*interconnection of the things* to which our thought-experiences (actual or possible) are intentionally directed, [and] an *interconnection of truths*” (Hua XVIII, p. 230/1970b, 144).

### 2.3 An Example and a Discussion

Readers may be uncertain as to exactly how it is, for Husserl, laws are supposed to explain the facts of descriptive science. Before proceeding, it is critical to provide one clear example—one that Husserl himself suggests. Proceeding from this example, we will observe that an unavoidable problem with DN explanations within natural science is that of forming precisely deductive arguments utilizing laws which are established inductively and thus hold only probabilistically. In closing our discussion of section two, we provide Husserl’s thinking on this problem.

Husserl provides some examples of nomological sciences, which can explain certain facts that have been gathered by concrete sciences. He states, for example, that “mathematical astronomy,” which belongs to the second tier of science, can provide the explanatory theory “for the facts of gravitation” as gathered from a tier one science, observational astronomy (Hua XVIII, p. 234/1970b, 147). What Husserl is here calling “mathematical astronomy” is a theory, that is, an organized series of nomological propositions. Examples of such propositions would be Newton’s law of universal gravitation and his laws of motion. One can apply these laws to *explain* certain empirical facts concerning the behavior of heavenly bodies under the effects of gravitation gathered from the field of observational astronomy, i.e., the elliptical orbit of Mercury. This means that the propositions, which express universal gravitation and the laws of motion, subsume and thus explain the proposition, which is expressed as the fact that Mercury exhibits an elliptical orbit (when arranged in a deductive argument).<sup>15</sup>

What Husserl states is that if “the interconnection of one fact with others is one of law, then its *existence* ... is determined as a *necessary existence*” (Hua XVIII, p. 234/1970b, 146, italics modified). What he means by this is that, *given* the laws of gravitation and motion (and other presupposed circumstances, such as Mercury’s spatial relation to the sun, etc.), Mercury could not but orbit elliptically.

Husserl emphasizes throughout this analysis that the second tier (the theoretical disciplines) borrow resources from mathematics and express their propositions in mathematical formulae (such as the formula for universal gravitation). For Husserl, this mathematization affords the essential ingredient of deduction. He writes:

Every science that is explanatory, in the strict sense, is ‘mathematical.’ Its explanations proceed deductively from principles that necessarily have deductive form; and the whole deductive system of theorization must be mathematical, and allow itself to be arranged according to its pure mathematical form. (Husserl & Stein, 2018, 460)

<sup>15</sup> Readers unfamiliar with this example can consult footnote 18.



We gather from this quote that, for Husserl, deduction follows from the precise extension that mathematical concepts afford. However, Husserl also recognizes that stating *natural* laws in a mathematically precise fashion is problematic. The laws of nature are imperfect.<sup>16</sup> These laws, such as the “law of gravitation, as formulated in astronomy, have never really been proven,” in the sense in which a mathematical fact can be given a deductive proof. Natural laws can be rendered at best empirically adequate. They are contingent on *ceteris paribus* clauses, only (highly) probably true, and falsifiable (HUA XVIII, p. 83/1970b, 52–53).<sup>17</sup> Husserl thus identifies many of the problems with the laws of nature that will later be recognized and addressed by Hempel (1988) and Cartwright (1983).

Furthermore, Husserl here presciently highlights that, scientists *idealize* natural laws in order to impart the necessary (yet insufficient) explanatory quality of deductive entailment. Thus, natural laws (such as the law that gravitational force varies in proportion to an inverse square) are, according to Husserl, “no more than idealizing fictions” (Hua XVIII, p. 82/1970b, 52). We reach “the ideal of explanatory theory, of law-governed unity” when we reduce these probabilities to “exact thoughts having the genuine form of laws, and so succeed in building up formally perfect systems of explanatory theory” (Hua XVIII, pp. 82–84/1970b, 52–53; see Byrne & Kattumana, 2022).

Although we will avoid comparing this account of idealization with the one found in the *Crisis* (Hua VI/1970a), we conclude that the early Husserl’s “scientific fictionalism” (according to which certain scientific propositions are merely helpful fictions) applies to natural laws but not to *the referents* of those laws (entities that exist in the real spatiotemporal world). For the early Husserl, scientific idealization is an *explanatory* practice, one related to semantically evaluable entities (i.e., the propositions that express laws).

This conclusion about the early Husserl is commensurate with Hardy’s (2020) analysis of idealization in the *Crisis* (Hua VI/1970a). However, Hardy advances a bi-level analysis that splits laws from theories and equates the latter to a causal account that explains how laws work. Although Hardy never goes as far as to say that *Husserl* endorses this bi-level division, he seems to elide the fact that in Husserl (at least in the *Prolegomena* and *Husserliana XXX*) theories are just organized bodies of laws,<sup>18</sup> and theorization is just the process of drawing deductive conclusions from those laws. And, although Hardy is not directly discussing Husserl’s theory of explanation, the above quotes reveal Husserl is clear in the *Prolegomena* that *it is laws that do the explaining*, not the causal account of those laws, and so Husserl

<sup>16</sup> This fact becomes even clearer, when we compare these laws to the laws developed via the *third-tier* sciences, which are discussed in Sect. 3.1 below. Concerning Husserl’s account of the “discovery” of the recursive mathematical system, see Byrne 2017a, b.

<sup>17</sup> Husserl writes, “Our knowledge up to date serves to found a probability of the highest theoretical dignity to the effect that, in so far as experience yields to the instruments on hand, either Newton’s law, or one of the endlessly many conceivable mathematical laws whose differences from Newton’s law lie within the limits of unavoidable experimental error is true” (1970b, 52).

<sup>18</sup> This definition is operant when Husserl writes: “In all domains of nature, [the understanding] unveils the inviolable system of laws *that we call the theory* of the particular field” (2019, 3, our italics).

does not support the bi-level analysis that Hardy operates with. Thus, where we diverge from Hardy is in explicitly noting that for Husserl, explanation and causality are not coextensive. There are explanatory disciplines in tier three of the sciences that fit the model of explanation we have outlined which have no causal content whatsoever (see Sect. 3.2).

## 2.4 Three Kinds of Explanation

To more accurately develop our interpretation of Husserl's theory of scientific explanation, in this section, we expound on Husserl's conclusion that there are *three* different kinds of explanations to be found *within the first two tiers* of science.

There is the already discussed explanation of “singular facts through general laws” (Hua XIX, p. 26/1970b, 178). Husserl, however, does not believe that singular facts are the only kind of facts that can be explained. Instead, he notes that there is a distinction between singular facts and general facts: “individual and general truths” (Hua XVIII, p. 233/1970b, 146). The second kind of grounding is the explanation of a general truth. This occurs when “we are referred to certain general laws which, by way of ... deductive consequence yield the [universal] proposition to be proven” (Hua XVIII, p. 233/1970b, 146). Simply stated, laws explain two types of facts: individual ones (“this starling was aggressive because...”) and general ones (“all starlings tend to flock because...”).

Third, Husserl concludes that not only *facts* may be explained. Rather, he observes that certain *laws* can be explained by other *more general* laws; as he calls them, more “basic” or “fundamental” laws (“*Grundgesetze*”). We can call this “inter-lawful” explanation. Husserl clearly endorses the notion of inter-lawful explanation, writing that the word “explanation”

has a twofold meaning if on one occasion one speaks of explanation with regard to what is concrete and its subsumption under the concepts of the abstract sciences, and on the other hand, says in the abstract sciences themselves within the context of the theory that through subsumption of the particular laws under the basic laws, the former receive their explanation. (Husserl, 2019, 357)

Accordingly, *within* nomological science, there are the explanations of “general laws through some fundamental law” (Hua XIX, p. 26/1970b, 178). One might think of how “for example, *Kepler's Laws* receive their explanation from the basic law of universal gravitation and the basic laws of mechanics” (Husserl XXX, p. 311/2019, 357).<sup>19</sup> In other words, it is not *only* the facts concerning the orbit of this or that

<sup>19</sup> We have chosen this example because it is one that Husserl suggests, and because it is a well-accepted example of explanation by inter-law subsumption from within the history of the philosophy of science. We unfortunately cannot provide the full lengthy proof here. However, the whole proof can be found in most introductions to classical mechanics pitched at the university level, such as Taylor (2005, pp. 91–92 & 112–113). Moreover, we feel that the basic idea that the laws of motion and gravitation explain the lawful orbital behavior of planets is intuitive enough.

planet on this or that occasion which Newton's theories explain. Rather, Newton's theories *also* explain the less fundamental Keplerian laws concerning the orbital behavior of *all* celestial bodies. We are thus, Husserl writes, "led upward in the hierarchical structure of the law-governed dependencies to the basic laws upon which all full, ultimate explanation is based" (Hua XXX, p. 244/2019, 257).

However, we should point out that, even with inter-lawful explanation, wherein we have departed from the activity of explaining concrete facts (either individual or general ones), the inter-lawful explanation just discussed still occurs within "the realm of natural laws" (Hua XIX, p. 26/1970b, 178). We are talking, therefore, about the explanation of one natural law by reference to another natural law. The explanation of a general law through a basic or fundamental law occurs *within* the second tier of science.

One way to put the point here is that, *within* this second tier—that is, the realm of natural laws—even basic or fundamental laws (ones we find up towards the "top" of the explanatory hierarchy) are impure, that is, empirical. For example, *gravitation* is an empirical phenomenon; one which occurs in the empirical world. Thus, when we explain Kepler's laws via the employment of the basic law of *gravitation*, the basic law of gravitation still has empirical content (such as the gravitational constant). Though basic natural laws may be *mathematized*, they are impure because they employ empirical concepts.

## 2.5 Explanation within A Priori Sciences

We move on now to an investigation of explanations within the third tier of regular science. The third-tier sciences are the a priori disciplines that—in *Ideas I*—Husserl refers to as the pure eidetic sciences, such as pure mathematics (Hua III-1, p. 21/1986, 16). On the one hand, explanation within a priori science mirrors explanation within natural science. The a priori sciences *are* in fact also nomological—in that they involve laws—and their explanations have the same DN form as already discussed. On the other hand, the explanations of these two tiers are distinct, because their major premises, though both laws, are of different natures.

In second-tier nomological sciences, *natural laws* serve as the major premise. When stated unconditionally, these natural laws are merely convenient fictions. In contrast, within a priori sciences, *axioms* serve as the major premise. Husserl writes:

*Theoretical explanation* means... [in] the realm of the *a priori*... to understand the *necessity* of specific, lower-level relationships in terms of comprehensive general necessities, and ultimately in terms of those most primitive, universal relational *laws* that we call axioms. (Hua XIX, p. 25/1970b, 178).

Axioms are fundamentally distinct from natural laws in two ways. First, they are "given" and established quite differently. Axiomatic laws are not established inductively, and it is impossible to think that they could be revised. Instead, axioms "must be able to come to givenness in directly evident insights, while the

opposite holds for factual laws” (Hua XXX, p. 247/2019, 261). Unlike the laws of the natural theoretical sciences, these axiomatic laws have “entire validity: they themselves in their absolute exactness are evident and proven” (Hua XVIII, p. 83/1970b, 53). For Husserl, the exact definition of a law is a proposition that holds with absolute unconditional universal necessity, such that—strictly considered—only pure laws qualify (Hua XXX, p. 221/2019, 234).

Second, while the deductive process of explanation is potentially *regressive* within natural science, such that more primitive laws can often be requested to explain *an explanans*, axioms “are the primitives or starting points in the order of justification” (Smith, 1989, 279). As we show below, it is a mistake to ask for further deductive explanation of a fundamental axiom. Explanation is not an *infinitely* regressive or recursive procedure for Husserl. For him, finding and referring to axioms is to hit explanatory bottom. Axioms are the ultimate grounds, that is, ungrounded explanantia.

To clarify what it means for axioms to be the initial point of justification, we discuss the example, where someone seeks an explanation for the theorem that “there is no even prime number greater than two.” We can offer a deductive and explanatory proof for this mathematical fact, which relies in part on the *axiom* that “even numbers are divisible by two.”

- (1) Prime numbers are divisible only by themselves and one (axiom).
- (2) Even numbers are divisible by two (axiom).
- (3) Any even number greater than two is divisible by two (inference from 2).
- (4) Any even number greater than two is divisible by a number other than itself and one (inference from 3).

Conclusion: Any even number greater than two is not prime (deduction from 1 + 4) (example adapted from Colyvan [2012, 91]).

Here, the explanandum follows deductively as conclusion, and the axiomatic premises serve as grounds that explain that conclusion.

Premise two is axiomatic because there is no similar form of deductive argument involving simpler axioms where this is the conclusion. Being divisible by two is part of the *definition* of an even number. There is *nothing* more basic that could be done to *deductively prove* that the concepts “even number” and “divisible by two” are equivalent<sup>20</sup> (the most one could do is to *explicate the concepts* of “even,” “number,” “two,” and so on. See Hua XVIII, pp. 241–244/1970b, 152–54). The axiom itself serves as a primitive starting point from which one can only move forward in the order of justification.

<sup>20</sup> One might employ a “brute force” approach of sequentially dividing every even number by two ad infinitum, but this is a non-deductive and therefore different sense of “proof” than we mean, and one that is canonically unexplanatory. See Byrne 2017a.

## 2.6 Non-Causal Explanation within A Priori Sciences

Husserl asserts in the *Prolegomena* that there is a strict separation between the sphere of the ideal and a priori, on the one hand, and the concrete and the empirical, on the other hand. The realm of the a priori is ideal, not *reale* or *reelle* being. In line with this, the pure and ideal explanatory axioms “exclude all factual content” (Hua XVIII, p. 83/1970b, 52). Because pure axioms are non-factual, they are non-causal, as “real” causality<sup>21</sup> is only to be found amongst the actual, that is, factual empirical world. This insight is inspired by Bolzano, who writes that mathematical explanations “exclude, therefore, causal content. Thus, mathematical truths can be related as ground and consequence, although they do not deal with objects that have reality” (Bolzano, 1972, 273).<sup>22</sup> While the axiom that all even numbers are divisible by two certainly explains why there is no even prime greater than two, the axiom does not *cause* the fact. For Husserl, explanations cover non-causal relationships. In the a priori and the empirical, explanation is established when the consequence is grounded in law, causal or otherwise.

When Husserl discusses explanation within tier three science, he has in mind what has come to be referred to as intra-mathematical explanation (that is, the explanation of one mathematical fact by another). In discussing intra-mathematical explanation, Husserl is again presciently providing an account of an area that has only recently assumed great importance for the theory of explanation (Lange, 2016; Mancosu, 2008). The Bolzanian/Husserlian thesis that intra-mathematical explanations are underwritten by grounding relationships is a unique one worthy of further research.

In summary, the explanatory relation can be found a total of *four* times within the hierarchy of the three tiers of regular science. Each of the four explanatory relations is represented by an arrow below (Fig. 2):

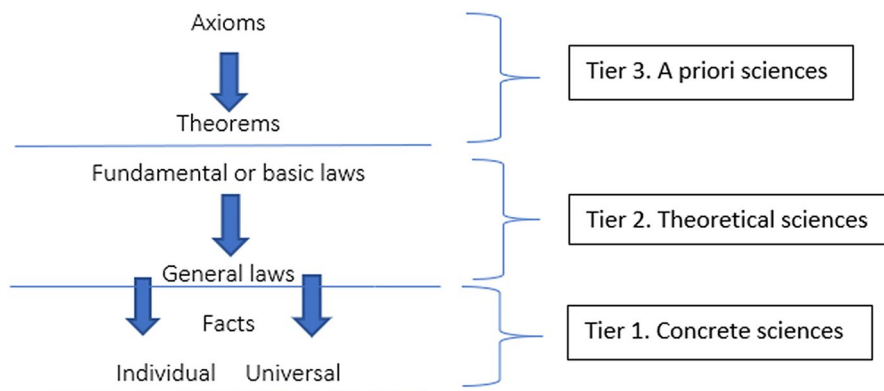
## 3 On Unification

Husserl’s three-tiered hierarchical theory of standard science correctly accounts for many aspects of scientific explanation. Yet, to understand the true value of Husserl’s theory, it is important to address a possible objection.<sup>23</sup> By presenting and belying

<sup>21</sup> We here distinguish “real” from “motivational” causality, see Sect. 56 of Hua IV, Byrne (2020), and Williams (2019; 2020b).

<sup>22</sup> A separate but related point is noted by Spinneli (2021) when he observes that grounding is a relation that pertains between propositions and is thus “causally inert” (17). This may be the case, but the objects that those propositions refer to may have causal properties from whence the explanatory force of the grounding relation derives. Our (and Bolzano’s) point here is that some objects referred to by propositions that instantiate grounding relations lack causal properties altogether, and so grounding explanations are not causal explanations.

<sup>23</sup> In this essay, we obviously cannot address all potential objections. One problem that Husserl does not discuss is whether—within natural science—mathematical concepts are genuinely explanatory or mere instruments. Contemporary discussion of this topic can be found in Baker (2005). We think Husserl’s position could perhaps be determined from a close reading of the *Crisis* (1970a), as is the task of our future research project.



**Fig. 2** The explanatory relation

this criticism, we can reveal crucial details regarding Husserl's position on scientific explanation. Specifically, the relevant criticism stems from the plausible thesis that Husserl subscribes to the standard DN model of scientific explanation. However, *if* Husserl did subscribe to this model, it would be quite problematic, because the Hempelian version of the DN model is now widely rejected due to a variety of objections, such as those outlined by Salmon (1984). The DN model—as presented in standard introductory texts on the philosophy of science—serves as the *foil*, the thesis which contemporary accounts seek to overcome (see for example Godfrey-Smith, 2009).

One attempt to overcome the shortfalls of the DN model by modifying it is the unificationist account of scientific explanation. The unificationist account does not deny the DN model but augments it, with the goal of meeting the challenges that have been put to it. In other words, the unificationist theory is an improved and more sophisticated *species* of the DN model. On the one hand, unificationists accept the DN thesis that, *locally* explanations have a DN structure. On the other hand, they add that, *globally* explanatory systems must exhibit patterns of unification.

In this final section of the essay, *we disclose that Husserl is not an adherent to the classical DN model, but instead subscribes to the unificationist version of the DN theory.* To prove this point, we return to the question that opened the paper: what, according to Husserl, provides science with unity? In following through this study of Husserl, we show that his account of explanation bears, again, similarities to the theory of explanation articulated by Bolzano (1972).<sup>24</sup> Of further note is that Bolzano's key insights have recently found support in the works of contemporary unificationists such as Friedman (1974), Kitcher (1989), and Kim (1994). We finish this essay by tracing the connection, thus far only hinted at, between explanation, unification, and grounding. In the final subsection (4.7), we show how Husserl's

<sup>24</sup> In addition to Bolzano, Husserl's development of the unificationist version of the DN theory was heavily influenced by insights of the mathematician David Hilbert. Concerning this relationship, see da Silva, 2016; Hartimo, 2017, 248–253.

unificationist account might handle the most pressing objection to the DN model—the problem of asymmetry.

### 3.1 Rudimentary Concepts

We begin our study of unificatory systems by laying out some fundamental concepts. First, there is the simple concept of *order*. This concept applies to items that occupy a position before and after one another. The concept of order is instantiated by, for example, the items that we call the cardinal numbers:

$$3, 2, 1$$

One can combine the concept of order with the concept of *groupings* or *sets*, yielding order amongst sets:

$$\{3, 3, 3\}, \{2, 2, 2\}, \{1, 1, 1\}$$

Moreover, there can be relations amongst the constituents of the sets, which determine the sequence or place in the order. One example of an ordering relation would be “greater than.” The diagram below represents an ordering of sets of items according to whether the constituents of one set are greater than the constituents of another:

$$\{3, 3, 3\} \quad R > \quad \{2, 2, 2\} \quad R > \quad \{1, 1, 1\}$$

We might call this a very basic *system*, one composed of ordered sets and relations. (For ease of visualization in what follows, we turn this model from a horizontal to a vertical display) (Fig. 3):

Building on the rudimentary concepts of order, set, relation, and system, we introduce the idea of a *reducing system*. In such a system, at each next step, the number of members of the sets decrease. (For clarity, in the following diagram, we replace the numbers with variables) (Fig. 4):

In Fig. 3, the place of each set in the order was determined by the “greater than” relation. In Fig. 4, there is an as-yet-unspecified relation which determines *both* the place of each set in the order *and* the reduction in the number of members of the sets. A system where the reduction in number of constituents and each sets place in the order is determined by the relation between them, such that *a smaller or reducing number of units always populate sets which come later in the progression of order*, is the basic model of a *unifying system*, so called because of the pyramidal, reducing pattern clearly recognisable in Fig. 4. The guiding insight or thesis of unificationist theories of explanation is that, globally, *explanatory systems exhibit this unifying pattern*.<sup>25</sup>

<sup>25</sup> We have displayed diagram 4 *vertically* to suggest a likeness with the pyramidal structure of sciences provided at the outset of this essay in Fig. 1. More elucidation of this basic structural picture follows below.

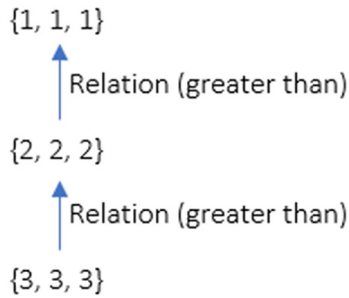


Fig. 3 Ordered sets

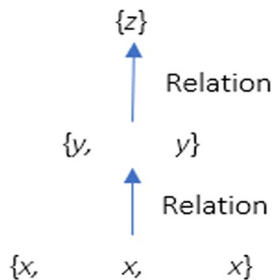


Fig. 4 A unificatory system

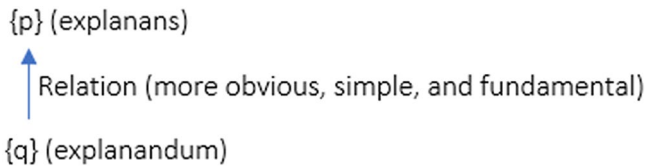
### 3.2 The Complex to the Simple

To reveal why an *explanatory* system exhibits this pattern, we begin by pointing out that explanations answer questions. An answer succeeds in accomplishing this goal when it provides us with an *understanding* of the topic of the question; the explanandum. Thus, one way to account for an apparent *ordering* of explanatory systems is to point out that the answer must be less in need of explanation than the question. If we provide a proposition as explanans that is less comprehensible than the explanandum, then our explanation has failed, because it does not allow for deeper understanding, but has rather caused more confusion. As Schurz puts it, “it is reasonable to argue that one cannot *understand something* (P) by means of some other thing (Prem) which one *has not understood*” (1999, 98).

Accordingly, this requirement for an explanatory science—to provide deeper understanding—establishes an essential ordering to the propositions comprising that science. A unique feature of both Husserl’s and Bolzano’s account of unification is that, for them, propositions are more obvious and self-evident when they are simpler (in having fewer parts), more general, and more fundamental.

To clarify the ordering of propositions from less obvious to more obvious, we might think of a child who, every time they are provided with an explanans that explains an explanandum, continues to respond “but why?,” turning each answer into a further question. Each further explanans provided in this explanatory regress would be more obvious than the last, until we begin to hit upon propositions that





**Fig. 5** Features of the unifying relation

are simple, self-evident, and can be given no further justification (imagine, throwing one’s hands up in response to questions like: “but, why is red a color?” or “why are even numbers divisible by two?”—“it just is!”).

An important insight can be drawn from the conclusion that propositions involved in explanation are ordered according to intelligibility. Specifically, because there are fewer simple truths than there are complex opaque ones, and very few truths that are axiomatic, the whole scientific field—which is a collection of all these propositions—has the structure of the reductive pyramidal pattern, which is the hallmark of unifying systems.<sup>26</sup> In other words, the ordering of propositions according to their role in explanation will take the pyramidal shape of model 4 above; the ordering proceeds from more and more complex propositions at the bottom of the pyramid to fewer, but more fundamental propositions at the top of the pyramid.<sup>27</sup>

To begin to diagram these conclusions—at the local level—explanations exhibit the following relation (replacing variables with proposition letters) (Fig. 5):

Because they exhibit this relation, at the global level *explanatory systems* are organised such that the relation between sets determines not only the place of propositions in the order, but also that there is a reduction of the number of members of sets concomitant with the progress in order (Fig. 6):

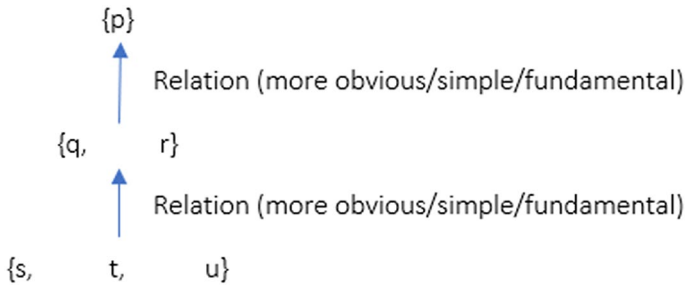
This means that the *explanatory* relation flows in *the other* direction (Fig. 7):

### 3.3 The Many to the Few

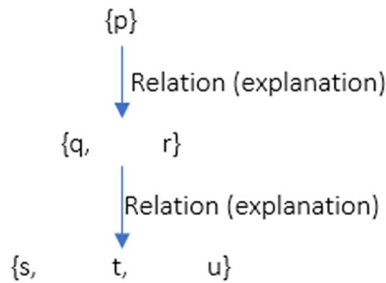
According to the unificationist theory of explanation, explanatory systems do not just happen to have this pattern. Rather, *this hierarchical pattern* is also the source

<sup>26</sup> This further means that, each axiom is presumably a terminus for many diverse lines of inquiry. One can start an inquiry at any point and end at significantly fewer axiomatic conceptual truths as final destinations.

<sup>27</sup> Though we find the Husserlian version of the unificationist account entirely *plausible*, we are not here trying to *defend* it in full, and so we will not attempt to respond to various objections that we are more than well aware might be levied at it (for example, the objection that perhaps the grand unifying theory will be very hard to understand indeed, and that there seem to be at least some counterexamples to the Husserlian thesis that axioms higher up the hierarchy of truths are more obvious than the theorems one might derive from them [see Berghoffer, 2020]). We thank the two anonymous referees for pressing these points. We think that these issues require greater analysis beyond the space available to us here. Although we think the present work is a good starting point for future research, we are unsure whether there are resources within Husserl to address these problems or whether Husserl’s ideas require amendment to be made fully defensible contemporarily. So, a full defense is beyond the scope of this paper. Our aims here are to explicate a broadly unificationist Husserlian picture, and merely to show that this picture is different and better than the much-maligned DN account (see Sect. 4.7).



**Fig. 6** A unifying system



**Fig. 7** The explanatory relation

of explanatoriness. We can understand a certain state of affairs, for example, when we see that this state of affairs derives from the same source as another state of affairs. That which seemed diverse and unconnected is actually homogeneous and connected. For example, one of the strengths of the theory of universal gravitation and the laws of motion is that they explain the behavior of celestial bodies and bodies on earth. This reveals that phenomena as diverse as an object falling to the earth and Kepler's laws can be explained by recourse to the same limited number of laws, thus greatly reducing the number of independent phenomena in the universe.

This reductive, unity-of-heterogeneity is another guiding impulse behind theories of scientific explanation through unification. Friedman writes that "the crucial property...; the essence of scientific explanation" is when "we have reduced a multiplicity of unexplained, independent phenomena to one" (1974, 15). Scientific unification reduces "the number of independent events, states, facts, and properties we need to recognize" (Kim, 1994, 68).

Unificationists like Husserl think that a law has more explanatory power the more premises that follow from it as consequence. Theories are more powerful when they contain a few laws that are highly unifying in this fashion. We better understand the seemingly random and chaotic events in the empirical world, when we see those events as systematically regulated by few natural laws. As Husserl puts it, the understanding "creates unity of theoretical knowledge out of unconnected experiences,

out of isolated convictions, presumptions, inferences. Thanks to it, nature figures before our mind's eye as a cosmos governed by laws" (Hua XXX, p. 3/2019, 3). Furthermore, we have a more coherent mathematics, when we can deduce a wide variety of theorems from a few simple axioms, such as with Husserl's favorite example of Euclidian geometry (Hua XXX, p. 260/2019, 274). We thus have an account of why pyramidal shaped systems of deductively related propositions are explanatory.<sup>28</sup>

### 3.4 Maximally Reductive

When developing science, we seek to formulate a system where there are the *fewest* unexplainables. As Friedman puts it (in the *de re* mode), "science increases our understanding of the world by reducing the total number of independent phenomena that we have to accept as ultimate or given" (1974, 15). Such a system is explanatory, because a "world with fewer independent phenomena is, other things equal, more comprehensible than one with more" (ibid). Kitcher further develops this insight (stated in the *de dicto* formulation), writing,

Science advances our understanding of nature by showing us how to derive descriptions of many phenomena, using the same patterns of derivation again and again, and, in demonstrating this, it teaches us how to reduce the number of types of facts we have to accept as ultimate (or brute). (Kitcher, 1989, p. 432)

Accordingly, if we had a fully developed science involving the fewest fundamental laws or axiomatic principles—principles that explain as many propositions as possible—such a developed science would bring about the best cognitive state of understanding. This is the ideal of a *maximally reduced* and *thereby* ideally unified field of scientific explanation. A unificationist thinks that explanation is afforded by the cognitive effect of deriving maximally many propositions from the very fewest propositions. Although Kitcher focuses on *patterns of derivation* (as opposed to the number of fundamental propositions), the basic idea here is expressed when he writes that an explanatory system is "a set of derivations that makes the best trade-off between minimizing the number of patterns of derivation employed and maximizing the number of conclusions generated" (Kitcher, 1989, p. 432).

### 3.5 Husserl is a Unificationist

Husserl is certainly committed to this unificationist picture of explanatory science. He concludes that science has a reductive pyramidal structure of unification. For example, in *Logic and Theory of Science*, he states that.

a deductive theory is no more than a web of proofs [*Gewebe von Beweisen*] by means of which an essentially related *group of truths* leads back to *one and the same store of ground-truths* [*einen und denselben Fond von Grundwahr-*

<sup>28</sup> Many of these conclusions are grounded or have their parallel in the insights of Husserl's pure logical grammar. Concerning this tenet of Husserl's thought, see Byrne (2017c).

*heiten*] as the consistently perfect irreducible basis out of which they are all provable and by this means are (as people also say) explained” (Hua XXX, p. 246–247/2019, 260, emphasis ours, translation modified).

As we have observed, the concrete sciences provide descriptions of the empirical world as given through observation. One might go on making such observations, in practice, *ad infinitum*. These observations can be explained by borrowing the resources from the nomological sciences. Husserl intimates that the store of general laws that we might employ in an explanation is as infinite as the store of observations. But the aim of the nomological sciences is “theoretically, i.e., deductively, to trace an *infinite* supply of laws back to a *finite* foundation of basic laws that united present the perfect basis for all other laws as necessary consequences” (Hua XXX, p. 255–256/2019, 271, our italics). Thus, the goal of theoretical science is to trace this limitless store of observations and laws to a *finite* number of laws from which they can be deduced and thus explained, and in doing so to *unify* science.

Husserl says something very similar about a priori disciplines, writing that,

we have a system unfolding itself in pure deduction into *infinity*, in which all further propositions follow purely analytically—and fully explicitly—from a *finite* number of independent basic propositions as a perfect, irreducible basis. (Hua XXX, p. 261/2019, 277, our emphasis).

Husserl also endorses the claim that explanations can allow for understanding due to the regress from the complex and opaque to the fundamental and obvious. He observes that less obvious propositions are explained via more obvious propositions, such that propositions of science are ordered according to how obvious and fundamental they are. In the *Investigations*, he states that theoretical explanation “means an ever increased rendering intelligible” (Hua XIX, p. 26/1970b, 178). This rendering more intelligible culminates in axioms which are the most basic or “most primitive [*primitivsten*] ... laws” (Hua XIX, p. 27/1970b, 178). The inward evidence with which these eidetic laws are given is felt for a “relatively quite limited group of primitive facts [*primitiver Sachverhalte*]” (Hua XVIII, p. 31/1970b, 19). In *Husserliana* XXX, he states that the axioms, which a deductive system begins with, must be given in such a way that they are “directly perspicacious,” or at least “easy to convince oneself” of (Hua XXX, p. 259/2019, 275). The definitions of the concepts involved in the axioms “are also directly obvious” (Hua XXX, p. 260/2019, 275). From here, one draws deductive inferences, eventually arriving analytically at propositions that are “no longer obvious” (Hua XXX, p. 259/2019, 275).

Husserl is committed to the thesis that producing an explanatory system, which is maximally reduced, is *the goal* of the tiers of science under discussion in this paper.<sup>29</sup> He states quite plainly that the overall aim of scientific explanatory theory “is that of reducing the vast abundance of particular formations to a smallest possible ... number” (Hua XXX, p. 338/2019, 355). Husserl envisions the *ideal* of such a maximally unified system. He has this ideal in mind when he remarks that a “a

<sup>29</sup> It is *not* the *only* goal, however, of a pure logic, or phenomenology.

theoretical discipline, has its chief grounds [*obersten Gründe*] upon which it rests” (Hua XXX, p. 247/2019, 260). More expansively, Husserl characterizes the notion of an ideally unified and *complete* theory as one in which all propositions can be traced to basic laws that cannot be further proven, by writing,

The systematic unity [*systematische Einheit*] of the *ideally* closed sum total of laws resting on *one* basic lawfulness as their final ground [*letzten Grund*], an arising out of it through systematic deduction, is the unity of a systematically complete theory [*systematisch vollendeten Theorie*]. This basic lawfulness [*Die Grundgesetzlichkeit*] may here either consist of one basic law or a conjunction of *homogeneous* basic laws [*homogener Grundgesetze*]. (Hua XVIII, p. 234/1970b, 146, translation modified)

Finally, Husserl is committed to the idea that *this* ideal of unity—the unity that governs nomological science—is the *essentially scientific* unity. Husserl makes clear that essential unity of science is explanatory unification, i.e., unity of reduction to explanatory laws:

The truths of a science are *essentially* one if their connection rests on what above all makes a science a science: a science is, as we know, grounded knowledge, i.e., explanation or proof (in the pointed sense). *Essential unity among the truths of a single science is unity of explanation ... Unity of explanation* means, therefore, *theoretical* unity, which means, on what was said above, homogeneous unity of lawful base, and, lastly, *homogeneous unity of explanatory principles* [*homogene Einheit der erklärenden Prinzipien*]. (Hua XVIII, p. 234/1970b, 147, translation modified; see also 18).

### 3.6 Tying it all Together

This analysis reveals that both Husserl and many contemporary theorists conclude that explanatory systems display a unifying pattern of ordered reduction. Moreover, it is Bolzano who first toyed with the idea that, if the system in question displays this unifying pattern and if the units of the system are *propositions*, then the relations that pertain between the units on different levels qualify as *grounding relationships*. Bolzano entertains the idea that the concept of ground and consequence is “none other than the concept of an ordering of truths which allows us to deduce from the smallest number of simplest premises the largest possible number of the remaining truths as conclusions” (1972, p. 287). The concept of maximal unification thus provides an operational characterisation of ground. Bolzano was the first to think that, perhaps, grounding relationships pertain between the members of maximally unified propositional systems ordered according to simplicity.

Finally, Husserl’s support of an account that has contemporary adherents (unification) is not accidental, as both the former and the latter draw from Bolzano. Not only is Bolzano exerting an influence on the contemporary theory of grounding (Fine, forthcoming), but he has also influenced contemporary

unificationists. For example, we know that Kitcher was intimately acquainted with the just quoted passage from Bolzano as he makes explicit mention of it in his scholarly study of the latter's account of grounding, intra-mathematical explanations, and the foundations of mathematics (Kitcher, 1975, 268; see also Kitcher, 1989, 424).

As a unificationist, Husserl's account of explanation is thus more sophisticated than the standard DN model. It resonates strongly and shares motivations with other expositions that continue to have contemporary adherents. Indeed, unificationists would be well served reading Husserl's thoughts on grounding, unification, and explanation alongside Bolzano, as Husserl's discussion is located in a more familiar milieu for contemporary philosophers of science.

### 3.7 Response to an Objection

We have argued that Husserl is a unificationist in large part to show that his account should not be dismissed on the grounds that it is simply a version of the ill begotten DN theory. What we have also mentioned is that the DN theory fell into disrepute due to a variety of insurmountable objections that have been levelled at it. It seems we are beholden to at least show how Husserl's unificationist version of the DN theory can overcome the most damning of these objections. The biggest downfall of the DN model is known as the problem of asymmetry. As we have shown, the schema for a DN explanation is as follows:

P1 Major explanantia: Law.

P2 Minor explanantia: Initial conditions.

P3 Explanandum: Deductive conclusion.

The symmetry problem results from the fact that we can swap the minor explanantia with the explanandum and the argument which results meets all the requirements for a DN explanation yet fails to be explanatory. The canonical example is that, I can explain the length of the shadow of a clock tower (P3) by citing the laws for the propagation of light (P1) and the height of the clock tower and position of the sun (P2). However, I can also draw a deductive conclusion about the height of the clocktower (now P3) from an argument which has the laws of the propagation of light (P1) *and the length of the shadow* as the minor explanantia (now P2). Yet, the length of the shadow of the clock and position of the sun obviously fails to explain why the tower is the height it is. The DN schema is thus *symmetrical*; the explanatory relation is *asymmetrical*.

In response, one might expect us to be able to show how the height of the clock tower sits higher up the hierarchy of truths than the length of the shadow, but this need not be the case. The hierarchy of truths does not imply that *all* the parts of an explanation are hierarchically ordered, and we should carefully distinguish between the major and the minor explanantia. The *laws* sit higher up the hierarchy, but the initial conditions might merely be singular empirical observations that are on the same "level" (i.e., be no more general, simple, understandable,

etc.) as the explanandum. What the unificationist picture tells us is that the laws can never be explained by the initial conditions, and this is true. The initial conditions, however, are themselves in need of explanation too by reference to laws, *but not the same laws* as the ones they join with to explain some fact.

Thus, the most straight forward response to the question of why the reversal of the initial conditions and the explanandum is not explanatory which fits with the unificationist picture we have provided is just to point to the fact that the height of the clock tower and the length of the shadow are grounded in different laws *and* are causally asymmetrically related. The height of the clocktower partially causally grounds the length of the shadow, but not vice versa; a grounding, unificationist picture of explanation has no problem with the contention that causes are asymmetric, partial grounds.

Moreover, as Kitcher points out in his answer to the asymmetry problem, the height of the clock tower is subject to a type of personal level explanation which cites the lawful connection between mental intentions and purposive action. The dimensions of all human artifacts are grounded in the intentions of a designer. From the Bolzanian/Husserlian perspective, what we would say is that the height of the clock tower holds in virtue of the designer's intentions, and thus the former is partially grounded in and explained by the latter. *Both* the laws for the propagation of light *and* the laws of human psychology might serve as a type of ground, sitting higher up our hierarchy and explaining different facts by subsuming them in a unifying fashion.

## 4 Conclusion

This paper has explored Husserl's account of scientific explanation. Important milestones in our investigation include our discussion of (1) Husserl's account of the local DN structure of explanation, (2) his theory concerning the idealization of natural laws, (3) the account of interlawful and intra-mathematical explanation, interspersed with (4) the leitmotifs of unification, grounding, and the seminal influence of Bernard Bolzano. In sum, we have revealed how sophisticated Husserl's account of scientific explanation is. We disclosed that he discusses themes, which were only to emerge as topics of serious philosophical investigation in the analytic community many years after he developed them. We hope our contribution serves as a starting point for future research programs interested in employing Husserl's insights to develop contemporary theories of scientific explanation.

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## Declarations

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

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