3. Scientific understanding, scientific explanation, and why they cannot be torn apart

The connection between understanding and explanation is a core topic in the debate about understanding, especially for philosophers of science. The presentation of the accounts of scientific understanding developed by Henk de Regt, Kareem Khalifa and Finnur Dellsén in the previous chapter exemplify this claim. On the one hand, the accounts of understanding from de Regt as well as Khalifa are only concerned with explanatory understanding, a type of understanding that is tied to explanation. De Regt admits that kinds of understanding without explanation exist, but his account of understanding is not intended to cover these kinds. In contrast to de Regt, Khalifa explicitly argues that at least one other kind of understanding, namely objectual understanding, can be reduced to explanatory understanding. On the other hand, Dellsén presents an account of scientific understanding in terms of objectual understanding, according to which explanation is not necessary for understanding. What should we make of these different positions? Does scientific understanding require explanation or not?

In this chapter, I argue that scientific understanding does require explanation. To do so, I first address the concept of explanation. Explanation is one of the core concepts in philosophy of science and various accounts and definitions of explanation have been provided in the last decades. To avoid confusion, I need to clarify what I mean by the concept and the term 'explanation'. Hence, I start with a very brief discussion of explanation in section 3.1, in which I introduce the generic conception of explanation that I adopt throughout this book. I then turn to the main topic of this chapter, the relation of scientific understanding and explanation. I do so by discussing arguments that are proposed to support a view of understanding that is independent of explanation. In section 3.2, I present and critically discuss Peter Lipton's view on understanding without explanation. I analyze the four examples that Lipton provides as instances of understanding without explanation and argue that none of the examples succeeds in being an instance of understanding without explanation. Subsequently, I delve into the discussion about two forms of understanding that some authors strictly distinguish, namely, objectual and explanatory understanding. In section 3.3, I present the view of Jonathan Kvanvig, who argues that

explanatory and objectual understanding are intrinsically different and the counterarguments from Khalifa against Kvanvig. I argue that Khalifa's critique of Kvanvig's conception of objectual understanding is in line with my criticism on Lipton's view. As the accounts from Lipton and Kvanvig are unrelated while facing the same problems, a conception of scientific understanding without explanation becomes more and more implausible. Finally, in section 3.4, I engage with further arguments in favor of and against a separation of objectual and explanatory understanding. Christoph Baumberger wants to distinguish objectual and explanatory understanding in terms of their targets and vehicles. Following Stephen Grimm's argument why a distinction in terms of the targets of understanding is not possible, I will argue that the distinction in terms of the vehicle is not possible either. I conclude that, at least for scientific understanding of phenomena, a differentiation between objectual and explanatory understanding is not reasonable, as both terms, in their prevalent use, cannot accommodate scientific practice and the function of explanation within it. Hence, scientific understanding is not possible without explanation.

One important remark is necessary before the analysis of the relation of understanding and explanation. Although I am exclusively dealing with scientific understanding of phenomena, understanding that is gained in the scientific domain, many authors in the debate are concerned with understanding in general and do not reduce their analysis to scientific understanding. The controversies about understanding and explanation, about objectual and explanatory understanding, which I examine in this chapter, are also not restricted to scientific understanding. However, this is not a problem for my project. I analyze the plausibility of arguments in favor of an independence of understanding from explanation for the scientific domain, whether it makes sense for science to conceptualize scientific understanding as being independent from explanation. I am not claiming that any type or kind of understanding requires explanation. In fact, I do think that there are types of understanding that are independent of explanation. But these types will not be typical or distinctive as an aim of science, so I shall argue. Therefore, any argument concerning the relation of understanding and explanation needs to be interpreted in light of scientific practice if scientific understanding as an aim of science is the target of investigation. Having this clarification in mind, I do not take it to be problematic that scientific understanding is not always clearly distinguished from other types of understanding by all authors.

3.1 A few words on explanation

Prior to delving into the discussion of whether understanding requires explanation, some considerations concerning the concept 'explanation' are necessary. Explanation has been and still is one of the most central concepts in philosophy of science.

As Henk de Regt nicely puts it, even "after sixty years of debate about scientific explanation, there is currently no consensus favoring one model but rather a plethora of different models of scientific explanation."[1] Among the types of explanation that are proposed and discussed are deductive-nomological, unificationist, model-based, causal, counterfactual, mechanistic, functional, probabilistic, or mathematical explanations, and this list is not exhaustive. Some of these types overlap, some can or might be reduced to another type.[2] Since I am concerned with scientific understanding, and not with scientific explanation, I do not attempt to develop and provide a specific conception of scientific explanation. This issue would be more than enough for another research project. However, I do adopt a generic conception of explanation. In this section, I delineate the basic features of this generic conception of explanation.

What is an explanation? Attempts to answer this question led to the emergence of two main opposing camps: adherents of an ontic conception of explanation versus proponents of an epistemic conception. While according to the ontic conception explanations are things or facts that exist or take place in the world, the epistemic conception suggests that explanations are (complexes of) representations of things or facts in the world. Consequently, for the ontic conception explanations exist independently of any cognitive subjects, whereas the epistemic conception requires subjects to construct explanations, representations, of things in the world. As no decisive argument in favor of or against one of the two conceptions could be provided so far, I follow my intuition and adopt an epistemic conception of explanation. In my view, it is more plausible to speak of things like entities, phenomena, events, or structures to be in the world, while explanations are constructed to represent these things. Explanations are created by subjects and if there were no subjects trying to explain things in the world, these things would still exist, but there would be no explanations.[3]

So, for the purpose of this book, explanations are representations. The next question is what makes a representation an explanation and not merely a description. In this regard, I follow Hayne Reese and, very roughly, view explanations to pro-

1 De Regt (2017), p. 49.

2 For an overview on the different types of scientific explanation, see for example Woodward, J. & Ross, L., "Scientific Explanation", *The Stanford Encyclopedia of Philosophy* (Summer 2021 Edition), Edward N. Zalta (ed.), URL = https://plato.stanford.edu/archives/sum2021/entries/scientific-explanation/ (last accessed April 12th, 2022).

3 For one line of argumentation against the ontic and in favor of the epistemic conception of explanation, see Wright, C. & van Eck, D. (2018), "Ontic Explanation Is either Ontic or Explanatory, but Not Both." *Ergo: An Open Access Journal of Philosophy*, 5, pp. 997–1029, DOI: 10.3998/ergo.12405314.0005.038.

vide reasons for *why* something is the case or could be the case,[4] while descriptions merely state what *is* the case. Descriptions provide us with facts (e.g. the sky is blue and blue light is scattered more than other colors by the atmosphere), while explanations give reasons for these facts (the sky is blue, *because* blue light is scattered more than other colors by the atmosphere). An explanation transcends a description, as a representation "becomes explanatory because it goes beyond the question answered by description – "What happens?" – to the question answered by explanation – "Why does it happen?"".[5] The notion of reasons is deliberately kept vague, in order to capture all kinds of reasons that are deemed crucial or adequate in different contexts. Reasons include causes, but they are not limited to causes, as not all types of explanation refer to an actual cause of a phenomenon. Famously, unificationist explanations provide unified accounts of various different phenomena by deriving descriptions of as many different phenomena as possible from as few argument patterns as possible, to use Philip Kitcher's technical vocabulary, but without referring to any actual causes of some phenomenon.[6]

De Regt and Khalifa, despite their differences with respect to understanding, agree on one crucial aspect: they allow for an explanatory pluralism to achieve understanding. Both authors argue that, depending on the historical or disciplinary context, various explanatory strategies lead to understanding. Following a review of various types of explanation, de Regt "conclude[s] that understanding is a universal aim of science that can be achieved by contextually varying modes of explanation."[7] And Khalifa claims that an explanation must "satisfy "local constraints" […] [as] the relevance of many explanatory features depends on the specific explanandum, the standards of the discipline, and the interest of the inquirer."[8] Hence, there is not one kind of explanation that provides the best or most accurate understanding in

4 I am referring here to the concept of how-possibly explanations, explanations that do not explain why something actually happened, but rather explain how something is or was possible. Yet, whether how-possibly explanations should be seen or treated as genuine explanations is a contested question, which I will not address here. For more information, see for example Brainard, L. (2020), "How to Explain How-Possibly." *Philosophers Imprint*, 20 (13), pp. 1–23; or Reydon, T. (2012), "How-possibly explanations as genuine explanations and helpful heuristics: A comment on Forber." *Studies in History and Philosophy of Biological and Biomedical Sciences*, 43 (1), pp. 302–310, DOI: 10.1016/j.shpsc.2011.10.015.

5 Reese, H. W. (1999), "Explanation Is Not Description." *Behavioral Development Bulletin*, 8 (1), pp. 3–7, DOI: 10.1037/h0100524, p. 4.

6 For Kitcher's account of unificationist explanation, see e.g. Kitcher, P. (1989), "Explanatory Unification and the Causal Structure of the World." In Kitcher, P. & Salmon, W. (eds.), *Scientific Explanation*, Minnesota Studies in the Philosophy of Science, Vol. 13, pp. 410–505, Minneapolis (MN), University of Minnesota Press.

7 De Regt (2017), p. 86. His full review of different models of explanation can be found ibid. chapter 3.

8 Khalifa, (2017b), p. 8.

all cases. Instead, the subjects involved in a process of gaining understanding must assess, according to the relevant standards that they follow, which explanation is the 'best' or appropriate one to lead to understanding in the respective context. Since the pluralist positions concerning explanation of de Regt and Khalifa are supported by a growing attention and literature on explanatory pluralism and diversity in science,[9] I adopt a pluralist position of scientific explanation as well. While being an explanatory pluralist, I do think that a generic conception of explanation, which leaves room for the various types of scientific explanation that can be found in scientific practice, can be articulated.[10] Hence, I provide the following conception of explanation:

> An explanation is a representation of relations of (parts of) the phenomenon under investigation, which provides reasons (an explanans) for features of (parts of) the phenomenon (the explanandum).[11]

This is the generic conception of explanation that I use and refer to when I speak about explanation in the remainder of this book. Again, I use the notion 'reasons' in this conception in order to include non-causal explanations, like unificationist, law-based, probabilistic, logical and further types of explanations. Having clarified what I mean by explanation, we can now turn to the actual topic of this chapter. Namely, the relation of understanding and explanation.

3.2 Cases of understanding without explanation?

Some philosophers in the debate on understanding maintain that in some cases, understanding can be gained without explanation. Peter Lipton is one of them. I

9 See for example Mantzavinos, C. (2016), *Explanatory Pluralism*. Cambridge, Cambridge University Press, DOI: 10.1017/CBO9781316440599; or Braillard, P.-A. & Malaterre, C. (2015), *Explanation in Biology. An Enquiry into the Diversity of Explanatory Patterns in the Life Sciences.* In History, Philosophy and Theory of the Life Sciences, Dordrecht, Springer, DOI: 10.1007/978-94-017-9822-8; or Weber, E., de Regt, H. W. & van Eck, D. (2021), "Investigating the Unity and Disunity of Scientific Explanation." *Found Sci*, 26, pp. 1021–2024, DOI: 10.1007/s10699-020-09704-x; or Rice, C. & Rohwer, Y. (2021), "How to Reconcile a Unified Account of Explanation with Explanatory Diversity." *Found Sci*, 26, pp. 1025–1047, DOI: 10.1007/s10699-019-09647-y.

10 I got the idea of formulating and using a generic conception of explanation from de Regt, who also provides a generic conception of explanation, though a different one. Cf. de Regt (2017), pp. 24f.

11 Note that I am concerned with scientific understanding of phenomena that are the targets of scientific investigations in this book and that I will not analyze what it means to understand a theory scientifically. Hence, I stay agnostic as to whether this generic conception of explanation is applicable to understanding other objects than phenomena, like for example theories.

present Lipton's examples, which he simply calls causation, necessity, possibility, and unification, and argue that he fails to show that scientific understanding is possible without explanation. Either he is wrong in claiming that no explanation is involved in the discussed cases, or he does not make a convincing point that his arguments are applicable to or can accommodate scientific understanding.

Before I address Lipton's arguments that there are cases of understanding without explanation, I want to mention some general aspects concerning Lipton's view of understanding. First, he is not exclusively concerned with scientific understanding, or at least he does not say so explicitly. Hence, I take it that Lipton is engaged in the analysis of understanding more generally and I have to analyze whether his view is plausible for science. Second, Lipton identifies understanding with the cognitive benefits that an explanation provides. These cognitive benefits are, in turn, identified as kinds of knowledge, including knowledge of causes, of necessity, of possibility, and of unification. In short, Lipton takes understanding to be certain kinds of knowledge that are provided by explanations. Importantly, understanding is not identified with the explanation itself, but rather with its benefits. This point is crucial, as it enables a separation of understanding and explanation.[12] As I have not addressed the question of whether understanding should be conceptualized as a kind of knowledge (-that) or rather as an ability (knowledge-how), which I do in chapter four, I adopt Lipton's conception of understanding as being knowledge of causes etc. for the discussion of his cases and argue that it is implausible how subjects should gain the understanding Lipton attributes to them without explanation.

3.2.1 Causation

The first example presented by Lipton is causation. He identifies causal information as a form of understanding. Many explanations provide this kind of understanding, but Lipton wants to investigate whether it is possible to gain causal information without an explanation involved.

> We need cases that, in addition to not being explanations themselves, do not work by means of generating explanations that are then the proximate cause of the consequent understanding. […] [In such cases,] the process of acquiring understanding does not begin with an explanation, but the understanding is nevertheless a product of an explanation, which is not what we are looking for here.[13]

12 See Lipton, P. (2009), "Understanding without explanation." In de Regt, H. W., Leonelli, S. & Eigner, K. (eds.), *Scientific Understanding: Philosophical Perspectives*, pp. 43–63, Pittsburgh, University of Pittsburgh Press, pp.43f.

13 Ibid. pp. 44f.

Lipton works with the premise that there is something like tacit understanding, but nothing like a tacit explanation. This assumption enables him to identify cases where causal information, alias understanding, can be achieved without the influence of any explanation. This happens via the use of images and physical models. Persons may grasp causal information that are provided by these devices, they may achieve genuine understanding, without being able to express an explanation that contains this information. Manipulation, in Lipton's view, is an even stronger example of understanding without explanation. A scientist may be an expert in using a complicated machinery because he acquired the relevant causal information, but he may not be able to explain this information to others. In sum, Lipton wants to be able to differentiate between someone who simply knows that a phenomenon occurs and someone who has a deep understanding of the causes of the phenomenon, but might not be able to verbalize the causal information. He also mentions a possible critique to this idea, namely that a person may at least be able to say something about the causes of a phenomenon, even if some causal information remains tacit, i.e. cannot be made explicit. In such a case, Lipton maintains, the person would be able to provide an explanation, but this explanation would not exhaust the understanding of the person. Therefore, parts of the understanding of the person still do not require explanation.[14]

I fail to see how understanding can be attributed in these cases, and also how understanding conceptualized in this way should be valuable for science. I will first address the case of images and models, second the case of manipulation, and finally Lipton's general point about the natures of understanding as being tacit and explanation as being verbal or explicit.

Images and models are created to convey information, to make certain features salient that might otherwise be hidden in the real phenomenon. But this information does not automatically pass on to the person. Every representation requires interpretation by the subject. Just by looking at a representation and not interpreting *what* is represented and *how* it is represented, the image or model will not provide understanding of the represented phenomenon for the subject. The user makes the image or model intelligible to herself only by interpreting the representation, interpretation is a crucial part of representation.[15] Interpretation requires some kind of reasoning about the object that is interpreted and relations of the object must be recognized. A user makes sense of the representation, recognizes the (causal) information captured in the model, by interpreting the model or image. And if some

14 See ibid. pp. 44ff.

15 The importance of interpretation is stressed in several philosophical accounts of representation, see for example Frigg, R. & Nguyen, J., "Scientific Representation", *The Stanford Encyclopedia of Philosophy* (Spring 2020 Edition), Edward N. Zalta (ed.), URL = https://plato.stanford.edu/archives/spr2020/entries/scientific-representation/ (last accessed April 12th, 2022).

causal information is represented, this relation will have to be recognized by the user and (correctly) interpreted. She must (correctly) identify what is the cause and what is the caused event shown in a representation. If the user achieves this, she will have a causal explanation of the represented phenomenon in her mind. For example, if a person sees an orrery, she will only gain understanding of planetary motion if she, first, identifies the model as a representation of the solar system (and not of an atomic nucleus orbited by electrons, for instance), and second, identifies the relations between parts of the representation. While parts of the process of interpretation might be tacit, I do not see how interpretation of representations is possible at all without recourse to some explicit conceptions that the person possesses. I engage with the relation of propositional or explicit knowledge and tacit knowledge or knowing-how in detail in sections 4.2 and 4.3. Additionally, it is not necessary that different people are able to give explanations that capture the same, or all, information. Representations can be good or bad, adequate or inadequate for certain purposes in certain contexts. People with different background knowledge might interpret a representation differently, their understanding of the representation might vary, but all of them would have gained some understanding, some causal knowledge, nevertheless.

I agree with Lipton that images and models provide information. But in the case of understanding, this information is not merely tacitly or unconsciously adopted and stored by the user. The information of a representation recognized by the user is consciously interpreted by her. If the user is not able to generate an explanation from an image or model, she has no understanding. Accordingly, she has not gained understanding without explanation, but she has rather not understood anything through the image or model, since she could not interpret the representation in light of her background knowledge. Lipton mentions the case of someone who "never *properly* understood the why of retrograde motion until [she] saw it demonstrated visually in a planetarium."[16] But this example implies that the subject knew about retrograde motion *before* she saw the visual representation and already possessed information about the planets apparently moving into an opposite direction, maybe even an explanation of retrograde motion, but she did not really understand the phenomenon merely on that basis. This is not the same as understanding retrograde motion by seeing it visually in a planetarium *without* having any explicit knowledge about it. And if the understanding provided by the model of retrograde motion is tacit understanding that cannot be made explicit, as Lipton argues, how would the person or anyone else be able to judge or to know that her understanding improved or is proper after seeing the visual model? Understanding the cause or an aspect of a phenomenon *properly* implies that the cause or aspect of the phenomenon must

16 Lipton (2009), p. 45, my emphasis.

be understood in a certain, proper, manner through a representation. If the understanding cannot be made explicit at all, it will not be possible to determine whether the person in question acquired a proper understanding, an inappropriate understanding, or maybe even no understanding at all, since tacit understanding is inaccessible for any subject, including the subjects that gained this understanding. If a person wants to make sure that she gained some understanding (causal knowledge) about a phenomenon by looking at a visual representation, she will have to make explicit what she understood.

Furthermore, according to my generic conception of explanation, which states that an explanation is a representation of relations of (parts of) the phenomenon under investigation, which provides reasons (an explanans) for features of (parts of) the phenomenon (the explanandum), images and physical models, the representations Lipton mentions, can be viewed as being explanations *themselves*. I do not restrict my conception of explanation to propositions. The same information concerning aspects of phenomena and their reasons can be captured in form of a proposition, an image, or a physical model, at least in many cases. Lipton apparently does not include images or physical models into his conception of explanation. I grant Lipton that models or images, in case they are not considered to be explanations themselves, can enable genuine understanding that is not possible by merely knowing a propositional explanation. This is a good point for arguing in favor of a genuine difference between knowledge of an explanation and understanding, but he does not show that understanding merely through visual representation and *without an (explicit) explanation at all* is possible. The visual representation of retrograde motion *alone* will not have provided understanding for the subject, since she would not have been able to make any sense of the representation without already knowing what is represented, and hence being able to identify the explanandum, the explanans, and their relation in this case.[17]

17 Victor Gijsbers is also not convinced by Lipton's example of images and models and his criticism is quite similar to mine. "Evidently, simply *seeing that* the planets perform a retrograde motion is not enough to count as understanding—if it did, we would not even need the planetarium, but could just look at the night sky. What more is needed? Well, we should be able to identify the salient features of the system, the features that determine that retrograde motion occurs. […] Anyone who hasn't grasped that the fact that the earth's shorter sidereal period is essential to the appearing of retrograde motion, has not understood why the phenomenon occurs. But anyone who has grasped this possesses an explanation of apparent retrograde motion. If the person were not able to express this explanation to others, perhaps because of a lack of useful vocabulary or linguistic skills in general, it would be pedantry to say that he understands but cannot explain. Even if he cannot express it, he does have an explanation." Gijsbers, V. (2013), "Understanding, explanation, and unification." *Studies in the History and Philosophy of Science*, 44, pp. 516–522, DOI: 10.1016/j.shpsa.2012.12.003, p. 518, original emphasis.

The case of manipulation is as problematic as the case of representation. How should it be possible to attribute genuine understanding of a machinery to a person who is not able to explain what the machinery does when she uses it? Simply using the machinery without the ability to explain at least parts of the processes is identical to the stump, automatic behavior of robots, who perform their tasks exactly by following rules without understanding what they do or why they are doing something precisely in that way and not another. When an agent really comes to understand a complicated machinery through using it, for example a complex laser system, it will be a trial and error process in the beginning. She will figure out what happens if she does certain things with the system. By continuing, she will be able to reason which actions produce which effects, she will understand it and articulate the relations. Again, it is not possible to reasonably attribute a sophisticated understanding, which is what Lipton wants to do, to someone who is able to manipulate a machinery very accurately and in every possible respect, but who is not able to articulate and explain in any way what is happening. Merely keeping a machine running does not amount to a genuine understanding of that machinery. Imagine the case of two scientists, Amy and Bob, who work with precisely the same laser system. Amy is able to explain that she gets a clear signal out of the system when all the mirrors are in a certain position, because this configuration ensures that all the light beams are in phase and, therefore, amplify the signal. Bob, in contrast, can only say that he gets a clear signal out of the system when all the mirrors are in a certain position, because he tried many other positions in which the signal is not that good. From a practical point of view, both Amy and Bob have the same understanding of the laser system, as they can generate the same signal with the same quality. But to whom of the two would we attribute the more sophisticated understanding? To Amy, as she can provide the more sophisticated explanation of why the laser system has to be set up in a certain way to work properly.[18]

Lipton seems to argue for some kind of intuitive or tacit understanding of machines or entities that people can have, like intuitively understanding the engine of one's car or one's computer. *Prima facie*, I agree that such a tacit understanding exists, especially in the context of *practical ends*, but for *epistemic ends* (which is the more common aim for understanding, especially within science) we need another conception of understanding. The reason is that we can assess the appropriateness of

18 Gijsbers is on my side here as well. "Simply knowing how to do something is not the same as understanding how to do that thing (in any significant sense of understanding). This is well known to anyone who has ever followed a step-by-step tutorial for making something work on your computer: even if you learn the tutorial by heart and are able to perform it correctly, that does not mean you understand what you are doing. You may know you have to type "sudo chmod 777 xorg.conf," but you do not understand what you are doing when you type in those signs." Ibid. p. 518.

"practical" or tacit understanding in achieving our practical goals. If it is my goal to fix the engine of my car and I succeed in doing so, one can say that I have some understanding of the engine, as I reached my goal. This kind of understanding, of knowing how to do something or handling an object, tool or instrument, is present in every human domain, including science. However, achieving some practical goal is not the same as achieving the epistemic goal of figuring out what exactly is happening and why, of understanding the behavior of a machinery. From an epistemic point of view, the understanding needs to be made explicit at least to some degree, as otherwise neither the understanding subject nor anyone else could assess whether something of epistemic relevance was understood at all.

In general, and this is my third point of criticism of this example, Lipton's view about causation providing understanding without explanation is based on two problematic assumptions. First, Lipton directly concludes from the assumption that if a person is not able to make all causal information she possesses explicit, but merely some pieces, this explicit information or explanation will not exhaust the understanding. So, whatever it is that she cannot make explicit will be independent from explanation. In other words, he claims that understanding requires or is tight to explanation only if the full understanding can be made explicit through explanation.[19] Lipton's second problematic assumption is that his conception of tacit understanding of causes is compatible with a deep and subtle appreciation of causes. In other words, Lipton is only interested in the difference between someone merely knowing that a phenomenon occurs and someone who has a deep and subtle understanding of the phenomenon. Concerning the first assumption, it is not plausible why understanding should be completely independent of explanation just because no explanation might capture the whole understanding (in this case all the causal knowledge) that a subject has of a phenomenon. Is there any explanation that accommodates this demand? Maybe, but even if an explanation only captures parts of the understanding, *this explanation will be related to the understanding*. And as Lipton himself takes understanding to be a cognitive benefit of an explanation, and not the explanation itself, understanding must somehow be related to explanation. Therefore, the demand that understanding cannot be made fully explicit is not a decisive argument for understanding without explanation at all. Concerning the second problem, Lipton cannot make a convincing case about why tacit understanding can be seen as or identified with deep and subtle understanding of causes, or phenomena more generally. How should that be assessable, for the understanding agent herself or for anyone else? I intuitively agree with Lipton that something like tacit understanding exists and that humans (and possibly other animals) have this tacit understanding. I do think that tacit understanding does not only cover

19 See Lipton (2009), p. 46.

practical understanding, the knowing-how to do something, but can also cover understanding of causes or phenomena. I address this issue in chapter four. However, such a type of tacit understanding should not and cannot be called a deep and subtle appreciation of causes, or a sophisticated understanding of machineries, as there will be no way to determine or to justify whether a subject actually achieved a deep and subtle appreciation of causes without making anything of her understanding explicit. Without providing any explanation, it will not be possible to distinguish a person who has a deep and subtle understanding, and another person who is just lucky in guessing and trying.

In sum, if we accept Lipton's conception of understanding of causes without explanation, we would face an epistemically problematic situation. Taking for granted that understanding is some kind of intellectual or epistemic achievement, the person who wants to understand the why of, say, retrograde motion would want to have access to her understanding. She would want to know whether she understood the causes of a phenomenon correctly, whether she indeed acquired a deep and subtle understanding of the why of retrograde motion. However, according to Lipton's view, she would not have access to her own understanding and could not survey or potentially revise it. Other agents would also never be able to assess whether the subject gained understanding and could never evaluate her understanding as proper or not. The crucial point here is that if a subject cannot provide an explanation, cannot articulate the knowledge or information that she gained, it is unreasonable and impossible to attribute genuine or deep understanding of any phenomenon to that person. There would be no justification at all to attribute genuine or proper understanding to anyone and no ways of identifying potential flaws and improving ones understanding actively and consciously. These are devastating consequences for epistemic endeavors like science, and epistemic achievements in general. Hence, Lipton fails to provide a convincing argument for an understanding of causes that is possible without any relation to explanation, at least for epistemic enterprises like science, enterprises that (primarily) serve epistemic ends. This is not to say that such a kind of tacit understanding does not exist at all, I address this topic in chapter four. What I claim here is that tacit understanding unrelated to explanation is not the kind of understanding that scientists refer to when they mention understanding of phenomena as an aim of science.

3.2.2 Necessity

Lipton's second example of cases where understanding is achieved without explanation concerns necessity. He investigates "arguments that are not explanations but do generate understanding by showing necessity."[20] Thought experiments (seem to)

20 Ibid. p. 47.

belong to this kind of arguments and Lipton presents the thought experiment of Galileo as a case in point.

Galileo argued that, according to Aristotelian physics, heavier bodies fall faster to the ground than lighter bodies. Heavier bodies have a higher acceleration. If you stand on top of a tower and let go two masses at the same time, one with a weight of 5 kg and one with the weight of 10 kg, the 10 kg body will reach the ground earlier than the 5 kg body. Following Aristotle, if you tie the two masses together with a rope, the lighter mass should slow down the heavier mass, so that the combined mass will fall slower than the 10 kg body, but faster than the 5 kg body. But this means that a mass of 15 kg (the two masses together) fall slower than a 10 kg mass, which is impossible according to the Aristotelian system. 15 kg cannot fall faster AND slower than 10 kg. Therefore, the assumption that acceleration depends on mass must be rejected.[21]

Imagine someone reads this version of Galileo's thought experiment who did not hear of it before and who has no training in physics, philosophy, or logic. This person then knows the thought experiment in the sense that she can remember it and tell it a third person. But although this person knows the thought experiment, she might not understand it. After reading it, she could ask: So what? What is the point or the problem? My answer could be: The thought experiment shows that *the acceleration of bodies is independent of their mass because it is logically impossible that the acceleration depends on the mass*. The thought experiment shows the logical impossibility. This is an explanation that is included in the thought experiment and that might not be obvious or clear to everyone. The thought experiment as a whole is not an explanation, but it *includes* a logical explanation of why acceleration must be independent of mass. Lipton writes "the system cannot accelerate both slower and faster, so acceleration must be independent of mass."[22] This proposition is an explanation (or at least part of an explanation, depending on the required level of detail concerning the system, acceleration, mass etc.), according to my generic conception, as it provides reasons for why something is the case. The proposition contains an explanans, the logical impossibility of a phenomenon exhibiting contradictory performances simultaneously, and an explanandum, the independence of acceleration of falling bodies from there mass.

Lipton himself addresses the question of why the thought experiment itself should not be regarded as an explanation. His argument is that "Galileo's argument […] though it gives the necessity and the understanding, seems to me not an explanation. […] It cannot because the Galilean argument is noncausal, giving no cause of the fact that acceleration is independent of mass. […] It does not provide

21 See ibid. p. 47. For an English translation of the original thought experiment by Galileo, see Galileo Galilei (1954 [1914, 1638]), *Dialogues concerning two new sciences.* Trans. Crew, H. & de Salvio, A., New York, Dover Publications, pp. 62f.

22 Ibid. p. 47.

a direct answer [to] the question "Why is acceleration independent of mass?""[23] These two features, that the argument is noncausal and does not provide a direct answer to the why-question, are not sufficient to not view parts of the thought experiment as an explanation. First, remember that I argue for an explanatory pluralism that is not limited to causal explanation. The explanation provided by Galileo's thought experiment might be viewed as a logical, counterfactual or a modal explanation, depending on how you conceptualize this type of explanation. In light of the vast amount of literature on non-causal explanation and explanatory pluralism, it becomes even less plausible that knowledge of causes is necessary for understanding.[24] As I already mentioned in section 3.1, the extensive philosophical investigation and literature on different forms of explanation in science show that a pluralist position towards scientific explanation should be adopted. The second feature is a result of Lipton's restriction to causal explanations, as he only takes information about causes to be direct answers to why-questions. While this might often be the case, it is not always so, as in certain contexts, scientific explanations are accepted as direct answers to why-questions although they do not refer to any actual cause. As soon as an explanatory pluralism is adopted and in accordance with my generic conception of explanation, reasons, not only causes, are accepted as direct answers to why-questions.

Additional support for the claim that thought experiments provide understanding through explanation can be found in the literature on thought experiments. For example, James Brown and Ulrich Kühne claim that thought experiments have a crucial function for developing explanations. Both authors argue in favor of the explanatory power of thought experiments throughout scientific history by referring to many other thought experiments in addition to the one from Galileo. Brown explicitly states that Newton wanted to *explain* the existence of absolute space with the bucket (thought) experiment[25] and Kühne argues that a person who accepts the derivation(s) provided by a thought experiment should be able to explain the phenomenon the thought experiment is about. According to Kühne, one function of thought experiments is their use as didactical tools for students who are experiencing a revolution in their personal understanding of nature. One asks for an explanation for a fact *p* if the fact *p* does not fit into the previous understanding of the

23 Ibid. p. 48.

24 For an overview on non-causal explanation and explanatory pluralism, see for example Reutlinger, A. & Saatsi, J. (2018), *Explanation beyond causation: philosophical perspectives on noncausal explanations*. Oxford, Oxford University Press, DOI: 10.1093/oso/9780198777946.001.0001.

25 See Brown, R. J. (1986), "Thought Experiments since the scientific revolution." *International Studies in the Philosophy of Science*, 1 (1), pp. 1–15, DOI: 10.1080/02698598608573279, p. 8. For more details concerning Brown's Platonism, the view that we are able to recognize natural laws *a priori* through the use of thought experiments, see Brown, J. R. (1991), *The Laboratory of the Mind – Thought Experiments in the Natural Sciences*. New York and London, Routledge.

world. One asks "why *p*?" to get an explanation which removes the irregular character of the fact *p* by establishing an acceptable connection of the appearance of *p* with what one regards as the normal course of things. The assertion that we are entitled to consider a factual assertion *p* to be explained if it has been obtained by an acceptable thought experiment is based on this common sense understanding of a good explanation, so Kühne argues.[26] Kühne's "common sense understanding of explanation" conforms to my generic conception of explanation, as the explanation embedded in the thought experiment provide reasons for *p*, or for why or how *p*.

Again, as in the case of causation, Lipton's view of explanation is much too narrow and he would have to exclude non-causal types of explanations from the realm of explanation, which are nevertheless successfully used and referred to as explanations in scientific practice as well as in the philosophical literature. Thus, there is no convincing reason to assume that thought experiments, or cases of necessity, provide understanding without explanation.

3.2.3 Possibility

Then Lipton turns to possibility. Recall that he views understanding to be a benefit of explanation, e.g. the possession of causal information or the apprehension of necessity. In this third case, actual understanding is gained from merely potential explanations, explanations of potential phenomena. Modal understanding is achieved, as in the case of necessity. "Information about other worlds illuminates the actual world. The fact that my computer would not have overheated if the cooling fan had not broken helps to explain why my computer overheated".[27] But this, in fact, is a counterfactual explanation of the breaking of the computer.

Lipton claims that such cases lead to understanding without explanation by arguing that counterfactual explanations, as in the computer example, have a different explanandum than 'real' explanation. In this example, the explanandum of the counterfactual explanation is a *possible* phenomenon, the non-overheating of the computer, and not the *actual* phenomenon, the over-heating of the computer.[28] So, we gain understanding of the phenomenon without an explanation of that phenomenon. If this is actually the case, and if Lipton still wants to allow for the possibility that the counterfactual explanation provides understanding of the possible phenomenon *as well as* of the actual phenomenon, then the counterfactual explanation has to be connected to the actual phenomenon. A subject will have to infer from the understanding of the possible phenomenon (the non-overheating of

26 See Kühne, U. (1997), "Gedankenexperiment und Erklärung." *Bremer Philosophica*, 5, pp. 1–51, pp. 15, 23, 26.

27 Lipton (2009), p. 50.

28 See ibid. pp. 49–52.

the computer) to the understanding of the actual phenomenon (the overheating of the computer). If this inference is not made, the potential explanation would not be connected to the understanding of the actual phenomenon. And this connection can be established by reintegrating the explanation. Instead of saying that the computer would not have overheated if the cooling fan had not broken, one can say that the computer broke because the cooling fan broke. If understanding of actual phenomena shall be possible through potential explanations, which is what Lipton is arguing for, the reason for the actual phenomenon (the over-heating of the computer), the broken cooling fan, must be identified. This again is in line with my generic conception of explanation, which demands that an explanation must provide reasons for the phenomenon. So there is an explanation involved in the understanding of possibilities. If I know the potential explanation that my computer would not have overheated if the cooling fan had not broken, while being unable to make the inference that my computer (probably) broke because of the broken cooling fan, I would not possess modal knowledge in this case, and hence no understanding.

Apart from that, the case that Lipton describes here is completely consistent with Woodward's counterfactual theory of causal explanation. In order for a genuine explanation to count as such, the explanation must provide answers to what-if-things-had-been-different questions. An explanation must exhibit systematic patterns of counterfactual dependence. To put it in Woodward's own words, "to causally explain a phenomenon is to provide information about the factors on which it depends and to exhibit how it depends on those factors. This is exactly what the provision of counterfactual information of the sort described […] accomplishes: we see what factors some explanandum *M* depends on (and how it depends on those factors) when we have identified one or more variables *S* such that changes in these […] are associated with changes in *M*."[29] Only by knowing which factor has an effect on a certain phenomenon and how a factor affects the phenomenon is it possible to understand the causal dependence, which is provided by counterfactual explanations.

Another approach that brings Lipton's analysis of this case into trouble is van Fraassen's pragmatic accounts of explanation. If a counterfactual explanation is used to explain an actual phenomenon, and the explanation is in accordance with the respective context in the sense that it provides an answer to a why-question posed, then the actual phenomenon will be explained by the counterfactual explanation. Whether the explanation that the computer would not have overheated if the cooling fan had not broken is evaluated as an adequate answer to the question

29 Woodward, J. (2003), *Making things happen: a theory of causal explanation*. New York, Oxford University Press, DOI: 10.1093/0195155270.001.0001, p. 204. For more details of Woodward's theory, see ibid.

why the computer actually overheated is contextually determined.[30] Van Fraassen argues that "the discussion of explanation went wrong at the very beginning when explanation was conceived of as a relation like description: a relation between a theory and a fact. Really, it is a three-term relation between theory, fact, and context. […] Being an explanation is essentially relative, for an explanation is an *answer.* […] It is evaluated vis-à-vis a question, which is a request for information. But exactly what is requested […] differs from context to context."[31] If such a pragmatic account of explanation is adopted, it can not only accommodate this case of possibility, but also explain why Galileo's thought experiment in the previous example of necessity provides an explanation. If a questioner asks why acceleration must be independent of mass, and receives the answer that acceleration must be independent of mass because the alternative, that acceleration does depend on mass, is logically impossible, and is satisfied with this answer because it fits into his background knowledge, this answer qualifies as an explanation of the acceleration of material objects for this specific questioner.

Hence, Lipton also failed in his attempt to show how understanding in the case of possibility can be acquired without explanation. Lipton's depiction of the case is at odds both with Woodward's counterfactual theory of causal explanation as well as with van Fraassen's pragmatic theory of explanation. In light of both these accounts, it is really implausible that an explanation of a *possible* phenomenon should not be regarded as an explanation that amounts or contributes to understanding the *actual* phenomenon.

3.2.4 Unification

The final example Lipton offers to argue for a kind of understanding without explanation is unification. He states that one way science improves our understanding of the world is by showing how diverse phenomena can share underlying similarities. The concrete example of unification as achievement without explanation he presents is Kuhn's account of the dynamics of normal science. From this, Lipton concludes that understanding through unification without explanation is ubiquitous in science. The central question that arises for Lipton is how rule-like behavior can be explained if rules are completely absent. The answer is that this behavior can be explained by shared exemplars. Normal scientists go on to choose new problems that seem similar to the exemplar. Exemplars perform the same function as shared rules, but in contrast to rules, exemplars provide knowledge in an implicit way. The

30 See van Fraassen (1980), pp. 134–157. For more details of van Fraassen's pragmatic account of explanation, see ibid.

31 Ibid. p. 156.

exemplar-based mechanism as proposed by Kuhn is an account of the ability of scientists to select problems that are similar to the exemplar, to try to find a solution for the chosen problem that is similar to a solution of the exemplar, and to assess the suitability of the proposed solution by reference to standards that are upheld for the exemplar. Kuhn mentions the inclined plane, the conical pendulum, Keplerian orbits, and also instruments like the calorimeter or the Wheatstone bridge as examples of exemplars in physics.[32] Lipton argues that the exemplar mechanism provides a plausible example of a route to understanding, i.e. knowledge of unification, without explanation. In an unarticulated way, exemplars provide information about the structure of the world, thereby unify phenomena, and provide understanding by analogy.[33]

Although I do not want to deny that exemplars can play an important role in achieving understanding, I do not think that they can do so without explanation. What Kuhn and Lipton are describing here are skills or abilities. Scientists acquire the skills to choose new problems and work with exemplars by participating in the scientific practice of their community. Through investigating a new problem by reference to an exemplar, scientists will gain new knowledge. In Lipton's words, "one of the ways science improves our understanding of the world is by showing how diverse phenomena can share underlying similarities."[34] Lipton as well as Kuhn are completely right in arguing that the discovery or identification of yet unknown phenomena that share underlying similarities with an exemplar is a matter of skill, not of an explicit theory or explanation. Merely knowing a theory or explanation will not automatically lead to identifying new phenomena. However, identifying or grasping similarity relations between an exemplar and a new problem without any reference to an explanation provided by the exemplar is not possible. When scientists grasp similarity relations, they relate knowledge they already have about the exemplar to the phenomenon that is actually investigated. Kuhn himself states that "learning [from problems to see situations as like each other] comes as one is given words together with concrete examples of how they function in use; nature and words are learned together."[35]

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32 See Kuhn, T. S. (2012 [1970]), *The structure of scientific revolutions* (4. ed., 50th anniversary ed.). Chicago, University of Chicago Press, p. 186.

33 See Lipton (2009), pp. 52ff. For more details concerning Kuhn's conception of shared exemplars, see Kuhn (1970), pp. 181–190.

34 Ibid. p. 52.

35 Kuhn (2012), p. 190. Kuhn puts so much emphasis on scientific practice, because philosophy of science in his time was almost exclusively concerned with scientific statements, e.g. theories, and their relation to empirical evidence, and regarded actual research practice as uninteresting for philosophical investigation. Although Kuhn's new focus marked the beginning of a crucial change in philosophy of science, later known as the Practice Turn, he never im-

The crucial point is that, according to Kuhn, exemplars are only one component of a disciplinary matrix. Kuhn introduces the concept "disciplinary matrix" in the postscript to *The Structure of Scientific Revolution* to replace and specify his notion of "paradigm". A disciplinary matrix is shared by all members of a particular scientific community, accounts for the functioning communication as well as for the consensus concerning judgements among the professionals, and has four components: symbolic generalizations, shared commitments, values, and exemplars. Exemplars in isolation will not provide, or enable scientists to generate, problem solutions. The four components of the disciplinary matrix are interrelated.[36] For example, group commitments "help to determine what will be accepted as an explanation and as a puzzle-solution."[37] That is, the solutions that scientists find are explicit explanations of phenomena. This becomes apparent in Kuhn's discussion of the impact of Newton's theory on seventeenth century physics:

> Before Newton was born the "new science" of the century had at last succeeded in rejecting Aristotelian and scholastic *explanations* expressed in terms of the essences of material bodies. […] Henceforth the entire flux of sensory appearances, including color, taste, and even weight, was to be *explained* in terms of the size, shape, position, and motion of the elementary corpuscles of base matter. […] In an earlier period *explanations* in terms of occult qualities had been an integral part of productive scientific work. Nevertheless, the seventeenth century's new commitment to mechanico-corpuscular *explanation* proved immensely fruitful for a number of sciences, ridding them of problems that had defied generally accepted solution and suggesting others to replace them. […] The search for a mechanical *explanation* of gravity was one of the most challenging problems for those who accepted the *Principia* as paradigm.[38]

Hence, in Kuhn's account of science, explanations are the problem solutions created by scientists, or at least explanations play an indispensable role in science in order to find solutions. If scientists discover an analogy between the exemplar and a novel phenomenon, they create an explanation, potentially an unificationist explanation, or they employ the same explanans for the exemplar as well as for the phenomenon, for two different explananda. For Kuhn, the process amounts to extending the explanation of the exemplar to the explanation of the new case. Therefore, Lipton is wrong in claiming that Kuhn's account of normal science is a case of understanding without explanation.

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plied that explicit components of science like theories or explanations were not required to conduct science, and thereby to understand the natural world.

36 See ibid. pp. 181–186.

37 Ibid. p. 183.

38 Ibid. pp. 104f, my emphasis.

The problem that Lipton faces in this example of unification is similar to the problem I point out in his example of causation. In the same way in which explicit knowledge of retrograde motion does not automatically amount to understanding of retrograde motion, merely knowing the explicit content of a theory that covers an exemplar does not automatically allow for an understanding of a new problem. But neither does the mere know-how of how to work with an exemplar without any explicit reference to the theory or established background knowledge. This explicit reference is made in form of an explanation. As in all the other examples, Lipton wants to present cases where "the routes to understanding […] do not pass through explanation."[39] Hence, also in the case of unification, he has the goal to present a case of understanding that is acquired without an explanation coming in at any point in the process of understanding. While Lipton does not mention the concept of tacit understanding again in the case of unification as he did in the case of causation, he nevertheless seems to imply a similar or the same concept here, namely that scientists can link several phenomena through similarity, and not causal, relations. I agree that the processes of choosing problems that seem similar to the exemplar and trying to find solutions that are similar to those that work in the exemplar require, at least partially, tacit processes or skills, a kind of knowing-how. However, I do not see how it should be possible for scientists to generate solutions and judge the adequacy of these solutions in reference to the exemplar without some reference to an explanation. As it is possible that scientists occasionally find solutions that are not adequate according to the standards the respective exemplar represents, no one would ascribe understanding to them in such cases, not even they themselves. As Lipton follows Kuhn in requiring that the scientists should not only be able to choose new problems that are similar to the exemplar and to find solutions for them, but also to assess the appropriateness of the developed solutions,[40] it is not clear how scientists would be able to do that if they cannot provide the solution of the problem in an explicit form, i.e. as an explanation of the new phenomenon that is based on the exemplar.

Concluding, Lipton fails to make a convincing point that understanding of new phenomena through exemplars is possible without any connection to an unificationist or any other kind of explanation. A closer look at Kuhn's account of normal science shows that Kuhn did not separate the process of finding a solution to a problem from explanation, as Lipton wrongly claims. Additionally, as in the case of causation where Lipton discusses understanding through visual representations or handling a machinery, it remains unclear how the appropriateness of a proposed problem solution should be assessed if understanding is a completely tacit process that cannot be made accessible to at least some degree.

39 Lipton (2009), p. 44.

40 See ibid. p. 53.

3.2.5 None of these examples is a case of understanding without explanation

In sum, none of the four examples presented by Lipton can reasonably be viewed an instance of scientific understanding without explanation. The reason for this is twofold. In the cases of necessity and possibility, Lipton only accepts a very limited and restricted notion of explanation. He only considers explicit causal explanations that refer to actual causes to count as explanations. This restriction is unreasonable in light of scientific practice, where various kinds of explanations (unificationist, counterfactual, analogue, probabilistic, logical, and this list is not meant to be extensive) are used to achieve understanding of phenomena, and of the various accounts of explanation proposed by philosophers to accommodate the diversity of explanations. In the cases of causation and unification, however, Lipton focuses too much on skills or tacit understanding, which leads to a view of understanding that is too narrow to accommodate the demands that Lipton himself sets up for understanding. He wants that the understanding is assessable, that the understanding subject herself or other agents in the community can judge the acquired understanding as adequate, deep, subtle, or insufficient. However, Lipton does not explain or specify how this should be possible if understanding is tacit and unrelated to any explicit representation like explanation. While I think that Lipton is right in putting so much emphasis on skills or tacit understanding to highlight the difference between understanding a phenomenon and knowledge of a phenomenon, which will be the topic of chapter four, I do not see how this claim automatically qualifies or amounts to understanding being *completely* separated from explanation. Especially when we think about epistemic activities like science and scientific understanding, it remains unclear in which way such a form of tacit understanding would be more valuable than understanding that can (partially) be made explicit and hence evaluated. And as I argue in this section, Lipton could not give a convincing argument to this effect.[41]

Independent of the persuasiveness of Lipton's position and his examples, the question about the relation of explanation and understanding has not lost any of its topicality in the last decade. In this context, two kinds of understanding lie at the center of the discussion: objectual and explanatory understanding. The former is said to be possible without explanation, whereas the latter, as the name suggests, is based on explanation. I now turn to these two kinds of understanding and the debate that emerged around them.

41 For another line of argument why Lipton's examples as cases of understanding without explanation fail, see Khalifa (2017b), chapter 5.

3.3 Objectual and explanatory understanding – a controversy

Lipton's work did not settle the question of whether understanding could be possible without explanation. Quite the contrary, the (possible) relation to explanation still is a central topic in the debate on understanding. This concerns philosophers of science as well as epistemologists. In the same year in which Lipton's cases for understanding without explanation were published, Jonathan Kvanvig introduced a different argument for the possible independence of understanding from explanation, which is not related to Lipton's examples at all, and a new terminology that should become formative for the debate on understanding, namely objectual and explanatory understanding. In section 3.3.1, I present Kvanvig's notions of objectual and explanatory understanding and his argument for their difference in (not) being related to explanation. Kvanvig's argument is extensively addressed by Kareem Khalifa and section 3.3.2 is devoted to Khalifa's criticism of Kvanvig's distinction. In section 3.3.3., I relate Khalifa's critique on Kvanvig's argument to my criticism of Lipton's view of understanding without explanation. I conclude that Lipton and Kvanvig, while presenting different and independent arguments for a separation of understanding and explanation, both make the same mistake of having a too narrow view of (scientific) explanation that is not defendable in light of an explanatory pluralism, which is supported by scientific practice and the various philosophical accounts of explanation. Thus, also Kvanvig fails to provide an argument for why scientific understanding should or could be independent of explanation.

3.3.1 Kvanvig's argument for a distinction of objectual and explanatory understanding

In order to make sense of Kvanvig's distinction between objectual and explanatory understanding, I will first lay out some claims he makes about understanding in general. At the beginning of his analysis, Kvanvig points to the different foci that investigations on knowledge or understanding have. When investigating knowledge, the focus lies on issues like what the evidence of a belief is, how reliable a belief is, or whether the connection between the reasons for a certain belief and the truth of this belief were formed accidentally. When understanding is the target of investigation, other questions are addressed. How are pieces of information connected to each other? What is the extent of the grasp of structural relations between the central items of information regarding which the question of understanding arises? Concerning understanding, questions about structural relations between pieces of information that are grasped arise and are addressed, while investigations on knowledge focus on questions like the non-accidentality or justification of

knowledge.[42] So, in contrast to Lipton, Kvanvig argues that understanding is not reducible to knowledge. This differentiation will be important for the chapters to come, though not for the discussion in this chapter.

In the case of understanding, the body of information that an individual possesses is constituted by a grasped relatedness of pieces of information. Importantly, Kvanvig claims that the mere existence of explanatory and other connections between these items or the easy accessibility of these connections are not enough for understanding. An already-possessed awareness of the connections is also required. An already-mastered grasp is needed to recognize the connections. If this grasp is absent, there can be as many obvious relations between pieces of information as you want, they would not be recognized by a subject and, therefore, the subject would not understand the body of information. In short, Kvanvig characterizes understanding as grasping structural relations and grasping amounts to making sense of the object of understanding.[43] Unfortunately, Kvanvig does not clarify the notion of grasping further and it remains obscure what it means that a subject is able to make sense of an object. I will return to the concept of grasping in section 4.3.1.

According to Kvanvig, the structural relations that can be grasped by a subject include not only explanatory, but also logical and probabilistic relations, and explanatory relations are only incorporated into understanding when they exist. A subject can have objectual understanding of an indeterministic system by grasping logical or probabilistic relations present in this system even if no explanatory relations between parts of the system exist. He uses an example to illustrate this point. The reader is asked to imagine an electron that goes to the left rather than to the right. The probability of the electron going left is exactly the same as the probability of going to the right. Such a quantum-mechanical system is an indeterministic system, we will not know in advance which way the electron will take. Kvanvig claims that whichever way the electron will go, it will do so by chance and there is no cause of why the electron goes that way. "If there is no cause of the electron going to the left rather than the right, there is no explanation why the electron went to the left either."[44] According to Kvanvig, it is possible to objectually understand such indeterministic systems by grasping logical or probabilistic relations, but it is not possible to have explanatory understanding of such a system, because there are no explanatory relations between facts of the system. In short, Kvanvig argues that we are able to objectually understand indeterministic systems that cannot be explained because

42 See Kvanvig, J. L. (2009), "The value of understanding." In Haddock, A., Miller, A. & Pritchard, D. (eds.), *Epistemic value*, pp. 95–111, Oxford, Oxford University Press, DOI: 10.1093/acprof:oso/9780199231188.001.0001, pp. 96f.

43 See ibid. pp. 97ff.

44 Ibid. p. 101.

they do not contain explanatory relations. However, such systems contain probabilistic or logical relations that can be grasped. Therefore, objectual understanding does not reduce to explanatory understanding, which is a type of propositional understanding.[45]

After presenting the example of the electron, Kvanvig concludes that objectual understanding cannot be reduced to explanatory understanding, because there is no causal explanation or relation of the event that could be grasped, then possessed by and attributed to a subject. It is not possible to state that Jill understands why the electron went left, since she could not grasp any explanatory relation. Notwithstanding this differentiation, Kvanvig claims that a unified conception of understanding, in contrast to the concept of knowledge, should be aspired. Neither objectual nor explanatory understanding are reducible to knowledge. We can objectually understand indeterministic systems and we can explanatorily understand deterministic systems, since deterministic systems contain explanatory relations that we can grasp. In both cases, understanding amounts to grasping structural relations, which is something different than having knowledge. Kvanvig does think that understanding as well as knowledge can be subdivided into their propositional, explanatory and objectual forms, but these do not affect the general difference between understanding and knowledge. In all cases of propositional, explanatory or objectual knowledge, something like non-accidentality is of interest, whereas cases of objectually understanding indeterministic systems and explanatorily or propositionally understanding deterministic systems comprise a grasp, a sense-making, of the relations involved, which is not covered by any of the forms of the concept 'knowledge'.[46]

To summarize, Kvanvig argues that understanding is the grasp of structural relations of the object that should be understood. A subject gains explanatory understanding of the object if she grasps explanatory relations, and she gains objectual understanding if she grasps logical, probabilistic or any other kind of relations that

45 See ibid. pp. 101f. Kvanvig merely refers to an intuition that "it is tempting to adopt the thesis that [explanatory understanding] can be explained in terms of propositional understanding." Ibid. p. 96. However, the identification of explanatory understanding with propositional understanding is a debated issue. For example, Christoph Baumberger argues that a reduction of "explanatory to propositional understanding is either impossible or unhelpful." Baumberger (2011), p. 87. He sticks to this opinion and provides the same argument in his later work again, namely "that explanatory understanding cannot be reduced to propositional understanding." Baumberger, Beisbart & Brun (2017), p. 25.

46 See ibid. pp. 97, 101f. Kvanvig then goes on to argue that understanding is compatible with Gettier-cases or types of epistemic luck, which is not the case for knowledge. This observation provides additional support for the distinction between understanding and knowledge, see ibid. pp. 103–109. Since I am concerned with the relation of understanding and explanation in this chapter, and not with the relation of understanding and knowledge, I will not discuss the question of the possible compatibility of understanding with epistemic luck.

are not explanatory. The concept 'understanding' always refers to (the extent of) this grasp, while the concept 'knowledge' addresses issues of reliability or non-accidentality of beliefs. Therefore, understanding in all its forms is not reducible to any form of knowledge.

3.3.2 Khalifa's argument for a reduction of objectual to explanatory understanding

Although I agree with Kvanvig that understanding cannot be reduced to knowledge, a claim I elaborate in chapter four, I disagree that objectual understanding and explanatory understanding can be clearly distinct. Kareem Khalifa is not convinced by Kvanvig's argumentation either and directly addresses Kvanvig's account. I now present Khalifa's arguments against Kvanvig, before I relate Khalifa's criticism of Kvanvig's distinction to my arguments against Lipton's examples in the next section.

Khalifa identifies four features that Kvanvig seems to assume in the system of the moving electron, which he provides as an example for objectual understanding without explanation:

> 1. The explanation has to be *causal*: "if there is no cause of the electron going left rather than right, there is no explanation why the electron went to the left either."
>
> 2. The explanandum is *indeterministic*: "In indeterministic systems, things happen that are uncaused, both probabilistically and deterministically."
>
> 3. The explanandum is *contrastive*: "the events in question are irreducibly indeterministic in such a way that there is no causal explanation as to why the actual events occurred rather than some other events."
>
> 4. The explanandum contrasts *equally probable* outcomes: "If the probability of an electron going to the left is precisely the same as that of going to the right (and there is no hidden variable to account for the difference), then whichever way it goes is the result of chance rather than causation."[47]

Khalifa concludes that "Kvanvig is denying the possibility of causal, indeterministic explanations of explananda contrasting equally probable outcomes."[48] Khalifa addresses all of the four features in turn to show that there are in fact explanatory relations present in the electron-example, which implies that it is possible to explana-

47 Khalifa, K. (2013), "Is understanding explanatory or objectual?" *Synthese*, 190, pp. 1153–1171, p. 1158, DOI: 10.1007/s11229-011-9886-8, original emphasis.

48 Ibid. p. 1158.

torily understand indeterministic systems and amounts to a reduction of objectual to explanatory understanding.

First, there is no good reason to limit the notion of explanation to causal explanation. Khalifa also argues for an explanatory pluralism. The mere fact that several kinds of explanations exist (causal, deductive, model-based, unificationist, mechanistic, functional, probabilistic, counterfactual, among others) and are used in scientific practice is a good reason to take all these kinds of explanation to be permissible in certain contexts and all of these kinds can provide explanatory understanding. If scientists in Kvanvig's example grasp the logical or probabilistic relations that he takes to be present, they will perform some reasoning about the system considering the "probability distributions about an electron's position [derived] from its quantum state. [To do so, scientists will have to incorporate the set of] quantum numbers and the eigenfunction that characterize the possible states of the quantum mechanical system"[49]. This line of reasoning can definitely be characterized as an explanation based on a theory, in this case, quantum mechanics, according to Khalifa.[50]

Second, Kvanvig identifies indeterminism with the absence of causes. However, as Khalifa highlights, the fact that a system is indeterministic does not automatically mean that there are no causes in play. It simply means that the same cause can produce varying outcomes. Therefore, there might causal relations (and hence, explanatory relations on Kvanvig's account). Moreover, if one accepts the first critique and does not limit the notion of explanation to causal explanation, it becomes even more obvious that we can have explanations of indeterministic systems. Some theories of explanation admit of indeterministic explanations. Christopher Hitchcock presents the core idea of indeterministic explanations as "a factor *A* is explanatorily relevant to [an explanandum] *E* if *A* plays a non-eliminable role in determining the probability of *E*."[51] If Kvanvig denies the possibility of explanations of this form, he is at odds with scientific practice where indeterministic explanations of the type conceptualized by such philosophical accounts can be found, so Khalifa. Since indeterministic explanations include theoretical statements, scientists derive probabilities or chances that Kvanvig views as non-explanatory from theories that are undeniably explanatory.[52] By using quantum theory, scientists can explain "why an electron had

49 Ibid. p. 1158.

50 See ibid. p. 1158.

51 Ibid. p. 1159. For more details concerning Hitchcock's argument, see Hitchcock, C. R. (1999), "Contrastive explanation and the demons of determinism." *British Journal for the Philosophy of Science*, 50 (4), pp. 585–612, DOI: 10.1093/bjps/50.4.585. For further information about probabilistic explanation, see e.g. Railton, P. (1978), "A Deductive-Nomological Model of Probabilistic Explanation." *Philosophy of Science*, 45 (2), pp. 206–226, DOI: 10.1086/288797; or Strevens, M. (2008), *Depth*. Cambridge (MA) and London, Harvard University Press.

52 See ibid. p. 1160.

a probability *p* of being in a spatial region *x* at a given time interval *t*. […] If the quantum state were different, then the probability of the electron being in a spatial region (e.g. "the left") would be different."[53]

So, it is possible to indeterministically explain why the electron went left. But what about the third requirement, that the explanandum is contrastive? If it is not possible to explain "why the electron went left *rather* than right", will this strengthen Kvanvig's argument? In other words, do contrastive explanations imply determinism? Not necessarily, according to Khalifa. He draws on Glymour's notion of parity, which states that all possible outcomes of a system can be explained by using the same information.[54] The same information (namely the derivations from the electron's quantum state) do explain why the electron went left, why it did not go right, why it could have gone right etc. Because the system is indeterministic, no further information are relevant for the contrast. In fact, there is no contrast in an indeterministic system that could be grasped, neither explanatorily nor objectually, "because the same factors produce both a likely outcome and an unlikely one – that is the crux of indeterminism."[55] And everything that is close to the contrast (e.g. why the electron did not go right) will be explained by an indeterministic explanation. The two explananda ("the electron went left" and "the electron did not go right") have the same explanans, namely the respective quantum states of the electron. Therefore, parity supports the reduction of objectual understanding to explanatory understanding.[56]

However, Kvanvig could object that with this strategy of parity, we are actually explaining different explananda than the one he offers in his example. Drawing on parity, we can explain "why the electron went left", "why it did not go right", or "why it could have gone right", but we do not explain the contrastive expanandum "why the electron went left *rather* than right". Fortunately, Hitchcock's account of contrastive indeterministic explanations provides a solution to this objection.[57] "*A* [should be viewed] as explanatorily relevant to the contrastive question 'why *E* rather than *F*' if *A* continues to be relevant to *E* when the (exclusive) disjunction *E* v *F* is held fixed. […] This means that *A* is explanatorily relevant to *E rather than F* when $P(E|(A\&B)\ \&\ (E\ v\ F)) \neq P(E|B\ \&\ (E\ v\ F))$."[58] *B* represents the given background conditions that are held fixed. Let's consider a pedestrian example. The explanandum that shall be explained is "Mary ate candy rather than fruits on Friday" (*E* v *F*), although she is on a diet

53 Ibid. p. 1161.

54 See Glymour, B. (2007), "In defence of explanatory deductivism." In Campbell, J. K., O'Rourke, M. & Silverstein, H. (eds.), *Causation and explanation*, pp. 133–154, Cambridge (MA), MIT Press.

55 Khalifa (2013), p. 1161.

56 See ibid. pp. 1161f.

57 See ibid. pp. 1161f.

58 Hitchcock (1999), p. 587.

for weeks (*B*). The explanatorily important factor *A* is that Mary's two best friends, who she met on Friday, offered her some candy. The explanans "because her friends offered her candy" explains both explananda "Mary ate candy" as well as "Mary ate candy rather than fruits". If Mary had not met her friends, the probability of her eating candy would have been much lower. In either case, the structural relations that could be grasped can be incorporated into an explanation of the system.

The last feature of Kvanvig's example is the equal probability feature of the system. One could deny that contrastive explanations imply determinism and then argue that contrastive indeterministic explanations are possible only when the probabilities of the outcomes are different. In this case, since the probabilities of the electron's going left or right are the same, the event could not be explained, and some kind of non-explanatory understanding is involved. This position is unreasonable, according to Khalifa, since it confuses the source of explanatory relevance. It is not necessary for an explanation to make the probabilities of two events different from each other. It can be explained why there is the equal probability of 50% to get head or tail when tossing a fair coin, namely because it is a fair coin with only two realizable options. Hence, an explanation might allow for identical probabilities of two events. Only if the explanans be different would the explanation have to account for these differences in probability. For example, the probability of a coin showing head is 70%, because it is not a fair coin. Additionally, Hitchcock's account of contrastive indeterministic explanations accommodates cases of identical probabilities of outcomes.[59] In sum, there is nothing special about equally probable outcomes.[60]

Khalifa concludes that there is nothing that "precludes the possibility of indeterministically explaining a contrast between two equally probable outcomes"[61]. He calls his general objection to Kvanvig's position and his example *the hidden explanation objection*, according to which logical or probabilistic relations can be explanatory.[62] Kvanvig's restriction of explanations to causal explanations that require the presence of causal relations between events is based on an assumption that is not reasonable in light of an explanatory pluralist position. Probabilistic and logical relations do figure into explanation, and thereby into understanding as well, in a variety of ways: at least, they can play an explanatory role. Khalifa calls this the *Explanatory Role Assumption*.[63] He offers four examples for this assumption:

59 That is, $P(E|(A\&B)\ \&\ (E\ v\ F)) \neq P(E|B\&(E\ v\ F))$ is consistent with equally probable outcomes, i.e. $P(E|(A\&B)\ \&\ (E\ v\ F)) = P(F|(A\&B)\ \&\ (E\ v\ F))$.

60 See Khalifa (2013), pp. 1162f.

61 Ibid. p. 1163.

62 See ibid. p. 1157.

63 See ibid. p. 1165.

> 1. Logical and probabilistic relationships are frequently explanatory, [as in the cases of indeterministic and contrastive explanations].
>
> 2. Logical and probabilistic information may be either an explanans or an explanandum. […] Since explanantia and explananda are essential elements of an explanation, [they can be incorporated into an explanation.]
>
> 3. Even when logical or probabilistic relationships are not "directly" explanatory, they may still be justifying parts of an explanation (i.e. the explanans, explanandum, or the fact that the two stand in a given explanatory relation).
>
> 4. Logical and probabilistic relations can facilitate correct explanations by specifying the presuppositions of a correct explanation.[64]

The first example, where logical and probabilistic relations are directly explanatory, is demonstrated by Khalifa's objection to Kvanvig's example of the moving electron, in which the event (explanandum) is explained in terms of the present probabilistic relations (explanans). That is, the electron went left because it had a certain probability to do so due to its initial quantum state. The second example is supposed to highlight that probabilistic or logical relations can also figure in an explanation if they are the explanandum, and not the explanans, as in the first case. The probability of a coin showing head is 50%, because a fair coin has only two sides that can show up and none of the two sides is favored.

In the third example, situations are addressed in which grasped logical or probabilistic relations give a better justification for an explanation so that the goodness of an explanation improves. In these cases, the explanatory understanding of a subject improves, but she will not have an additional, irreducible form of objectual understanding. Unfortunately, Khalifa does not provide an intelligible example for this third claim. If I understand Khalifa correctly, one could say that if I understand the stability of atoms through the features presented by Bohr's model of the atom, the information that Bohr's model of the atom also explains the emission of spectral lines described by the Rydberg formula provides additional justification for my understanding of the stability of atoms in terms of Bohr's model. However, I admit that this third explanatory role that Khalifa ascribes to logical or probabilistic relations is the least comprehensible one.

In the final example, by specifying presuppositions of an explanation, logical and probabilistic relations add aspects of an explanation.[65] "For instance, my arm bumping the inkwell explains why it spilled, and the inkwell's spilling presupposes (e.g., through logical entailment and auxiliary assumptions) that an object is extended in

64 Ibid. pp. 1165f.

65 See ibid. pp. 1165f.

space. The relationship between the inkwell's spilling and the presupposition is not explanatory, yet without the presupposition, correctly explaining it would be difficult if not impossible (e.g. try explaining why the inkwell spilled if it could have been a one-dimensional object)."[66] The crucial thing to note here is that not every relation or information that contributes in some way to an explanation must itself be explanatory or even explained. In the case of the spilled inkwell, the presupposition that inkwell is extended in space on its own is not explanatory at all for why the inkwell spilled. And furthermore, it is also not necessary to have an explanation of why objects are extended in space. Logical or probabilistic relations can be indispensable for explaining a specific event or object, but they themselves neither need to be explanatory nor explained.[67]

In short, Khalifa argues that objectual understanding, at least in the form in which Kvanvig introduced it, is reducible to explanatory understanding, because the presence of logical or probabilistic relations provides understanding only if they play one of the four explanatory roles.[68] If probabilistic or logical relations do not figure in an explanation by taking one of the four roles, they will not be incorporated into understanding, since it would not be clear how they are related to the phenomenon that should be understood. Therefore, understanding always requires some form of explanation.

3.3.3 The flaws of separating scientific understanding from explanation

Summing up, Kvanvig tries to show with the example of the electron that we can have objectual understanding of a system for which we have no explanation. In his view, we cannot explain indeterministic systems, as these systems do not contain explanatory (causal) relations, but only probabilistic or logical relations. Since understanding is grasping structural relations, we can have explanatory understanding only if we grasp explanatory relations. Thus, we can explanatorily understand deterministic systems, and we can objectually understand indeterministic systems. According to Khalifa, this distinction is not plausible, as scientists can and regularly do explain indeterministic systems, including quantum mechanical systems, through relating probabilistic or logical relations to an explanation.

Is there some common ground in the attempts of Lipton and Kvanvig to specify cases or types of understanding without explanation? Both provide different and independent arguments and examples and do not refer to each other's work. However, a closer look reveals that, despite the differences, both views suffer from the same two flaws. First, they are explicit about only viewing causal explanations to be actual

66 Ibid. p. 1166.

67 See ibid. p. 1166.

68 See ibid. p. 1166.

explanations and they do not allow or consider a pluralism of explanation. If an explanatory pluralism and a generic conception of explanation are adopted, for which I argue in section 3.1, the cases provided by Lipton and Kvanvig are explanatory, just not in a causal sense. It will probably be very hard to find cases of understanding that work without any reference to some type of explanation in this generic sense.

Second, Lipton and Kvanvig do not pay sufficient attention to scientific practice. This becomes particularly clear in Kvanvig's example of the moving electron. Contrary to what Kvanvig claims, physicists can and do explain why electrons or other subatomic particles do certain things based on quantum theory, as Khalifa extensively elaborates. And Lipton would have anticipated the problem his view is facing, namely conceptualizing understanding (of phenomena) as something tacit, while demanding that the quality, the adequacy or depth, of understanding (of phenomena) can be accessed and evaluated. If understanding would be completely tacit and unrelated to explanation, or any other explicit representation, it could not be assessed. Quite obviously, both flaws are related. A closer look at science would have shown that narrowing explanation to causal explanation and taking understanding (of researched phenomena) to be (completely) tacit does not accord with scientific practice. I will substantiate this claim and analyze the relation of tacit and explicit dimensions in science based on the work of Michael Polanyi in chapter four. In any case, various types of explanation are ubiquitous in scientific publications and discourse, and the discoveries made in research are grounded in understanding, at least ideally. Scientists explicitly communicate what they discovered and understood about a phenomenon, the results of their research, and they often do so by using explanations, in order to argue why they think that something about the phenomenon is the case, to provide reasons for why they think that a newly discovered insight about a phenomenon is actually the case. How exactly understanding and knowledge are related is the topic of chapter four. The point I want to make here is that, independent of what understanding turns out to be exactly, neither Lipton nor Kvanvig provide a convincing argument for why scientific understanding of researched phenomena should be separated from explanation. This would leave open the question of how the myriad explanations present in science are related to understanding, and what a type of tacit or non-explanatory understanding would add to explanatory understanding acquired in science that explanatory understanding does not already offer.

Nonetheless, the debate about explanatory and objectual understanding still is far from being settled. Both conceptions gained and maintained central importance in the literature on understanding. In the next section, I address and analyze further attempts to justify a distinction between objectual and explanatory understanding, and therefore a separation of understanding from explanation, and argue that these attempts also fail to make such a separation conclusive for scientific understanding.

3.4 Further attempts to differentiate objectual and explanatory understanding

Kvanvig and Khalifa are by far not the only authors who are concerned with the concepts of objectual and explanatory understanding. In general, objectual understanding is treated as a broader type of understanding than explanatory understanding. Catherine Elgin, for example, follows Kvanvig and distinguishes between propositional understanding, which involves grasping a fact and covers explanatory understanding, and objectual understanding, which consists of grasping a range of phenomena.[69] Baumberger, Beisbart & Brun introduce the following differentiation between the two types of understanding:

(OU) *S* understands some subject matter or domain of things;
(EU) *S* understands why something is the case.[70]

In this section, I present further arguments in favor of and against a distinction between explanatory and objectual understanding and argue that for scientific understanding of phenomena, the distinction between objectual and explanatory understanding remains untenable, also in light of these further arguments.

3.4.1 Differentiating objectual and explanatory understanding according to their targets and vehicles

Christoph Baumberger is another proponent of a distinction between objectual and explanatory understanding. He distinguishes three different types of understanding in terms of the object or target that is understood and the vehicle by which the object is understood. In the case of objectual understanding, the object that is understood is a subject matter, a topic or system (like electromagnetism or global warming), and the vehicle is a comprehensive body of information, like a whole account or theory. The object of explanatory understanding are phenomena that are in some way narrower, like events (the appearance of a certain electromagnetic field or the rise of temperature). The same holds for the vehicle. Whereas a whole body of information or theory is required for objectual understanding, an explanation is the necessary vehicle for explanatory understanding. Finally, Baumberger addresses propositional understanding, by which a fact can be understood (e.g. this particle

69 See Elgin (2017), chapter 3. Interestingly, in an earlier paper Elgin states that objectual understanding is the kind "of understanding that is closely connected to explanation." See Elgin, C. Z. (2007), "Understanding and the Facts." *Philosophical Studies*, 132, pp. 33–42, p. 35, DOI: 10.1007/s11098-006-9054-z.

70 Baumberger, Beisbart, & Brun (2017), p. 5.

is charged, or the temperature has increased) through a proposition.[71] However, he later argues that the concept of propositional understanding is useless, because it either reduces to propositional knowledge or it amounts to explanatory understanding. Therefore, there are only two types of understanding, namely explanatory and objectual understanding.[72]

And these two kinds of understanding are genuinely distinct, according to Baumberger, because explanatory understanding is neither sufficient nor always necessary for objectual understanding. In addition to understanding why some event involved in a subject matter occurred, it also has to be understood what effects the subject matter might have and how it is related to all kinds of other subject matters or systems. Conceiving objectual understanding of a subject matter as explanatory understanding of significant subsets of events concerning the subject matter is not feasible, because explanatory understanding does not include an "awareness of how the different explanations fit into, contribute to, and are justified by reference to a more comprehensive understanding in which they are embedded."[73] These requirements are not fulfilled by Baumberger's conception of explanatory understanding, which is the reason why explanatory understanding is not sufficient for objectual understanding.[74] He provides the following example to illustrate the difference between explanatory and objectual understanding:

> Understanding a subject matter involves more than understanding why some fact involved in it obtains. Besides understanding why it occurs, understanding global warming involves, for instance, understanding what effects (on natural and social systems) it will have, how it is linked to human activities (such as burning fossil fuels and deforestation) and related phenomena (such as the destruction of stratospheric ozone and global dimming), how far greenhouse gas emissions and, as a result, temperatures are likely to rise in the future, and how the changes will vary over the globe. A broader understanding of global warming may even involve instrumental and moral understanding, such as understanding the (dis-)advantages of different responses to climate change (such as mitigation, adaptation and geoengineering), and what a just distribution of emission rights amounts to.[75]

71 See Baumberger (2011), p. 71.

72 See ibid. pp. 86f. I do agree with Baumberger that a conception of propositional understanding is not helpful or illuminating in the discussion about the nature of understanding. This is why I am only concerned with explanatory and objecutal understanding, too. However, even if a useful concept of propositional understanding will be developed in the future, it remains to be seen whether this new conception has any effects on the concepts of explanatory and objectual understanding.

73 Ibid. p. 78.

74 See ibid. pp. 77f.

75 Ibid. pp. 77f.

In this example, explanatory understanding of the events involved in the subject matter (e.g. the increase of greenhouse gas emissions due to human activity) is included in, and therefore a part of, objectual understanding, but explanatory understanding of these aspects does not exhaust the objectual understanding of global warming. Hence, explanatory understanding is not sufficient for objectual understanding. And in some cases, objectual understanding of a subject matter can be gained without any relation to explanatory understanding, as the following example shall demonstrate:

> Eighteenth-century biology, conceived of as a pure science of classification with no interest in explanation but with rigorous criteria of success, seems to provide some understanding of the animal kingdom since its classifications reveal significant similarities and allow successful predictions (e.g. about whether an animal of a hitherto unknown species is warm- or cold-blooded). However, this understanding cannot be formulated as understanding why something is the case (e.g. why some organism has a certain feature or why animals of a certain species exist).[76]

In Baumberger's view, these classificatory theories are not the best vehicle to understand animals, exactly because they cannot provide answers to all these why-questions. Evolutionary theory, which did provide these answers, marked a great advance in understanding. However, since understanding comes in degrees and because the classificatory theories provided at least some understanding, as Baumberger claims, it is wrong to think that explanatory understanding is always and in every case included in objectual understanding. Therefore, explanatory understanding is not necessary for objectual understanding. Still, according to Baumberger, both examples show that *typically* explanatory understanding is a part of objectual understanding. In order to have objectual understanding and not merely explanatory understanding, more relations have to be grasped by using a more comprehensive body of information as it would be necessary for explanatory understanding. Baumberger identifies grasping with the manifestation of certain abilities and claims that more of the same abilities, which are already necessary for explanatory understanding, are needed in the case of objectual understanding.[77]

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76 Ibid. p. 78. Baumberger took this example from Gijsbers, who presents an account of understanding through unification without explanation. However, Gijsbers, as all authors who argue for an account of understanding without explanation, employs a very narrow notion of explanation, since he ties explanation to determination. As I have already argued in sections 3.1 and 3.3, if we allow for an explanatory pluralism that is neither tight to causation nor to determination nor any other concept, we will see that the animal kingdom can be explained in terms of similarity or kinship. For more details concerning Gijsbers' account, see Gijsbers (2013).

77 See ibid. pp. 78f. The concept of grasping will be further discussed in section 4.3.1.

However, Baumberger cannot argue convincingly that explanatory understanding is neither sufficient nor necessary for objectual understanding. Basically, his argument for the claim that explanatory understanding is not *sufficient* for objectual understanding rests on two assumptions. First, objectual understanding requires *more* of the same abilities as explanatory understanding to grasp more relations of various kinds, as explanatory understanding is limited to the understanding of causes of an event, whereas objectual understanding includes probabilistic, teleological, conceptual and other forms of relations as well.[78] This argumentation only shows a difference in degree between explanatory and objectual understanding, but not in kind, precisely because *more of the same* abilities are necessary. If Baumberger could have shown that objectual understanding requires genuinely different abilities than explanatory understanding, his claim would stand. He does not show that, as he states that "compared with a single instance of explanatory understanding, objectual understanding of a subject matter involves grasping more dependence (and similarity) relations in and by means of a more comprehensive body of information […] Understanding global warming involves more of the same abilities as does understanding its causes."[79] And second, as Lipton and Kvanvig, Baumberger also seems to have a very narrow concept of explanation that only allows for causal explanation, since explanatory understanding amounts to abilities to understand causes of an event. As I especially argued throughout sections 3.1 and 3.3, such a narrow causal notion of explanation is inappropriate for accommodating the diverse types of explanations found and employed in scientific practice. If a pluralistic notion of explanation is accepted, various kinds of explanation can easily accommodate the grasping of various kinds of relations present in a subject matter, which can serve an explanatory purpose or role. If more of the various kinds of relations are grasped than only causal relations, the explanatory understanding will be better.

To show that explanatory understanding is not even *necessary* for objectual understanding, Baumberger presents the example of eighteenth-century biology and claims that these theories provide understanding of the animal kingdom without explaining why animals have specific characteristics. Therefore, one can achieve objectual understanding with these theories as vehicles, but not explanatory understanding. I disagree and claim that these theories do not provide understanding without some kind of explanation. True, classificatory theories do not causally explain why animals have certain characteristics or why they exist at all, but the successful prediction of whether a newly discovered species is warm- or cold-blooded can be explained by referring to the classificatory criteria provided by the theory. Whether a new species is warm-or cold-blooded can be explained by reference to already established taxa and their assigned criteria. It will be predicted that, for example, a

78 See ibid. p. 79

79 Ibid. p. 79.

new turtle species is cold-blooded exactly *because* it belongs to a taxon whose members are all cold-blooded. The newly discovered species must share some characteristics with already established taxa, and based on the identified (dis-)similarities, the membership to a specific taxon can be clarified and additional characteristics predicted. If you discover a new animal species and see that this animal has flakes, a carapace and flippers, you conclude that it is a turtle. Based on that insight, you predict that this animal is also cold-blooded, because turtles are cold-blooded.

In light of some standards, this might not be a very good or satisfying explanation, but it clearly is an explanation. Again, if the notion of explanation is not limited to causal explanation, but instead seen as a representation that provides reasons for features of the phenomenon, like my generic conception of explanation introduced in section 3.1, explanations are involved in eighteenth-century biology as well. Classificatory biology provides reasons for why new discovered reptile or fish species will be cold-blooded, while new discovered birds or animal species will be warm-blooded. If predictions based on a classification system fail, this would point to flaws in your classification system and also in your understanding of the animal kingdom. If you cannot provide reasons for why you made a certain prediction, why you think that a new animal species will have a certain characteristic, you would not have made a prediction, but merely a guess, as you would not have understood the animal kingdom through the classificatory theory. Since Baumberger even goes on to argue that evolutionary theory, which provides explanations, trumped the other biological theories and that, typically, objectual understanding includes explanatory understanding, he does not provide a convincing argument for the independence of objectual understanding from explanatory understanding. Trying to claim that explanatory understanding is not necessary for objectual understanding seems to be an artificial and counter-intuitive move.

In sum, Baumberger argues that objectual and explanatory understanding are distinct, as these types of understanding have different objects as their targets (subject matters, topics, or systems vs. events) and employ different vehicles (whole accounts or theories vs. explanation). They differ in terms of vehicles and targets, because explanatory understanding is neither necessary nor sufficient for objectual understanding. Explanatory understanding is not sufficient for objectual understanding, as objectual understanding requires more of the same abilities, and it is not even necessary for objectual understanding, since it is possible to understand phenomena in the world based on theories that do not provide explanations, like classificatory theories in biology. I have argued in this sections that Baumberger fails to provide a convincing argument for why explanatory understanding is neither sufficient nor necessary for objectual understanding. On the one hand, as he demands that for objectual understanding more of the same abilities as for explanatory understanding are required, the difference between explanatory and objectual understanding will only be a matter of degree, but not in kind. Objectual understanding

would just be a label for 'better' or 'more comprehensive' explanatory understanding, but we will always talk about the same kind of understanding, namely explanatory understanding. On the other hand, Baumberger, like Lipton and Kvanvig, limits his notion of explanation to causal explanation. Having explanatory understanding of an event amounts to grasping its cause. Taking explanatory pluralism into account and allowing reasons to be a variety of explanantia, and not only causes, reveals the ubiquitous presence of explanation and their function of relating theory and worldly phenomena. So, the ground on which Baumberger rests his claim that objectual and explanatory understanding differ in terms of their targets and vehicles is collapsed. Or is it not?

3.4.2 Why a differentiation in terms of the target does not hold

In the work of Stephen Grimm, I find additional support for the identification of objectual and explanatory understanding, since Grimm does not think that the distinction between the two forms should or could be drawn, either. Again, Baumberger differentiates between explanatory and objectual understanding in terms of their vehicles (explanation vs. theory) and their objects (event vs. whole subject matter). Grimm agrees that the objects of understanding are of various kinds. It is possible to understand subject matters like quantum mechanics, particular states of affairs like the spilling of a cup, institutions like the U.S. House of Representatives, or persons like our best friends.[80] However, Grimm claims that "the differences among these various objects of understanding can be (and have been) overstated, and the reason is that in all these cases understanding seems to arise from a grasp of what we might call dependency relations. Although when it comes to more complex structures (the House of Representatives, for example), *more* of these relations are grasped than when it comes to understanding particular states of affairs; this does not amount to a difference in kind but instead to a difference in degree."[81] Grimm himself does not refer to or cite Baumberger, but instead addresses Kvanvig's account of a distinction of objectual and explanatory understanding and Pritchard's notion of holistic and atomistic understanding.[82] I apply the critique offered by Grimm to Baum-

80 These are the examples proposed by Grimm, see Grimm (2017), p. 214.

81 Ibid. p. 214, original emphasis.

82 Although Pritchard does distinguish holistic and atomistic understanding, he does not provide a detailed account of these forms of understanding. He merely states that atomistic understanding, understanding why such-and-such is the case, is the paradigm usage of 'understanding', that holistic understanding applies to subject matters, and that both usages are related to each other. Pritchard is more interested in the epistemic value of understanding than in its different types. See Pritchard, D. (2010), "Knowledge and Understanding." In Pritchard, D., Millar, A. & Haddock, A., *The Nature and Value of Knowledge: Three Investigations*, pp. 3–90, New York, Oxford University Press, DOI: 10.1093/acprof:oso/9780199586264.001.0001.

berger's notions of explanatory and objectual understanding, since the differentiation in terms of their objects is a crucial characteristic of the two types of understanding in Baumberger' view.

To illustrate his argument that the various objects of understanding only amount to a difference in degree, but not in kind, Grimm presents the two examples of understanding why a cup spilled and understanding the U.S. House of Representatives, which Kvanvig and Baumberger would distinguish as cases of explanatory and objectual understanding. In the first case, Claire sits in a café and observes how the person sitting at the next table accidentally nudges her table with her knee, which causes the shaking of the table as well as of the cup and results in the spilling of the cup. Understanding this event requires Claire to correctly identify the nudging as the cause of the spilling. Claire has to be able to grasp the correct causal relation that led to this event and to omit irrelevant factors such as the time of the day, the music playing in the background etc. In other words, in order to understand the spilling of the cup Claire has to grasp the genuine dependency relation that led to this event (in this case, a causal relation), and not an "empty" or non-causal relation like, for example, between the spilling and the time of the day.[83]

After finishing her coffee, Claire goes back to the library to prepare for an exam. Let us assume Claire is a student in political science and has to learn how the U.S. House of Representatives functions. In contrast to the spilling of the cup, which is a certain event or a particular state of affairs, the House of Representatives is better referred to as a large and complex subject matter. Understanding the House of Representatives means to grasp how the various elements of the institution are dependent on each other, for example "what it takes for bills to be proposed, or for amendments to be introduced, or for them to become laws; who is entitled to speak, at which times; how committees are formed, and how leadership is determined, and so on."[84] Baumberger would argue that this understanding of the House of Representatives is genuinely different than the understanding of the spilling cup, since Claire does not want to understand a particular event via an explanation, but instead a large subject matter via a huge body of information. Grimm disagrees. Just as for understanding the spilling of the cup, to understand the House of Representatives Claire has to be able to grasp the genuine dependency relations between elements of the system and to omit empty relations. Grimm admits that the understanding of

83 See Grimm (2017), pp. 214f. Grimm's idea of grasping the genuine dependency relation between the present factors to understand a certain event instead of „empty" dependency relations could serve as a basis for an account of understanding and misunderstanding. It could be argued that Debbie misunderstood the spilling of the cup if she, for whatever reason, takes the music in the café to be the cause of the spilling. However, the elaboration of this idea will be a task for future work.

84 Ibid. p. 215.

the House of Representatives is more demanding, since many dependency relations have to be grasped and that a visual representation of the grasped dependency relations in the case of the House of Representative would look more like a web, whereas the understanding of the spilling of the cup would look like a singular causal chain. Still, this only amounts to a difference in degree of understanding, not in kind. Even though understanding can vary, on the one hand, with respect to the quantity of grasped dependency relations and, on the other hand, in terms of different foci, namely either on individual nodes (for particular events) or on whole systems, the basis of understanding in all these cases is the grasping of the correct dependency relations. According to Grimm, this fundamental similarity is much more relevant for the concept of understanding than the observed differences, which can easily be accommodated as being the characteristic features for different degrees of understanding.[85]

Khalifa addresses this issue about the object of understanding as well and calls for a *Fair Comparison Requirement.* If one wants to compare objectual and explanatory understanding, the comparison should, for example, take the following form:

a) Lea (objectually) understands the occurrence of the Arab Spring in the early 2010s.
b) Isa (explanatorily) understands how/why the Arab Spring occurred in the early 2010s.[86]

Khalifa accuses proponents of a distinction between the two forms of understanding of frequently making unfair comparisons. For example, they would compare b) with something like

a') Lea (objectually) understands the Arab Spring.

In a'), a different target is addressed as in a) and b). To make a proper comparison to a'), one needs to consider cases like

b') Isa (explanatorily) understands how/why the Arab Spring took place in the way it did.

As soon as fair comparisons are made and objectual apples are no longer compared to explanatory oranges, the distinction between objectual and explanatory understanding seems to disappear.[87]

85 See ibid. pp. 215f.

86 Khalifa also claims that understanding *why* is too narrow to account for explanatory understanding, since answers to some how-questions, like "How does DNA replicate?" are also explanations. See Khalifa (2013), p. 1164.

87 See ibid. p. 1164f.

So, there seems to be little or no hope for a differentiation of objectual and explanatory understanding in terms of their targets. If we pay attention to what precisely the object of understanding is and take understanding to be something like the grasp of correct dependency relations, a view that is not contested by any of the scholars I refer to so far, including Baumberger,[88] a genuine difference of explanatory and objectual understanding in terms of their targets disappears. But what about the other distinction in terms of the vehicles, a theory or explanation, respectively? Can such a distinction be maintained?

3.4.3 Can the difference concerning the vehicle be maintained?

This is exactly what Christoph Baumberger & Georg Brun want to argue for, to defend a genuine distinction of objectual and explanatory understanding in terms of the vehicle. They refine their notion of objectual understanding and limit it to the understanding of a subject matter by means of a theory. They explicitly exclude other forms of understanding, like understanding other things than subject matters (e.g. the specific action of a person), understanding via other means than theories, understanding theories themselves and, of course, explanatory understanding, which Baumberger & Brun characterize as understanding why something is the case by means of an explanation. At this point, they address Grimm. Baumberger & Brun argue that, even if there is no genuine difference between the objects of understanding, a state of affairs and a subject matter, in the sense that a subject matter is a very complex state of affairs, the genuine difference in the vehicle of understanding remains.[89] "Objectual and explanatory understanding are also distinguished in terms of the means by which they are achieved. Now, theories enable explanations, but they are not merely sets of systems of explanations. Hence, even if subject matters are simply complex states of affairs, this does not imply that the distinction between objectual and explanatory understanding is spurious."[90] Baumberger & Brun do not adopt a specific account of theories, and view theories to be systems of propositions.

Theories are not themselves explanations, but rather, according to Baumberger & Brun, enable (objectual) understanding and also explanations. Since the authors want to defend a strict distinction between objectual and explanatory understanding in terms of their vehicles, they seem to argue that a subject can gain understanding of a subject matter on the basis of a theory without generating an explanation

88 See Baumberger (2011), p. 79.

89 See Baumberger & Brun (2017), pp. 166f. Note that Baumberger has limited his notion of objectual understanding significantly. In Baumberger (2011), he presented the vehicle of objectual understanding more generally as a comprehensive body of information (a whole theory or account) and the object of understanding as a subject matter, a topic, or a system.

90 Baumberger & Brun (2017), p. 167.

from the theory. Is that a plausible idea of how science produces understanding of the natural world? It is not. As Khalifa argues in his reply to Kvanvig's example of the moving electron, which I address in section 3.3.2, scientists usually employ a theory (e.g. quantum theory) to generate an explanation of the respective phenomenon (the subject matter) they want to understand. Henk de Regt provides a whole account of scientific understanding, according to which understanding is achieved by developing explanations of phenomena on the basis of intelligible scientific theories, and he presents three detailed case studies that make up the basis for his account.[91]

Surprisingly, although Baumberger & Brun claim that objectual understanding through a theory and without an explanation is possible, they themselves present examples of their notion of objectual understanding where the subjects do provide explanations! According to Baumberger & Brun, a scientist who understands climate change must be able to use a climate model in *explanations*, and a philosopher understands issues of medical ethics through an ethical theory if she can provide *explanations* for actual or counterfactual cases.[92] Thus, the notion of objectual understanding from Baumberger & Brun does *not* exclude explanation from understanding! It merely states that an explanation is not the starting point or origin of understanding, in contrast to explanatory understanding. That means, a subject would have explanatory understanding of a subject matter if she receives an explanation as an answer to her question while lacking any theory. And she would have objectual understanding if she uses a theory as a basis for generating explanations. Finnur Dellsén, whose account of objectual understanding without explanation I present in section 2.3, admits as well:

> Although [my] account is not an explanatory account of understanding, it does preserve the kernel of truth in explanatory accounts in so far as a sufficiently accurate and comprehensive dependency model contains the sort of information about a phenomenon that is required to explain it and related phenomena, provided that they can be explained at all. This is so for the simple reason that the dependence relations that these models must correctly represent in order to provide understanding (for example, causal and grounding relations) are precisely the sort of relations that form the basis for correct explanations.[93]

Although Dellsén argues for an account of objectual understanding, he, too, does not deny a strong connection between understanding and explanation. I get back to the issues of Dellsén's account in more detail in chapter six.

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91 See section 2.1 for a summary of de Regt's account. For more details concerning his account and the case studies, see de Regt (2017).

92 See Baumberger & Brun (2017), pp. 167f.

93 Dellsén (2020), pp. 1282f.

So, scientific understanding is *explanatory understanding* in the sense that explanations are a necessary component of scientific understanding. But this does not mean that scientific understanding is achieved only via explanation. As the examples from Baumberger & Brun and the discussion of Khalifa's view in section 3.3 make clear, taking understanding to be necessarily explanatory does not mean that every component of one's understanding has to be explained or that the understanding is exclusively based on explanations. It only means that *explanations are necessarily somehow involved in the understanding* of a phenomenon. Again, in practice scientists achieve explanation and understanding of a phenomenon via a combination of background knowledge, theories, empirical data and methods. To claim that scientific understanding is, therefore, always objectual is possible *if and only if* the important role of explanation for understanding is appreciated. However, the term 'objectual' understanding is problematic, because it is used to oppose explanatory understanding. As I show in this and the previous section, objectual understanding is often defined or used as a form of understanding that does not require or include an explanation. Both notions of objectual and explanatory understanding, in the sense in which they are usually used in the debate, do not accommodate scientific understanding. Explanatory understanding is too narrow in the sense that it is achieved through an explanation only, objectual understanding gets things wrong if it is construed as having no relation to explanation at all. If taken in these senses, both notions need to be broadened if they are to be applicable to scientific understanding. If both notions are extended, the proposed differentiation between objectual and explanatory understanding becomes insignificant. Hence, a differentiation between objectual and explanatory understanding in the case of scientific understanding of phenomena is superfluous (while it might be useful for other types of understanding).

3.4.4 Objectual and explanatory understanding cannot be differentiated

Let me summarize the discussion presented in this section. Baumberger first contrasts explanatory and objectual understanding in terms of their vehicles (explanation vs. theory) and objects (event vs. subject matter). Grimm, in contrast, argues that it is not conclusive to differentiate the two types of understanding in terms of their objects, because structural relations are grasped in both cases. Therefore, the difference between explanatory and objectual understanding is only a matter of degree, but not in kind. Still, Baumberger & Brun object that the difference in the vehicle of understanding, namely an explanation or a theory, remains. Therefore, explanatory and objectual understanding seem to be distinct. However, Baumberger & Brun do claim in the examples they present that subjects need to generate explanations from the theory they use if they want to acquire understanding. Investigations of scientific practice conducted by philosophers of science provide further support for a tight connection of explanation and understanding in science. Additionally, it

becomes clear that the prevalent notions of objectual and explanatory understanding, which were meant to exclude or clearly contrast each other, both do not capture scientific understanding. Therefore, a strict distinction between objectual and explanatory understanding is needless for accounting for scientific understanding. Instead, scientific understanding should be conceived of as understanding that necessarily involves explanation, but it is not achieved only or exclusively through an explanation. Theories or comprehensive bodies of knowledge are necessary for scientific understanding as well. Gaining explanations and understanding of empirical phenomena are two interrelated goals of science, and there is no reason to tear them apart.

3.5 Why scientific understanding and scientific explanation cannot be torn apart

Is explanation necessary for scientific understanding or is it possible to achieve scientific understanding without any explanation? Proponents of the second option present examples in which understanding is (apparently) achieved without explanation or introduce a conceptual difference between explanatory understanding, which is gained merely through or on the basis of an explanation, and objectual understanding, for which a larger body of information is required. As I show throughout this chapter, none of the proposed examples or accounts of understanding without explanation is convincing in light of a pluralist stance on scientific explanation, which should be adopted as it is more appropriate for accommodating scientific practice.

The crucial mistake that all proponents of a separation of understanding and explanation make is to limit the notion of explanation only to causal or deterministic explanation. This flaw becomes especially obvious in the discussions in sections 3.1, 3.2, and 3.3, where I engage with the positions of Lipton and Kvanvig. Such a narrow view on explanation is neither reasonable nor defendable in light of the vast amount of different types of explanation that can be found in various scientific disciplines, including medicine and biology.[94] Or consider physics, where explanation often invokes conservation laws instead of causes. For example, the moon recedes from the earth because of the conservation of angular momentum.[95] The conservation of angular momentum is a (partial) reason for why the moon is slowly drifting away from the earth, but it is not a cause of the phenomenon. The cause is the difference in the

94 See for example Braillard & Malaterre, (2015), or De Vreese, L., Weber, E. & Van Bouwel, J. (2010), "Explanatory pluralism in the medical sciences: Theory and practice." *Theor Med Bioeth*, 31, pp. 371–390, DOI: 10.1007/s11017-010-9156-7.

95 I thank Martin Carrier for mentioning this example.

rotational speeds of the Earth and the moon. The point I want to make here is that in various disciplinary and historical contexts, in which different and changing norms for acceptable explanations are maintained, various forms of explanation can lead to understanding. Therefore, as also de Regt and Khalifa have argued already, a pragmatic and pluralistic position towards explanation should be taken if scientific understanding, understanding gained in science as a whole, should be accommodated. I do justice to this demand by employing my generic conception of explanation and only require that an explanation must present some reason for some feature of a phenomenon.

In addition, Lipton tries to separate understanding from explanation by arguing that, since understanding is tacit and explanation is always explicit, the two things can be independent from one another. Although I agree that understanding should be conceptualized as tacit in some sense, and I address and explain this topic in detail in the next chapter, I disagree that a *purely* tacit conception of understanding without any relation to an explicit representation is appropriate to characterize scientific understanding of phenomena. This is because scientists want to get things right. They want to discover facts about the world, gain knowledge of the world, construct explanations that capture facts about the world and want to understand the world in the right (true) way. Although we know from the pessimistic induction that scientists can never be sure that they reached the ultimate truth about the world, they want to get as close as possible. Science is an epistemic endeavor. If scientific understanding is completely tacit and unrelated to any explicit representation, may it be explanation or something else, it could not be partially communicated. Consequently, it would not be possible for the individual scientist or her colleagues to assess whether her understanding is appropriate in light of the respective standards of the discipline, as the understanding would not be accessible at all. Scientists want to receive the best possible confirmation that what they understood about a phenomenon is true or that it is justified to understand a phenomenon in this or that way. In order to get the best confirmation possible, understanding should somehow be communicated to or shared with other experts in the respective field, and this is only possible if understanding is not conceptualized as being purely tacit.

Finally, in sections 3.3 and 3.4, I argue that the attempt to distinguish explanatory and objectual understanding in terms of their vehicles and targets does not succeed, either. The shared fundamental assumption is that understanding involves grasping relations of the target that is intended to be understood. Grasping these relations can be more or less demanding, given the different kinds and amounts of relations involved in different targets, given their varying complexity. However, possible differences of the objects of understanding only amount to a difference in the degree, but not in the kind of understanding, as the correct relations have to be grasped in any case. Focusing on the vehicle, the extreme conceptions of explanatory understanding as exclusively stemming from an explanation and objectual under-

standing as gained via a whole body of information without an explanation both cannot accommodate scientific understanding. Explanatory understanding is too narrow, as scientists (usually) do not understand a phenomenon exclusively through an explanation without any additional information, and objectual understanding does not do justice to the role of explanations in scientific understanding and practice. In order to find explanations of phenomena, scientists need a huge amount of knowledge, ranging from well-established theoretical background knowledge to newly gained empirical data. And, as I already mentioned repeatedly, explanations are pervasive across the sciences and one of their main goals. If a pluralist position concerning scientific explanation is taken, it will be very hard to find examples of scientific research that were conducted and achieved their goals without generating and presenting explanations. Therefore, a discussion on whether scientific understanding is explanatory or objectual in the senses mentioned above is superfluous. Importantly, however, I am making this claim only for scientific understanding of phenomena, leaving open the possibility that other kinds of understanding, such as every day, practical, or aesthetic understanding, may be (more) clearly distinguished into objectual and explanatory forms of understanding. If it is the case that scientific understanding, in contrast to other forms of understanding, always contains both objectual and explanatory components, this characteristic could be the essential feature that makes scientific understanding distinctively valuable or special. However, whether this is or could be the case will be a question for future investigations.

In sum, why does scientific understanding requires scientific explanation? Conceptualizing scientific understanding as requiring scientific explanation can better accommodate both scientific practice as well as fundamental intuitions regarding understanding. Concerning scientific practice, two features are especially striking. First, explanation is omnipresent in science. And second, explaining as well as understanding phenomena are undoubtedly two goals of science, both achieved through conducting research. If scientific understanding is viewed as requiring explanation and explanation is everywhere in science, understanding will be everywhere, too. Hence, when scientists arrive at an explanation, they will also have gained understanding. No matter what comes first, understanding or explanation, there is no good reason to assume that they might be separated in scientific practice. Whether explanation is the result of understanding or the other way around, they will advance together if understanding is tight to explanation. I address my view concerning the relation of understanding and explanation in detail in chapter six. Furthermore, these thoughts are in line with the widely shared intuition of many scholars involved in the debate that usually understanding and explanation are related. If someone understands something, she will be able to explain this thing, or at least some features or aspects of it. Even proponents of a separation of understanding and explanation, like Baumberger and Dellsén, admit that *usually* understanding and explanation are related. If a scientist gains understanding of a

phenomenon and cannot make anything of this understanding explicit, the understanding would never be open to scrutiny and would not contribute to science as an epistemic community endeavor. How should such a type of tacit understanding be of value to science? Or in other words, why should we attribute understanding of some phenomenon to a scientist who cannot explain any aspect of the phenomenon? My answer is that we have no reason or justification to attribute understanding to this scientists, and hence should not do so. Turning this into a positive formulation, I argue that scientific understanding should require explanation, because such a conception of understanding makes it externally assessable, and hence valuable for science.

The relation of scientific understanding to scientific explanation is one of the issues on which the accounts of scientific understanding from de Regt, Khalifa, and Dellsén differ. I agree with de Regt and Khalifa in this regard, as the three of us take scientific understanding to be necessarily explanatory. However, the three scholars mentioned also disagree on another crucial and in my view more fundamental topic. What is understanding? De Regt and Dellsén take understanding to be some kind of ability, while Khalifa views understanding to be a type of knowledge. If understanding turns out to be an ability, some kind of know-how that is tacit, like Lipton for example claimed, how exactly does understanding then relate to explanation, which is explicit? These are the topics I address in the next chapter.