Sense and Reference of a Believer

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Abstract. Pierre Duhem's philosophy of science was criticized by several of his contemporaries for being surreptitiously influenced by his Catholic faith. In his essay "Physics of a Believer," Duhem defends himself against this appraisal. In this paper, I detail Duhem's argument and reconstruct his view concerning the relationship between theoretical science and religious belief. Ultimately, Duhem claims that the propositions of physical theory cannot contradict the propositions of religious belief because they do not share a domain of reference. To clarify why Duhem holds this view, I present a case study: the discovery of entropy. By examining how the term "entropy" was introduced into thermo-dynamic theory, a story with which Duhem was intimately familiar, much of the apparent conflict in Duhem's philosophy of science is resolved.

I. Introduction

As a physicist and chemist working at the turn of the twentieth century, Pierre Duhem made significant contributions to scientific theory, the history of science, and the philosophy of science. In addition to his intellectual rigor and prolific work, Duhem gained notoriety as an open and committed Catholic during a period in the history of France where religious attitudes were unwelcome, especially among academics. Late in his career, Duhem was accused of intellectual bias resulting from his faith. In the essay "Physics of a Believer," Duhem responds to these criticisms.

Perhaps the most central claim in Duhem's philosophy is that scientific theory does not offer explanations, and the propositions of scientific theory are not metaphysical truths. Duhem's critics suggest he defends this position in order to protect his dogmatic Catholic beliefs from the threat of scientific discoveries. However, Duhem adamantly asserts that his view of science is the product of his intellectual work and is grounded in the nature of science rather than his religious beliefs. In this paper, I unpack Duhem's claims about the relationship between science and religion. I argue that his view is corroborated by his scientific and historical work, as he claims; but because contemporary readers

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are unfamiliar with the particular scientific developments that were of primary interest to Duhem, we tend to misinterpret his prose. To remedy this problem, I offer a case study in the history of entropy and use it to model Duhem's apparently contradictory claims.

II. The Aim and Structure of Physical Theory

Before reviewing Duhem's claims about science and religion, I'll present a brief overview of his conception of scientific theory.

Duhem insists that physical theory is not *explanatory*; the laws provided by physical theories are not explanations of the phenomena they describe. Instead, these laws represent the content of our experience in an orderly way. Duhem writes, "A physical theory is not an explanation. It is a system of mathematical propositions, deduced from a small number of principles, which aim to represent as simply, as completely, and as exactly as possible a set of experimental laws."[1]

Given his disavowal of scientific explanation, Duhem defends a pragmatic formulation of scientific theory. Physical theory is not a revelation of ontological truth but a tool we use to interact with natural regularities, allowing us to engage with the world:

> Concerning the very nature of things . . . a theory . . . teaches us absolutely nothing. . . . Of what use is it then? . . . Instead of a great number of laws offering themselves as independent of one another, each having to be learnt and remembered on its own account, physical theory substitutes a very small number of propositions. . . . Such condensing of a multitude of laws into a small number of principles affords enormous relief to the human mind, which might not be able without such an artifice to store up the new wealth it acquires daily.[2]

This pragmatism arises as a response to worries about the ability of experiments to reveal the essential nature of reality: "The experimental method . . . does not capture the essence of things, but only the phenomena through which things manifest themselves to us. It does not allow us to reconcile the laws with one another except through exterior and superficial analogies which translate the true affinities of the essences from which the laws emanate [and] perhaps frequently betray them."[3]

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[1]Pierre Maurice Marie Duhem, *The Aim and Structure of Physical Theory*, vol. 13, trans. Philip P. Wiener (Princeton, NJ: Princeton University Press, 1954), 19.

[2]Ibid., 21.

[3]Duhem, "The Logical Examination of Theory," *Essays in the History and Philosophy of Science*, ed. and trans. Roger Ariew and Peter Barker (Indianapolis/Cambridge: Hackett Publishing, 1996), 68.

Duhem frequently distinguishes between experimental laws and essences or first causes. He took the experimental method to be quite effective in discovering physical regularities and the laws which describe the phenomena we experience, but he was skeptical about what, if any, information about the essence of nature and the realm of first causes the experimental method might provide.[4]

Skepticism about the connection between the experimental method and metaphysics led to Duhem's most troubling position—his stalwart denial of atomism. Even after Perrin confirmed Brownian motion in 1908, Duhem remained unconvinced that matter is composed of atoms. This is evidenced in his essay "The Logical Examination of Theory" written in 1913:

> The school of the neo-atomists, the doctrines of which center on the concept of the electron, have taken up again with supreme confidence the method we refuse to follow. This school thinks its hypotheses attain at last the inner structure of matter, that they make us see elements as if some extraordinary ultra-microscope were to enlarge them until they were made perceptible to us.
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> We do not share this confidence. We are not able to recognize in these hypotheses a clairvoyant vision of what there is beyond sensible things, we regard them only as models.[5]

Contemporary philosophers, such as Nancy Cartwright, take Duhem's resistance to atomism as evidence that he denies the existence of unobservable entities in scientific theories. If this is right, it's best to think of Duhem as an early antirealist.[6]

Ironically, despite his skepticism about the existence of atoms, and his worries about the ability of science to uncover truth, Duhem asserts that science *does* engage with reality. Although he denies that physical theory ventures "behind the veil" of the phenomena, he maintains that science is slowly progressing toward a "natural classification," an ordering of the phenomena which aligns with natural kinds. As he writes, "[Physical theory] assumes, while being completed, the characteristics of a natural classification. The groups it establishes permit hints as to the real affinities of things."[7]

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[4]Duhem famously worried about theoretical underdetermination and confirmational holism. I suspect these worries are deeply related to the skepticism I discuss here, but to say how is a project too large for the scope of this paper. In "Physics of a Believer" (in *The Aim and Structure of Physical Theory)*, Duhem focuses on the different domains of reference used in physics and metaphysics, and this paper is a treatment of that particular argument.

[5]Pierre Duhem, "The Logical Examination of Theory," 238.

[6]For a detailed explanation of why Cartwright takes Duhem to be antirealist, see Nancy Cartwright, *How the Laws of Physics Lie* (Oxford: Oxford University Press, 1983).

[7]Duhem, *The Aim and Structure of Physical Theory*, 30.

Duhem's claim that science hints at the real affinities of things, in conjunction with his pragmatic description of physical theory, creates a tension for his view. What sort of insight about the natural world is physical theory able to provide if it is instrumental and classificatory? How might a pragmatic process, such as the one Duhem sketches, provide this kind of insight?

This tension is further magnified by Duhem's comments on science and religion. In "Physics of a Believer," Duhem argues that science is *incapable* of contradicting religious doctrines. Nevertheless, he maintains that science does give insight into the natural world and sets boundaries for philosophical conversations. But this is problematic. If science describes the true nature of the natural world, and is to shape our philosophical views, shouldn't it also constrain religious belief?

This robust separation of science and religion led to the suspicion that Duhem's view is strongly influenced by his Catholic commitments and is intended as a response to the secularism of the French Third Republic. The Republicans, as the political majority, contended with the Catholic church, particularly because of its former alliance with the monarchy. Given the success of formalized scientific theories at the time, Republicans relied on the natural sciences to undermine many traditional church ideas.[8] This led to an increasing tension between the church and the state, much of which played out in the domain of education.

Jules Ferry, mayor of Paris and a prominent political figure, argued strongly against the Catholic influence within public education. As Martin writes,

> In the opinion of Jules Ferry, it was the right of every French child to be taught only what had been proved, but there can be little doubt about what, generally speaking, Ferry had in mind, and it did not include the Catholic faith . . . Ferry had set out, with his predecessors and successors, to build on the revolutionary inheritance a national lay educational system free of clerical control or influence, and as a university professor Duhem was to serve that system.[9]

The Church responded to the increasing anti-clericalism by urging Catholic thinkers to engage in public debate, defend the teachings of the Church, and argue that faith and science are not irreconcilable. This call was particularly extended to believers like Duhem, who held positions of intellectual credibility

[8]Helge Kragh, "Pierre Duhem, Entropy, and Christian Faith," Physics in Perspective (*PIP*) 10, no. 4 (2008): 379–95, at 384.

[9]R. N. D. Martin, *Pierre Duhem: Philosophy and History in the Work of a Believing Physicist* (La Salle, IL: Open Court Publishing, 1991), 24–5.

within secularized institutions.[10] Given this social context, and the strange tension at the heart of Duhem's philosophy, contemporaries of Duhem, such as Abel Rey, were suspicious about Duhem's motivation for his view. Rey criticized Duhem, claiming his philosophy of science was a product of his Catholic faith rather than an honest result of intellectual inquiry. In Rey's words, "In tendencies toward a qualitative conception of the material universe, in its challenging distrust with regard to a complete explanation of the universe itself, and . . . with respect to an integral scientific skepticism, Duhem's scientific philosophy is that of a believer."[11]

Put cynically, Duhem espouses the "ideal" view for a Catholic physicist under a secular regime. Science is a valuable form of knowledge that continues to make real progress, and yet, disputes between religion and physical theory are theoretically impossible. This prevents any possible tension between Duhem's identity as a Catholic and his role as a prominent scientist. It also calls into question Ferry's idea that educators ought only teach what can be "proven." If it turns out that scientific theories aren't actually proven, why set them on a firmer intellectual ground than religious doctrine?

Duhem, however, explicitly rejects this characterization of his work in "Physics of a Believer":

> I have never concealed my faith, and that He in whom I hold it will keep me from ever being ashamed of it, I hope from the bottom of my heart: in this sense, it is permissible to say that the physics I profess is the physics of a believer. But surely it is not in this sense that M. Rey meant the formula by which he characterized this physics; rather did he mean that the beliefs of the Christian had more or less consciously guided the criticism of the physicist, that they had inclined his reason to certain conclusions, and that these conclusions were hence to appear suspect to minds concerned with scientific rigor but alien to the spiritualist philosophy of Catholic dogma. . . . If that were the case, I should have been singularly pursuing the wrong course and failed of my aim. In fact, I have constantly aimed to prove that physics proceeds by an autonomous method absolutely independent of any metaphysical opinion. . . . If all these efforts have terminated only in a conception of physics in which religious faith is implicitly and almost clandestinely postulated, then I must confess I have been strangely mistaken about the result to which my work was tending.[12]

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[10]For a detailed history of the social and political context in which Duhem wrote, see S. L. Jaki, *Scientist and Catholic: An Essay on Pierre Duhem* (Front Royal, VA: Christendom Press, 1991).

[11]Duhem, "Physics of a Believer," 273.

[12]Ibid., 274.

According to Duhem, his opinion of physics results from years of participation in scientific research programs as well as his extensive devotion to the history of science, and is independent from his Catholic faith. In fact, he further argues that because he views physics as autonomous—independent from any set of metaphysical beliefs, Catholic or otherwise—his analysis of science neither contradicts nor supports his Catholic faith.

In the next section, I take a closer look at Duhem's comments on science and religion in "Physics of a Believer." I argue that Duhem's view flows from his research in thermodynamics and the use of variational principles in physics. To support this thesis, I focus on a case study that lies at the core of Duhem's philosophy: the discovery of entropy.

III. Physics of a Believer

Duhem responds to Rey's criticism of his view in "Physics of a Believer." Rey insists Duhem intends to protect the dogmas of Catholicism from the discoveries of theoretical science. However, Duhem contends that his account of physics is *impartial*; while other Catholics interpret scientific results in a way that support their beliefs, Duhem's scientific convictions prevent him from following suit. In order to prove the neutrality of his view, Duhem discusses the issue of entropy, showing how his view deviates from that of many Christian apologists.

According to the second law of thermodynamics, the entropy of an isolated system constantly increases. At Duhem's time, this increase in entropy was understood as the general tendency of systems to move toward a state of equilibrium or rest. Helmholtz was the first of many scientists and philosophers to suggest that this second law of entropy had rather severe implications: given that the entropy of the universe must be consistently increasing, it would eventually arrive at a completely static state—one void of motion and change—which he considered indistinguishable from death.[13]

Not only did the second law suggest that the universe had a definite end, it also suggested it had a beginning. After all, if the universe were infinite it would have already arrived at a state of rest. This latter argument found great support among Catholics interested in using science to justify doctrine. As Kragh writes,

> This entropic argument for a beginning of the universe was introduced in the late 1860s and adopted as a reasonable hypothesis by leading physicists such as Thomson, Maxwell, and Peter Guthrie Tait (1831–1901) who were impressed by its apparent agreement with the Christian message of a created world. A substantial part of the debate in the late nineteenth century was concerned with the apologetic use of thermodynamics and

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[13] Kragh, "Pierre Duhem, Entropy, and Christian Faith," 383.

> the significance of the second law in the ideological and cultural battle that raged through much of Europe at the time. By and large, those in favour of political conservatism, idealism, and Christian values looked with sympathy to the cosmological claims of thermodynamics, whereas socialists, materialists, and atheists denied these claims, in part because they suspected them to be Christian religion masquerading as science.[14]

In "Physics of a Believer," Duhem discredits these arguments, particularly those of Catholic origin, as misunderstandings of science. Such broad, theoretical claims cannot, he insists, be applied outside of their original scientific context.

> In the middle of the last century, Clausius, after profoundly transforming Carnot's principle, drew from it the following famous corollary: The entropy of the universe tends toward a maximum. From this theorem, many a philosopher maintained the conclusion of the impossibility of a world in which physical and chemical changes would go on being produced forever; it pleased them to think that these changes had had a beginning and would have an end . . . basing our argument on the very essence of physical theory, we shall show that it is absurd to question this theory for information concerning events which might have happened in an extremely remote past, and absurd to demand of it predictions of events a very long way off.[15]

As Duhem goes on to explain why the second law of thermodynamics does not imply the finitude of the universe, his argument takes a surprisingly linguistic turn. The problem with gleaning metaphysical truths from physical theories is that the domain of reference for physical theories is distinct from the domain of reference for metaphysical theories. Because the claim that entropy tends toward a maximum is true only in thermodynamic domains, it cannot be used to make generalized claims about the trajectory of the universe. To unpack this argument, I will outline the categories of propositions Duhem employs when discussing scientific practice, physical theory, and metaphysics.

According to Duhem, metaphysics (which he often calls cosmology) is the study of the "true, absolute" system of causes within the physical world. A large portion of Catholic dogma (e.g., teachings on the Trinity, creation *ex nihilo*) falls into the domain of metaphysics. When we assert a truly metaphysical proposition, our terms refer to these primary causes and "ultimate facts." Were we aware of the complete picture of first causes, Duhem believes we would be able to derive our everyday facts of experience from them.

[14]Ibid., 384.
[15]Duhem, "Physics of a Believer," 287–8.

These "scientific facts of everyday experience" are generalizations about the observable world that occur in ordinary language. For example, the claim that "things fall toward the Earth" is a fact of experience. Because such facts are formulated in ordinary language, we can judge them true or false by observation. Duhem affirms that these experience-based propositions can bear on the "metaphysical realities" of religious judgments:

> The facts of experience—in the current meaning of the words and not in the complicated meaning these words take on in physics—and empirical laws—meaning the laws of ordinary experience which common sense formulates without recourse to scientific theories—are so many affirmations bearing on objective realities; we may, therefore, without being unreasonable, speak of the agreement or disagreement between a fact or law of experience, on the one hand, and a proposition of metaphysics or theology on the other.
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> If, for example, we noticed a case in which a Pope, placed in the conditions provided by the dogma of infallibility, issued an instruction contrary to the faith, we should have before us a fact, which would contradict a religious dogma.[16]

Duhem does not deny any connection between religious propositions and experience. He insists that the Pope's infallibility is subject to our experience of the world, because ordinary facts of experience can be derived from cosmological facts. Therefore, from the metaphysical proposition "the Pope is infallible," and the knowledge that Pope Francis is currently Pope, we can deduce that "Pope Francis will never deny the divinity of Christ *ex cathedra*"—a fact about everyday experience. If the Pope does make this sort of denial, it serves as evidence against papal infallibility.

The third category of propositions Duhem discusses is scientific laws; the second law of thermodynamics falls into this category. Many contemporaries of Duhem, especially those following Descartes, viewed scientific laws as identical to metaphysical propositions, supposing that the laws of physical theory describe the "true, absolute" system of causes. On such a view, it follows that scientific laws can directly bear on the truth of religious claims. After all, they are both metaphysical claims. As Duhem writes, "It is not meaningless to ask whether a certain principle of Cartesian or atomistic physics is or is not in disagreement with a certain proposition of metaphysics or of dogma; . . . it may be maintained that the essence of Cartesian matter is irreconcilable with the dogma of the real presence of the body of Jesus Christ in the Eucharist."[17]

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[16]Ibid., 284.
[17]Ibid.

Duhem, however, denies that scientific laws refer directly to first causes. Scientific laws are formulated in a highly technical language, which is disconnected from both ordinary language and the domain of metaphysics. In Duhem's words, "the proposition which formulates [a scientific] fact or law is generally an intimate mixture of experimental observation endowed with objective import and theoretical interpretation, a mere symbol devoid of any objective sense."[18] The language of science, according to Duhem, is difficult to interpret because it synthesizes observation and theory, resulting in terms and symbols that do not directly refer to any observable phenomena.

Because the domains of reference for metaphysics and physical theory are distinct, the claims of physical theory do not directly engage with the claims of metaphysics. "Thus, physical theory can never demonstrate or contradict an assertion of cosmology, for the propositions constituting one of these doctrines can never bear on the same terms which the propositions forming the other do, and between two propositions not bearing on the same terms, there can be neither agreement nor contradiction."[19]

The view Duhem holds seems clear enough: The propositions of physical theory can't directly contradict the propositions of religious belief because the terms refer to different domains. What remains to be seen, however, is whether Duhem has any scientific reason for holding such a view. After all, physical theories are often used to derive everyday facts of experience in the same way Duhem alleges the "true causes of nature" might be used. If this is right, why not think the two refer to the same domain? What else might scientific laws refer to? What is this strange mixture of observation and theory?

To answer these questions, we must have a clear grasp, as Duhem did, of the odd historical trajectory that scientific theories tend to take in their development. One exemplary case of the strange linguistic content embedded in physical theories is found by considering entropy—the term at the heart of Duhem's argument. Let's now turn our attention to how this term was first introduced.

IV. The Carnot Cycle, Entropy and Idealization

The term "entropy" first arose to help explain the loss of energy observed in heat engines.[20] In the seventeenth century, several engineers noticed that steam has motive force—it is able to power the mechanical motions of machines. The earliest steam engines were incredibly inefficient, producing only a little

[18]Ibid., 292.

[19]Ibid., 301.

[20]For an excellent discussion of the history of entropy see Ingo Müller, *A History of Thermodynamics: The Doctrine of Energy and Entropy* (New York: Springer, 2007).

mechanical work for a large amount of heat. James Watt noticed that much of this wastefulness was due to steam lost to condensation. By minimizing the condensation, Watt was able to increase the efficiency of heat engines significantly.[21] The trend of building increasingly efficient heat engines continued. Attempts to make machines more efficient were works of engineering genius but did not reflect an increased understanding of the nature of heat. As Ingo Müller writes, "None of the engineers who invented or improved the steam engine—or the air engine—was in any way distracted by any soul-searching about the nature of heat, or whether or not there was a caloric. They proved that heat could produce work by doing it,—and doing it better and better as time went on."[22]

The drive of engineers to produce increasingly efficient heat engines culminated in the work of Sadi Carnot. Carnot wondered about the limits of heat engine efficiency. He decided to approach the problem of engine efficiency from the perspective of mathematics rather than applied engineering. Recognizing that any actual steam engine would lose heat due to frictional forces and complications such as vaporization, he constructed an idealized heat engine, called a Carnot engine, which is not subject to such effects.

Carnot used mathematics to define a theoretical cycle, the Carnot cycle, which describes the process a heat engine would undergo if it were isolated from friction, as well as other environmental interferences. The cycle consists of four stages; the engine traverses the four stages and then returns to its original state (in order to start the cycle once more). During each cycle the engine converts heat into work, much like an actual steam engine.

By means of the Carnot cycle, Carnot proved a theorem that states no heat engine is more efficient than a Carnot engine (because any other engine, which existed in the actual world, would lose heat due to friction). Interestingly, however, he was unable to quantify *how* efficient a Carnot engine actually is. The problem for Carnot was he believed, along with most engineers of his time, the caloric theory of heat. The caloric theory of heat suggests that heat is a substance—a fluid—which moves in and out of bodies. On that picture, Carnot's engine ought to have the same quantity of heat when it begins the cycle and ends the cycle.[23] Unfortunately, Carnot's allegiance to this theory of heat caused him to miss the most significant natural insight contained in his model.

[21]Ibid., 48.

[22]Ibid., 51.

[23]Carnot thought that heat was a state variable. A state variable depends on the system's state and is independent of its history. When a cycle returns to its original state, all of the state variables should be the same as they were at the beginning of the cycle. If heat were like fluid, and temperature a measure of heat, as the Caloric theory suggests, then when the cycle returned to its initial state the quantity of heat would be unchanged.

What's most fascinating about the Carnot engine is that it actually *loses* heat in every cycle—*even though it is isolated from the typical causes of energy loss.* This phenomenon proved quite difficult to explain.

It took about thirty years and the brilliant mind of Clausius to recognize this heat loss. Clausius was able to calculate the efficiency of the Carnot engine by introducing a new state variable to Carnot's model that returns to its original value after traversing the Carnot cycle. He named this new quantity entropy.

Clausius claimed it was entropy that is conserved in the Carnot cycle, not heat. The additional heat loss is actually a result of entropy.[24] The discovery of entropy led to the foundation of thermodynamic theory—a theory that allows us to recognize and classify a great deal of natural phenomena.

The aim of this historical detour is to consider a particular term in scientific theory, and see if it corroborates Duhem's claim that scientific laws do not refer to everyday facts of experience or metaphysical facts. In this case, the heat loss due to entropy is certainly not an everyday fact of experience, because this heat loss is only noticeable within an abstract mathematical model. Even if we assume some of the heat loss that occurs in actual engines is a result of entropy, the heat lost to entropy specifically is impossible to parse out via observation from the heat lost to friction and the atmosphere.

Perhaps, then, entropy refers to a metaphysical fact. Why not suppose the success of Carnot's model proves that it reveals something "beyond the veil of experience" and takes us into the realm of first causes? To answer this question, we have to look more carefully at the specifics of Carnot's model.

Although we speak of the Carnot engine moving through the four stages of the Carnot cycle, this language is only metaphorical. The Carnot cycle, like all cycles in classical thermodynamics, is composed of a series of equilibrium states—states where the system is at rest. And, according to the theory of thermodynamics, when a system is in equilibrium, it does not change states. This poses a contradiction within the theory. The Carnot engine allegedly moves from one state of equilibrium to the next, but this is incompatible with the notion of rest (since a system at rest does not change states unless provoked by an external force). This means if the Carnot engine actually occupied any of the four stages of the Carnot cycle, it would never move on to the next phase.

Why represent the Carnot cycle as a series of equilibrium states? Because the variables that define classical thermodynamic systems (e.g., pressure, volume, and temperature) can only be defined when a system is at rest. To understand this complexity, it's helpful to consider an example.

[24]"A system always loses some energy" is an alternative way of pointing out that the entropy of a system always increases, what is now the Second Law of Thermodynamics.

Imagine you place three large ice cubes in a glass of lukewarm water. Immediately after dropping the ice cubes in the water, the temperature is indefinable; the water has different temperatures at different points (e.g., close to the surface, around the ice, at the bottom of the glass, etc.) If you give the water some time, letting the ice melt, the water will eventually adopt a homogenous temperature throughout the glass. Only once the system (in this case, glass of water) has come to rest with respect to its temperature does the temperature have a definite value.This is why thermodynamic states are only "well-defined" when the system is at rest. In the case of the water, the state at the beginning of the process, before the ice is dropped, and the state at the end of the process, once the ice has melted, are both well-defined states. But all of the states in the middle—the states the water undergoes while the ice is melting—cannot be represented in thermodynamic state space.

So how might we build a representation, within the state space of thermodynamics, of all the changes that happen in between the initial and final state? Suppose that, instead of placing three large ice cubes in the water, we place one. After the ice cube melts, the state is definable. Then we may place the second ice cube in the water, allow the water to come to equilibrium, and define the final state of the system. Finally, we can repeat the process with the third ice cube. Presumably, the final state (after the third ice cube) will be the same as the equilibrium state the system reached when all three ice cubes were placed in the water at once. The difference is, the one-at-a-time approach provides four well-defined states instead of two: the initial state, the final state, and the two equilibrium states after ice cubes one and two. To create even more intermediate states, we can imagine using smaller and smaller ice cubes; this will add an increasing number of intermediate states. Once we've defined these intermediate states, we can string them together to resemble a process. This type of representational maneuvering is what is used to construct formal quasistatic processes such as the Carnot cycle.

Although this procedure has proven effective for representing many thermodynamic phenomena, such as the work cycle of heat engines, it is hard to believe that these artificially constructed processes actually take us "behind the veil" of experience and into the domain of first causes. Metaphysical truths must be internally consistent, but these processes rely on heavy handwaving around a theoretical contradiction: that a cycle might consist of only equilibrium states.

The term "entropy" refers to a strange mix of observational data and theoretical terms, as Duhem suggests is the case with scientific laws. On the one hand, it is the observation of actual heat engines, the cycles they traverse, and their ability to transform heat into work that serves as a basis for Carnot's model. On the other hand, it takes a fair amount of mathematical maneuvering to transpose those real-world cycles into the language of classical thermodynamics—a language that only allows for the definition of equilibrium states. Entropy, then, exemplifies Duhem's claim that "the proposition which formulates [a scientific] fact or law is generally an intimate mixture of experimental observation endowed with objective import and theoretical interpretation."[25] As a result, claims about entropy, such as the second law of thermodynamics, cannot be extrapolated to the contexts of either ordinary language or metaphysics, because the term itself can only be defined within an abstract, idealized, theoretically impossible context (such as the Carnot cycle).

V. Conclusion

Duhem aimed to prove that science is *autonomous*; it is not married to any particular metaphysical view. But while he insists physical theory is not explicitly metaphysical, he affirms it provides insight into the natural order. At first glance, this view seems untenable. After all, metaphysical insight just is insight into the natural order. What could explain Duhem's strange position other than, perhaps, his Catholic bias?

I have argued that this position is supported quite well by an actual historical development. Duhem's analysis of science is exactly right in the case of entropy. Certainly Clausius's postulation of entropy fails to take us "behind the veil" of experience—entropy was, after all, introduced as a quantity in a fictitious mathematical model that embodies a theoretical contradiction. Nevertheless, introducing entropy into thermodynamic theory allows for a wealth of scientific discovery, which suggests it somehow reflects the true order of things. Given that scientific terms are often introduced in strange contexts, as we see in the case of entropy, Duhem is right that it's hard to make sense of what these terms refer to. This explains why he separates the claims of physical theory from the claims of metaphysics. And if the two sorts of claims do not refer to the same domains, it follows they cannot directly contradict each other. This explains Duhem's position without any appeal to Christian predilection.

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[25] Duhem, "Physics of a Believer," 292.