Maxwell, Peirce, and Planck: The Quest for Absolute Measurement and Absolute Reality

Mahmoud Jalloh [*,†]

St. John's College, Santa Fe

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Abstract

People are often interested in physics due to its purported objectivity. It aims to truly be a study of nature ($\varphi \acute{\upsilon} \sigma \epsilon \iota \varsigma$) in itself. On the other hand, physics is a human construct, a language we use to describe the world as we experience it. In our quest for absolute reality, then, it seems that we must rid our description of the world of all subjectivity. This lecture concerns part of a story of such an attempt: the quest for absolute measurement. We will consider physical and philosophical aspects of the attempts of Maxwell, Peirce, and Planck to rid our language of physical measurement of undue subjectivity. This will shed some light on the possibility of knowing absolute reality—and the possibility of communication with aliens.

[*]Much of the conception of this essay was generated by conversations with Benjamin Scott, Caleb Thompson, Howard Fisher, my junior lab class and archon group (led by Ken Wolfe). I thank them all for the inspiration, but I reserve responsibility for the form and content of this work.

[†]mahmoudtimbojalloh@gmail.com

Introduction

Today I wish to talk about an aspect of science which is both rudimentary and profound: measurement. In Johnnie fashion I want to frame this discussion around the works of some the great masters in the foundations of measurement: Maxwell, Peirce, and Planck. Their efforts, which span one of the most consequential periods in the development of physics, continue to this day, in matters as diverse as quantum foundations, high precision metrology, and the search for extraterrestrial intelligence (or SETI).

Now what was it that they were trying to do? I will argue that each attempted to make our measurements absolute—what that means exactly will vary a bit in each case. Why care about making measurements absolute? To know absolute reality. If we have come to know absolute reality it is in a piecemeal and minor way, but each of these scientists have made noble contributions to the quest.

The history of measurement I am giving here is a partial, but relatively standard, one. What I hope to add is an explanation of the connection between absolute measurement to the question of absolute reality, a connection often left obscure.

Maxwell and Absolute Units

I want to start by considering a passage encountered by Johnnies in their junior laboratory class, which tends to cause confusion and debate. This is from the preface to the first edition of Maxwell's *Treatise on Electricity and Magnetism*:

> Having thus obtained the data for a mathematical theory of electromagnetism, and having shewn how this theory may be applied to the calculation of phenomena, I shall endeavour to place in as clear a light as I can the relations between the mathematical form of this theory and that of the fundamental science of Dynamics, in order that we may be in some degree prepared to determine the

> kind of dynamical phenomena among which we are to look for illustrations or explanations of the electromagnetic phenomena. (J. Maxwell C 1873, vi)

Largely our discussion on this point centers on the meaning of "dynamical". If someone recalls the classical distinction between statics, the physics of forces in equilibrium, kinematics, the physics of motion, and dynamics, the physics of forces as causes of motion, the statement starts to make more sense. Maxwell's aim would then be to bring electricity and magnetism into the fold of ordinary dynamical physics (where statics and kinematics are seen as special cases of dynamics), as Newton showed optics to be a species of dynamics with his corpuscular theory of light. This unificationist impulse can further be seen in the work of one of Maxwell's heroes, the great experimentalist, Michael Faraday.

Alternatively, to understand Maxwell's understanding of "dynamics", one can do the extremely un-Johnnie thing and take a look at a secondary text by a supposed expert. Now I happened to have on hand a book on Maxwell by John Hendry.[1] Here we find an interesting contextualization of Maxwell's remarks in an opposition between mechanistic and dynamistic conceptions of physics in the 19th century. What are these two ways of approaching physics?

We might first get a sense of the distinction by lining up some of the names associated with each camp. On the mechanist side we have: Descartes, Newton, Locke, Condillac, and Laplace. On the dynamicist side we have: Leibniz, Kant, Faraday, Boscovich, Whewell, and Lagrange. While no simple statements of these two conceptions can do justice to the variety of contributions and philosophies associated with these sets of names, we can use a working distinction between the two in terms of what they count as a good physical explanation. A good mechanistic explanation explains some phenomenon in terms of the force interactions of distinct particles of matter. The mechanist privileges separability, visualizability, and constructibility in their explanations. The standards for a dynamicist explanation are more vague. A good dynamicist explanation explains some phenomenon in terms of a general underlying principle, like the conservation of energy, without recourse to

[1] Hendry (1986).

any specific mechanistic model. A natural dynamicist philosophy is energeticism, which holds that all physical phenomena are constituted by and explainable by reference to changes in states of energy.

I say that dynamicist explanation requires no *specific* mechanistic model, because some will be familiar with the multitude of mechanistic models Maxwell uses to illustrate and motivate his development of electromagnetism, like the well known vortex and idle wheel model of the electromagnetic field developed in his 1861 paper, “On Physical Lines of Force”. (The rotational strain in the electric medium produced by the vorticies is supposed to explain phenomena like the Faraday effect—the rotation of the polarization of light passing through a magnetized medium.) I agree with Hendry that such mechanistic models are best understood as *analogies* to spur on mathematical development, rather than *hypotheses* which purport to be true explanations of the phenomena. Going back to the *Treatise*, we find some support for this reading in the quote I have already given. There the purpose of connecting the mathematical theory of electromagnetism to “the fundamental science of Dynamics” is to prepare the way for dynamical “illustrations” or “explanations” of electromagnetic phenomena. There are ambiguities in the strength of this claim. Hendry, in favour of a dynamicist reading, would emphasize the role of dynamical *illustrations*, while a mechanist would emphasize the role of dynamical *explanations*. We might even accept that these mechanical models are indeed *explanations* with the mechanist, but preserve the dynamicist reading of Maxwell by further distinguishing what we can call “how actually” explanations from “how possibly” explanations. Regardless, these ambiguities show some limitation with the contextualist approach.

So let’s explore a different approach to interpreting Maxwell. Let’s go back the text. The beginning of the paragraph I have been quoting from runs so:

> In the following Treatise I propose to describe the most important of these phenomena, to shew how they may be subjected to measurement, and to trace the mathematical connexions of the quantities measured. (J. Maxwell C 1873,

> v–vi)

This is an accurate description of the method of theory building that is exhibited in the *Treatise*. First the measurable quantities of electromagnetic phenomena are defined, and only then is a theoretical superstructure built on the foundations of those quantities. Maxwell goes on to say:

> The most important aspect of any phenomenon from a mathematical point of view is that of a measureable quantity. I shall therefore consider electrical phenomena chiefly with a view to their measurement, describing the methods of measurement, and defining the standards on which they depend. (J. Maxwell C 1873, vi)

I suggest we interpret Maxwell's unificationist project—uniting electromagnetism with dynamics—by focusing on his foundational theory of measurement.

In his preliminary on the measurement of quantities, Maxwell gives influential expositions of the foundations of what are now known as dimensional analysis and vector analysis. My focus today is on the former. It is in the exposition of dimensional analysis that Maxwell effects the unification of electromagnetism and dynamics that prepares the way for dynamical models of electromagnetic phenomena, however you interpret the significance of these models. The pivotal paragraph reads:

> There must be as many different units as there are different kinds of quantities to be measured, but in all dynamical sciences it is possible to define these units in terms of the three fundamental units of Length, Time, and Mass. Thus the units of area and of volume are defined respectively as the square and the cube whose sides are the unit of length. (J. Maxwell C 1873, 1)

The relation of derivative units to fundamental units give the dimensions of the derivative dynamical quantities, now including electromagnetic quantities, so that, as area has a second dimension in length and volume has a third dimension in length, the electrostatic unit of charge has three-halfs dimension in length, minus one dimension in time, and half dimension in mass. The dimensions of the electrostatic unit of charge are determined by the Coloumb equation and the condition of dimensional homogeneity, which states that the dimensions of every term in an equation must be the same. Forces must equal forces and lengths must equal lengths, and so on.

Why adopt such a condition as dimensional homogeneity? For Maxwell the aim is international communicability:

> The formulae at which we arrive must be such that a person of any nation, by substituting for the different symbols the numerical value of the quantities as measured by his own national units, would arrive at a true result. (J. Maxwell C 1873, 1–2)

This means defining an *absolute* unit system which is invariant under an arbitrary choice of national unit standards—this is provided by a dynamical system of dimensions. In other words, Maxwell's equations must be valid whether one is working with the metric system or the imperial system. I will just mention as an aside that Maxwell in fact defines and relates two distinct absolute unit systems, the electrostatic and the electromagnetic.

Maxwell had good reason to be concerned with the international communicability of scientific laws. Over the course of the 19th century, science became more and more internationalized, especially geodesy (more on this shortly). Further, electrical units needed to be standardized between engineers and physicists for projects like the transatlantic telegraph cable. Maxwell joined a Committee on Electrical Standards formed by the British Association for the Advancement of Science in 1861 and led by his friend William Thomson, who you likely know as Lord Kelvin, famous for his work on thermodynamics. It is in work for this committee, in collaboration with Fleeming Jenkin, an engineer, that Maxwell developed his dimensional formulae and his conception of absolute units.

It is worth adding in a bit more context at this juncture. In the wake of various exhibitions and congresses concerned with displaying and promoting the international progress of science and its industrial results, the United Kingdom made use of the metric system legal in 1864 (an earlier 1861 bill for full adoption of the metric system failed in the House of Lords). It would not be until 1973 that the UK would fully adopt the metric system. Surely the need for the electrical standards developed by Maxwell and others to be acceptable to other nations (in part) motivated the allowance of the metric system in British science.[2]

Spurred on by revolutionary dreams of rationalization, the metric system has its origins in France. The meter was to be based on a stable, universal natural phenomenon—naturally it was defined to be one ten-millonth of the Paris equatorial meridian, that is to say, one ten-millonth of the line from the north pole to the equator that passes through Paris. Maxwell, taking the long view, remarked on the instability of the Earth's figure in his 1870 presidential address to the Math and Physics section of the BAAS, claiming that its figure is less permanent than the properties of fundamental molecules, since the Earth is susceptible to cooling (and so contraction), meteorites, and variations in rotational speed.[3] In the *Treatise*, Maxwell also remarks on the desirability of a more absolute length standard, preempting the sort of standard adopted in the 20th century:

> In the present state of science the most universal standard of length which we could assume would be the wave length in vacuum of a particular kind of light, emitted by some widely diffused substance such as sodium, which has well-defined lines in its spectrum. Such a standard would be independent of any changes in the dimensions of the earth, and should be adopted by those who expect their writings to be more permanent than that body. (J. Maxwell C 1873, 3)

While, as far as I know, Maxwell does not further elaborate on the desirablity of *absolute standards*, he provides good reasons and lasting models of *absolute unit systems*, which allow for changes in standards, hopefully trending towards the more absolute. Maxwell's work founds the quest for absolute measurement on two powerful motivations, international

[2] See Mitchell (2017) for more on this story.
[3] J. C. Maxwell (1870).

cooperation and the unification of physics, but a connection between absolute measurement and absolute *reality* is largely left implicit—Maxwell often leaves such considerations for "the metaphysician". For a more robust connection between our scientific methodology and the metaphysics of the world, we must turn to the peculiar realism of Charles Sanders Peirce.

Peirce and Community

It is probably best to begin with a consideration of Peirce's day job, which in fact led to his crossing paths with Maxwell.[4] In 1872, the Superintendent of the U.S. Coast Survey Benjamin Peirce, Harvard mathematician and astronomer, assigned his son Charles to the position of acting head of the DC office. During an 1875 trip to Europe motivated by the need to get American geodesy up to European standards, Peirce met with Maxwell, apparently to discuss pendulum theory. (I do not know if they discussed a light length standard, but more on that later.) Further, Peirce was to retrieve a precision pendulum from a German firm, designed by the famed astronomer Bessel. Peirce's trip to Europe, which would not be his last, highlights the internationalization of science in this period, which I have already mentioned. It is particularly significant that Peirce's object on this trip was a precision pendulum. Why the interest in pendulums?

The U.S. Coast Survey was renamed the United States Coast and Geodetic Survey in 1878, indicating the rising significance of the geodesy—the science of measuring the earth—for the governmental body. Geodetic work had many political and technological purposes, from mapping the vast U.S. interior for homesteading, to managing borders and the new purchase of Alaska, to the laying down of telegraph wire and railroads across the nation. Further, confirmation of the degree of the Earth's polar flattening was scientifically important as a test of Newton's gravitational model, especially as elaborated upon by Laplace. However, the figure of the earth cannot be determined solely in one's backyard and requires data from

[4] I am relying heavily on Crease (2009), Crease (2011), and Brent (1998) for information on Peirce's life and scientific work. See also Lenzen (1972) for detailed accounting of his geodetic work.

around the globe, making geodesy an essentially international science.

A subdiscipline of geodesy, gravimetrics, relied heavily on high precision pendulums. Given that the strength of gravity varies with distance from the center of the earth, variations in gravity can measure the figure of the earth. The variation in a pendulum's swing period is a proxy for the strength of gravity—hence the need for high precision and Peirce's interest in metrology, the science of measurement, which he considered as logic in action. Peirce made many contributions to the theory of pendulum gravimetrics (e.g. the determining of systematic error due to the flexture of pendulum stands) and even designed invariable, reversible pendulums which eliminated this source of error.

Peirce's internationally oriented scientific work in geodesy provides important context for his famous *Popular Science Monthly* articles of 1877 and 1878, in which he provides a logic of chance and scientific methodology as well as early statements of the philosophy which came to be known as American Pragmatism. I wish here to focus on the first two essays of this series, "The Fixation of Belief" and "How to Make our Ideas Clear". In the first, Peirce compares several methods of fixing our beliefs in the face of the inquiry inducing irritation of doubt. These are: the method of tenacity, wherein we cling onto our current beliefs; the method of authority, wherein we have our beliefs determined for us; the *a priori* method, wherein our beliefs are determined by our natural reason; and finally, the method of science. While he thinks all of these methods have something to commend them, Peirce holds that all of them, besides the method of science, are ultimately unstable in the face of our social impulse. This social impulse being that the fact that either our contemporaries or past peoples have (or have had) differing views from ours inevitably causes doubt, which is the unfixing of belief.

What is this method of science? Peirce articulates two important aspects of this method:

> To satisfy our doubts, therefore, it is necessary that a method should be found by which our beliefs may be caused by nothing human, but by some external permanency—by something upon which our thinking has no effect. (Peirce, Houser, and Kloesel 1992, 1:120)

As we will see in a bit, we might call this condition the reality condition on the scientific method. Secondly,

> Our external permanency would not be external in our sense, if it was restricted in its influence to one individual. It must be something which affects, or might affect, every man. (Peirce, Houser, and Kloesel 1992, 1:120)

We might characterize this as the long-run intersubjective agreement condition on the method of science. Peirce puts this "fundamental hypothesis" of the method of science more directly by saying it is (1) a commitment to real things and (2) their eventual knowability.

Discussions of the second essay, "How to Make Our Ideas Clear", rightfully focus on Peirce's articulation of the pragmatic maxim, that the meaning (or truth) of a claim is constituted by its empirical manifestations (whether these are experimental confirmations or results of believing the claim). While there is much of interest and controversy surrounding various interpretations of this maxim, I instead want to focus on the further articulation of realism which picks up where "The Fixation of Belief" leaves off.

Late in "How to make our Ideas Clear", Peirce makes a further connection between what I have distinguished as the reality condition and intersubjective condition of the method of science:

> The opinion which is fated to be ultimately agreed to by all who investigate, is what we mean by the truth, and the object represented in this opinion is the real. That is the way I would explain reality. (Peirce, Houser, and Kloesel 1992, 1:139)

It appears that the intersubjective condition provides an *explanation* for the reality condition. That in the long-run all scientific agents come to a unified agreement is supposed to be an account of what the mind-independence of reality consists in. To this we might add, that, in this hypothetical long-run, it is the case that our beliefs are fixed and that doubt can no longer work its way in.

Peirce also provides an example of such an emerging consensus, which connects back to his metrological work:

> One man may investigate the velocity of light by studying the transits of Venus and the aberration of the stars; another by the oppositions of Mars and the eclipses of Jupiter's satellites; a third by the method of Fizeau; a fourth by that of Foucault; a fifth by the motions of the curves of Lissajous; a sixth, a seventh, an eighth, and a ninth, may follow the different methods of comparing the measures of statical and dynamical electricity. They may at first obtain different results, but, as each perfects his method and his processes, the results will move steadily together toward a destined centre. So with all scientific research. (Peirce, Houser, and Kloesel 1992, 1:138)

The consilience and convergence of multiple methods of determining the speed of light *explain* its objective reality. High precision physics, therefore, is evidence for an absolute reality. Peirce's account provides a link between absolute measurement and absolute reality. Absolute measures, particularly absolute *standards*, provide a point of agreement for all scientific agents to fix their belief to. By doing so, these absolute standards, if ever finally found, would constitute bits of absolute reality itself. Community provides the bridge between absolute measurement and absolute reality.

This brings me back to the other aspect of Peirce's metrological investigations that were alluded to earlier. Peirce, in consonance with Maxwell's suggestions, worked towards the first spectrographic meter standard (which he called a "spectremetre", not be confused with a spectrometer). Peirce's interest and competence in spectroscopy dates back to at least his assistantship at the Harvard Observatory (another position arranged by his father), if not his chemistry degree at Harvard. Similar to Maxwell's complaints regarding the variability of the Earth's figure, Peirce complained that the metallic bar meter standard was subject to too much variation for the degree of precision needed in the sciences, particularly geodesy.

Spectra, the characteristic color profile of a material, whether they be solar or atomic, are produced by the passing of the light from the material through a diffraction prism or grating. Think of Newton's demonstration of the color spectra of solar light. High precision spectra, like that of elements, requires high precision gratings. Peirce sourced his gratings from Lewis Rutherford, an amateur astronomer who was at the cutting edge of precision instrument making. These gratings were produced by the passing of a diamond stylus over a piece of glass or metal advanced by a micrometer screw. Such diffraction gratings could get to around 13,000 lines per inch.

Peirce had a very difficult life and did not get to pursue this metrological work to completion. However, diffraction gratings became ever more precise, and Peirce's publications on the prospects of a spectremetre did inspire Michelson and Morley to get the job done. Systematic errors in Peirce's attempts with elemental sodium were fixed by the Michelson-Morley interferometer instrument design—famous for its use in failed attempts to measure aether drift, leading to Einstein's special theory of relativity. It wasn't until 1960 that the meter was official redefined on this optical basis.

Planck and Absolute Reality

Max Planck is one of the initiators of the quantum revolution of the 20th century. This was after the shock of relativity theory and before the shock of the Nazi party's electoral victory in Germany. Both in science and in politics, the world Planck grew up and matured in was destroyed. His life was filled with tragedy, having outlived his first wife and four of his five children, one of whom his great influence failed to spare from execution by the Nazi's—this son, Erwin Planck was involved in a failed plot to assassinate Adolf Hitler. It is remarkable in all this upheaval and destruction that Planck held fast to his faith in God and absolute reality.

Let's begin by noting the rigor to which Planck held the standard of absoluteness. As early as the turn of the twentieth century, Planck introduced the notion of "natural units" as a more absolute alternative to even the so-called absolute standards desired by Maxwell and Peirce. I quote Planck at length:

> All the systems of units which have hitherto been employed, including the so-called absolute C.G.S. system, owe their origin to the coincidence of accidental circumstances, inasmuch as the choice of the units lying at the base of every system has been made, not according to general points of view which would necessarily retain their importance for all places and all times, but essentially with reference to the special needs of our terrestrial civilization.
>
> Thus the units of length and time were derived from the present dimensions and motion of our planet, and the units of mass and temperature from the density and the most important temperature points of water, as being the liquid which plays the most important part on the surface of the earth... It would be no less arbitrary if, let us say, the invariable wave length of Na-light were taken as unit of length. For, again, the particular choice of Na from among the many chemical elements could be justified only, perhaps, by its common occurrence on the earth, or by its double line, which is in the range of our vision, but is by no means the only one of its kind. Hence it is quite conceivable that at some other time, under changed external conditions, every one of the systems of units which have so far been adopted for use might lose, in part or wholly, its original natural significance. (Planck 1988, 173–74)

Planck goes on to suggest a less parochial alternative based on the constants, two that would go on to be named for himself (the quantum of action) and Boltzmann (which relates temperature and energy) in combination with the gravitational constant and the speed of light—elevated to a constant in the special theory of relativity. The natural units defined in terms of these constants are to be "independent of special bodies or substances" and "necessarily retain their significance for all times and for all environments, terrestial and human or otherwise". (Planck 1988, 174)

What was an international invariance standard of absolute units is now an intergalactic standard. Planck's natural units are to hold what he calls a "natural significance" as long as and wherever the laws of physics are valid.

One might wonder whether Planck would have been disappointed with the contents of the records sent on the Voyager probes in 1977 into interstellar space. The content of the Voyager record is highly anthropocentric, with the cover having directions to earth and the record itself having images and sounds from Earth. These are unlikely to have a "natural significance". On the other hand, after an initial calibration circle and a lesson in arithmetic, the record defines units in a way more agreeable to Planck's conception of natural units. Rather than define units in terms of constants which figure in fundamental laws, the authors of the Voyager record (a committee headed by Carl Sagan) used the Hydrogen atom as its foundational source. The transition of an electron spin state (depicted in the top-left of the image) and its radiation (depicted in the top-right of the image) is used to define natural units of mass, length, and time, which are then related to ordinary, terrestrial units like the centimeter, the gram, and the second. A series of further scientific diagrams depicting astronomical, chemical, and biological facts are built on the measurement system established in this image.

The existence of this alternative system of natural units does raise an issue for Planck's notion of "natural significance" which I will simply leave as an open question. There are in fact a number of possible natural unit systems and a number that are or have been in use. In fact, George Stoney suggested a system of natural units about 25 years before Planck! Contemporarily, we define natural unit systems by setting a subset of the fundamental constants to unity, doing the natural dimensional reductions, and then determining the scale of whichever unit quantities (e.g. mass) are of interest. There is an ongoing confusion about the seeming arbitrariness and conventionality of a choice of natural units and the seeming significance of some such defined units (it is often said that a theory of quantum gravity is needed beyond the Planck scale).[5]

The constants of nature continue to have a major role in Planck's philosophy of science up until the end of his life. In a 1947 essay titled "Religion and Natural Science", Planck makes the claim that the constants are "immutable building blocks of the edifice of theoretical physics", but there is a question as to their own nature:

> What is the real meaning of these constants? Are they, in the last analysis, inventions of the inquiring mind of man, or do they possess a real meaning independent of human intelligence? (Planck 1968, 170)

The first view, Planck attributes to his longtime philosophical enemies, the positivists. Indeed he claims that the acceptance of the existence of such constants is proof against the positivist position, as their existence is "palpable proof of the existence in nature of something real and independent of every human measurement" (Planck 1968, 172). And as the existence of absolute constants is necessary to scientific practice, according to Planck, the positivist position is untenable.

Planck in fact elevates the constants to the ultimate goals of scientific research, the ultimate elements of reality that orient our practice. From another 1947 essay titled "Phantom Problems in Science":

> In the realm of exact science, there are the values of *absolute constants,* such as the elementary quantum of electricity, or the elementary quantum of action, and many others. These constants always prove to be the same, regardless of the method used for measuring them. The endeavor to discover them and to trace all physical and chemical processes back to them, is the very thing that may be called the ultimate goal of scientific research and study. (Planck 1968, 77–78)

[5] I have some work under development on this issue. See Jacobs (2025) for a recent, interesting, and lucid paper addressing of this issue.

With Planck we see a complete alignment of the quest for absolute measurement and the quest for absolute reality.

What about quantum mechanics? Doesn't it show that there is a limit in our approach to absolute measurements? This limitation not merely being that of a Peircean limit or Kantian regulatory principle, but a real concrete limit in the present. Doesn't Planck's absolute realism get undermined by his own intellectual offspring? I cannot tell a full story here of how quantum mechanics is to be dealt with, by Planck or by anyone else, but I can say a bit about how Planck proposes to solve the issue. First I should say that Planck presents the problem raised by quantum mechanics as one regarding causality. In particular, he characterizes quantum mechanics as challenging a notion of the principle of causation that holds that every physical event is in principle exactly predictable on the basis of some earlier established facts—this is determinism. Planck recognizes quantum principles, like Heisenberg's uncertainty principle, do indeed limit *our* predictive capacities, but he thinks this need not undermine the principle of causality in full generality. In multiple essays, Planck posits the existence of an ideal observer, a Supreme Wisdom or a Lapacian Demon, with perfect knowledge of the complete state of the universe. For this being quantum mechanics is assumed to be of no consequence. On whether this response is tenable in light of various no-go theorems and restrictions on hidden-variable theories (e.g. violations of Bell inequalities), I remain silent.

Ultimately, Planck ties his quest for absolute reality to the quest for God, both providing a stable foundation for a tumultuous life. "Religion and Natural Science" closes so:

> Religion and natural science are fighting a joint battle in an incessant, never relaxing crusade against scepticism and against dogmatism, against disbelief and against superstition, and the rallying cry in this crusade has always been, and always will be: "On to God!" (Planck 1968, 187)

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