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Questioning Reality: The Progressive Development of Modern Physics

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By Joshua Lancman

Introduction

Humanity has a tendency to divide time. The past is distinct from the present which is entirely separate from the future. In supposedly 20-20 vision history is neatly divided into different sections, distinct eras with sharp lines between them. What is present and in the future is always modern. What is past is something else with another name.

Yet time is not divided so neatly. We know this living through it: years and decades blend into one another in a non-uniform progression. To divide human history into separate eras is a necessary simplification, as it helps to ascribe order onto otherwise chaotic chronology. It is still, however, a simplification, and gives incorrect significance to the people and events used to mark beginnings and ends. Rather, the view of history as a constant and uneven progression is more correct.

Abstract: The Distinct Line or Gradual Development of Ideas

In a simple definition, modern is "of, relating to, or characteristic of the present or the immediate past."[1] To be modern is to be in current times, meaning that which is pre-modern is necessarily in the past. If, then, modernity is also defined by the characteristics of the immediate past, what caused that dividing line to fall down between the pre-modern and current eras, so different between one another? What makes modernity?

The field of physics exhibits a sharp divide between modern and classical branches, defined by different theories, each true in different ways. The modern era of physics is commonly defined as beginning in the 20th century, with the classical era, having begun with the works of Galileo Galilei and Isaac Newton in the 16th and 17th centuries respectively, preceding it.[2] "The beginnings of anything like a corrected history of the science which is now called physics may be placed with considerable definiteness about the beginning of the 17th century and associated with the great name of Galileo," as Henry Andrews Bumstead writes.[3]

1905, the so-called miracle year of Albert Einstein, in which he published revolutionary papers on mass-energy equivalence, brownian motion, and, most importantly, the photoelectric effect and special relativity,[4] is most often used as the sharp dividing line between physics' past and present. "Modern physics is the physics of the 20th century…" since "the main building blocks, the theory of relativity and quantum mechanics, were developed early in that century."[5]

Einstein's breaking down of absolute time and space in his theory of special relativity, a commonly held assumption for millenia beforehand, is what would distinguish the modern from the classical. The aftermath of special relativity is quantum theory, in which strict causality and infinitely divisible space in physics (assumptions from Newton) were also broken down to show that these concepts did not entirely apply at the atomic and subatomic realms. This concept was also preceded by Einstein's work, building on that of Max Planck.

Alternatively to a dividing line, physics can also be viewed as a gradual development in which assumptions are constantly broken down and reshaped, a position I will argue for here. Newton demolished the prime mover theory of Aristotle, James Clerk Maxwell reshaped Newtonian concepts with

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[1] Merriam-Webster Dictionary, 2023
[2] Breinig, Marianne. "Modern Physics." *Elements of Physics*, U of Tennessee, Department of Physics and Astronomy,
[3] Bumstead, Henry Andrews. "The History of Physics." *The Scientific Monthly*. Excerpt originally published in *The Scientific Monthly*, vol. 12, no. 4, Apr. 1921, pp. 289.
[4] Einstein, Albert. "The Swiss Years: Writings, 1900-1909." Edited by John Stachel et al. Vol. 2 of *The Collected Papers of Albert Einstein*.
[5] Breinig, "Modern Physics"

the addition of fields and statistical mechanics, Einstein altered the absoluteness of space and time, and the great quantum physicists of Planck, Niels Bohr, Erwin Shrodinger, and Werner Heisenberg, along with others, undid determinism, infinitely divisible space, and orderly mechanics with the discovery of the absolute strangeness of quantum mechanics.

Instead of seeing two eras as completely separate and distinct from one another, with a point in time or event dividing the two, I will argue in this paper that scientific development in physics is always preceded by previous discoveries by looking at the development of modern physics out of the classical. Nothing comes about independently, as some sort of scientific isolate, as I will show in part I. All advances in physics are built upon the shoulders of giants, and mostly come about as a result of developments within the field itself. In part II, I will also focus on how the great revolutions which created what is now commonly referred to as modern physics were the effects of a larger, sociological questioning of authority occurring throughout the Western world at this time. Modern physics' emergence is notable for occurring at a time and place in human history, the western world at the turn of the 20th century, which was rife with intense social and intellectual upheaval.

Part I: Scientific Development is Never Isolated
The Dividing Line of 1905

The common distinction between classical and modern in physics is centered around the year 1905, when Einstein emerged with the soon-to-be monumental theory of special relativity. In this paper, quickly hailed as the epitome of modernity, Einstein broke down the assumption that space and time were absolute, meaning that time moved evenly everywhere and space was never distorted or warped.[6]

In special relativity, space and time are relative, altered by the extreme speed of light. As a body increases in speed nearing that of light, time slows down to an outside observer yet runs at the same rate for those moving at that speed, while space would also be physically warped.[7] Planck, writing on Einstein's revolution in 1910, described the shift "from the so-called classical mechanics of the mass-point, which has until now been assumed to be generally valid, towards the general dynamics arising from the principle of relativity."[8]

Planck's specific usage of the word classical to describe older physics only five years after Einstein's discovery demonstrates the monumental shift of relativity from the earlier Newtonian system. To Richard Staley, the time of Einstein made "classical and modern physics [into] co-creations, mirror image twins of the fault line between the physics of the past and that of the future."[9] What was before Einstein was classical. Everything afterwards was modern.

By the time of the Solvay Conference of 1911, discussion chair Hendrik Lorentz (who developed the Lorentz Transformations that describe special relativity) "contrasted 'old theories' and 'modern investigations,' with his brief address being most pointed—and extending the contrast to one between modern studies and classical theory. Lorentz stated that 'we have no right to believe that the physical theories of the future will be subsumed under the rules of classical mechanics.'"[10] By drawing the distinction between classical ideas and the new, modern theories of physics, Lorentz's address placed the end of the classical era in the recent past, showing Einstein's theories as marking the beginning of a new era.

However, it is flawed to believe that Einstein simply broke down the absoluteness of space and time on his own accord. To attribute such a quality is to ascribe a sort of messianic, otherworldly genius to the man, and although he surely possessed unprecedented brilliance (see how Einstein is now a synonym for genius), to call his ideas unprecedented is false. Rather, the theory of special relativity emerged from previous ideas, not a separate era but an addition, another chapter in physics' development.

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[6] Einstein. *The Swiss Years: Writings, 1900-1919*
[7] Ibid; source of explanation
[8] Staley, Richard. "On the Co‑Creation of Classical and Modern Physics." *Isis*, vol. 96, no. 4, 2005, pp. 547
[9] Ibid 533
[10] Ibid 554

A Tradition of Questioning

The particular flaw of dividing classical from modern at 1905 is the assumption that Einstein's special relativity was an unprecedented breakdown of everything previous. Rather, the history of physics is that of scientific developments which are preceded by previous ideas, and that may extend and/or alter what comes beforehand.

The classical era Einstein supposedly ended had itself begun with an alteration of earlier physical theories. Aristotle's belief in a prime mover posits that a body could only move unless constantly acted upon by an external force, an idea which held for nearly two millennia. Velocity and force, in this view, were related. Newton's three laws of motion, however, introduced that a body would remain in motion unless acted upon by an external force, undoing this dominant theory. By this, it became acceleration and force which were related.[11]

A similar precedent to development occurred with electromagnetism, itself a predecessor to relativity. Maxwell's field equations, which built on Newtonian mechanics, applied them in describing how electric and magnetic fields behaved. The idea of a field, a "line of force spread throughout space," was an addition to Newtonian mechanics, showing that "the Earth moves around the sun because it moves in the sun's gravitational field."[12] Einstein was heavily influenced by Maxwell and his predecessor, Michael Faraday, keeping pictures of them, along with Newton, on the wall in his study.[13] "Since Maxwell's time," Einstein wrote, "physical reality has been thought of as represented by continuous fields… this change in the conception of reality is the most profound and fruitful that physics has experienced since the time of Newton."[14]

Yet "physicists at that time did not realize that the two great pillars of science, Newton's and Maxwell's equations, were actually incompatible," as Michio Kaku writes. "They contradicted each other."[15]

For nearly a decade, Einstein was puzzled by a certain quirk of Maxwell's electromagnetic field equations. According to Newtonian mechanics, the velocity of a body is dependent on the reference frame of an observer. If an observer is stationary, then the moving body's velocity is an amount relative to that. If an observer is moving at the same velocity of the moving body, then the body appears to be stationary.[16] However, according to Maxwell's equations, the speed of light is a constant, devoid of any reference frame. If one is traveling at the speed of light, then light still moves at the same speed regardless of how the observer is moving. As Einstein thought to himself, "can you outrace a light beam?"[17]

To solve this contradiction, Einstein broke a powerful assumption. "[He] abandoned absolute space and absolute time."[18] To make the speed of light a constant, regardless of the speed of a body, space and time would have to warp at extremely high velocities nearing the speed of light. This new theory, the

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[11] Imagine you are rolling a bowling ball. As you roll the ball, it increases in velocity; yet, once it has left your hand, it begins to slow down. It seems as though because you're not providing a constant force to the ball, the ball loses velocity (more technically, momentum). This is Aristotle's hypothesis. However, Newton proposed that the bowling ball would maintain its velocity, and that it was a separate force, that of friction, which would slow it down. As you roll the ball, you are accelerating it, after which it moves in a straight line at constant velocity, slowed down by the separate force of friction.

[12] Kaku, Michio. *The God Equation*. Doubleday, 2021, pp 21

[13]Stone, A. Douglas. *Einstein and the Quantum*. Princeton UP, 2013, pp. 34

[14] Ibid pp. 35

[15] Ibid pp. 31

[16] Einstein. *The Swiss Years: Writings, 1900-1909*

Sitting in a train, the train appears stationary. If you walk forward in the train, in reference to an observer outside the train, your velocity is equal to the velocity you're walking in the train added to the velocity of the train itself. According to Einstein, however, this simple addition and subtraction of velocities (or, again more technically, momenta), does not apply to the speed of light, which is constant.

[17] Kaku 32

[18] Staley 544

special relativity described above, did not emerge as an independent act of genius. Rather, Einstein's genius was in breaking down and altering earlier ideas, rather than completely abandoning them. Special relativity was preceded by the brilliance of Maxwell and his electromagnetism, making relativity not independent of previous physics, but a key successor. As Einstein said, "I owe more to Maxwell than to anyone."[19]

As Douglas Stone writes, "what became special relativity was very much in the air by 1905, and when Einstein wrote his first paper on that topic, four months later, it involved a new derivation of mathematical properties of space and time that had already been written down by Lorentz (albeit without the radical interpretation given to them by Einstein)."[20] Although the absoluteness of space and time seemed essential, and their undoing revolutionary, special relativity "in fact *completed* classical mechanics and made it compatible with Maxwell's electromagnetic theory."[21] Special relativity was the extension of Maxwell's equations which, although breaking down one of Newton's primary assumptions, completed and united the two. As Einstein wrote,

> "There is a false opinion widely spread among the general public that the theory of relativity is to be taken as differing radically from the previous developments in physics… the four men who laid the foundations of physics on which I was able to construct my theory are Galileo, Newton, Maxwell, and Lorentz."[22]

All of these physicists are commonly deemed classical. Despite special relativity being perceived even at the time of its creation as something totally new, it was a revolution only in *extending* physics, rather than practically undoing all previous contributions in the field.

From Newton to the Quantum

Although Einstein's upsetting of absolute space and time was, supposedly, what kickstarted the modern era of physics, it was truly the undoing of strict Newtonian determinism, as well as other classical assumptions with the development of quantum mechanics which made physics into its distinctly modern form. "The theory of special relativity… can be seen… to be the culmination of classical physics and its deterministic worldview,"[23] meaning that, if there is a true dividing line between the classical and modern, it is not defined by a specific year, but by a perception of continuity. Classical physics, including special relativity, is based around a deterministic conception of reality, as well as one in which space was infinitely divisible and motion was orderly. Nothing necessitates this fact: it is simply assumed that events have causes, and everything occurs for some reason. Quantum mechanics, what could truly be described as modern, undid these assumptions on the microscopic level.

Strict causality defines Newtonian mechanics, and was stated in quite an extreme form by the Marquis de Laplace:[24]

> "We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at any given moment knew all of the forces that animate nature and the mutual positions of the beings that compose it, if this intellect were vast enough to submit these data to analysis, could condense into a single formula the movements of the greatest bodies of the

[19] Stone pp. 35
[20] Ibid pp. 70-71
[21] Ibid pp. 89
[22] Folsing, Albrecht. *Albert Einstein: A Biography*, trans. and abrid. Ewald Osers. New York: Penguin Press, 1998. pp. 211
[23] Stone pp. 84
[24] Ibid pp. 29

universe and that of the lightest atom; for such an intellect nothing could be uncertain and the future just like the past would be present before its eyes."[25]

There is, of course, an obvious problem for a mere mortal with gathering this sort of immense knowledge, one that was later undone by Maxwell and his colleague, Ludwig Boltzmann, in the development of statistical mechanics.[26] Their credo was simple: "to predict the physical properties of a large aggregation of molecules, one needed only to find their average behavior,"[27] something that greatly simplified a process which, according to Laplace, would require a god-like intelligence.

Yet the techniques of statistical mechanics, which assumes molecular motion is chaotic (by how many molecules there are in a gas and how often they interact), are still derived from Newtonian mechanics. "The key point is that the statistical mechanics of Maxwell and Boltmann was still *Newtonian mechanics*, just applied to a system so complicated that one imagines it behaving like a massive game of chance... the *worldview* is the same as that of Newton and Laplace; only the method is different."[28] Determinism was not yet broken down, only simplified, yet in such a way that it recognized chaos and probability in mechanics, rather than randomness. It would only be in the later quantum theory that deterministic science would truly be undone.

Several years before Einstein was developing his theory of special relativity, Planck was questioning thermodynamic radiation. In Newtonian theory, heat is the vibration of atoms, while in Maxwell's understanding, these vibrations should emit electromagnetic radiation in the form of light.[29] Particularly, these emissions should be in an even spectrum based on the heat of the particular object.[30]

However, these ideas did not accurately fit experimental testing of objects, and to solve this problem, Planck proposed in 1900 that energy was instead emitted in packets, which he called quanta, rather than in a continuous spectrum of emissions. While this theory, the Planck Law, worked accurately to describe this sort of radiation, it completely contradicted Newtonian mechanics, proposing that "each vibration [of atoms or molecules] could only have certain energy values, constrained to be a whole number *hv*."[31]

> "Planck's little, technical fudge [the Planck constant of h], if taken seriously, said something very, very strange about forces and motion at the atomic scale…The fact that [atoms should be able to] have any amount of energy (between some limits) appears intuitively to be related to the very fact that space is continuous. Nothing in Newtonian physics could explain quantized amounts of energy.... atoms and molecules were not little Newtonian billiard balls; they obeyed completely different and counterintuitive laws…" [32]

Einstein, influenced by this, applied Planck's quantization of energy to light, finding "that light was not just a wave but acted like a packet of energy."[33] In Einstein's fabulous paper of 1905 on the photoelectric

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[25] Lindley, David. *Uncertainty: Einstein, Bohr, and the Struggle for the Soul of Science*. New York: Doubleday, 2007. pp. 22.
[26] Stone pp. 40
[27] Ibid pp. 40
[28] Ibid pp. 42
[29] Ibid pp. 56-57
[30] Staley pp. 551
[31] Stone pp. 67
[32] Ibid pp. 60-61 In terms of calculus (invented by Newton), the issue with this fact is that it violates the Intermediate Value Theorem (IVT), a pillar of mathematics which states that if something changes between two states (or positions, or any other condition) over time, at some point in time, it must have equally all possible values in between those two states. According to Planck's theory, energy must jump from one level to another instantaneously, contradicting IVT.
[33] Kaku pp. 58

effect and nature of light, for which the Nobel committee specified in 1921 that the Nobel Prize in Physics would be awarded to him "especially for his discovery of the law of the photoelectric effect,"[34] he writes:

> "The wave theory of light... has proved itself splendidly in describing purely optical phenomena and probably will never be replaced by another theory… According to the assumption to be contemplated here, when a light ray is spreading from a point, the energy is not distributed continuously over ever-increasing spaces, but consists of a finite number of energy quanta that are localized in points in space, move without dividing, and can be absorbed or generated only as a whole."[35]

Light, proven by Maxwell to be a wave, was quantized into packets of energy[36] by Einstein, building on the work of Planck. Although this wave-particle duality contradicted the nature of Maxwell's equations, it was proven to be correct, and is now the commonly accepted model.

The Quantum Shock

Although continuity of space was broken down by Planck's quantization of energy, the destruction of determinism developed gradually over the next two decades.

First came the work of Bohr. Having worked in the lab of New Zealand experimental physicist Ernest Rutherford, who, in 1909, had discovered the existence of a dense positive charge at the center of an atom (which he named the nucleus), Bohr utilized the previous theories of Planck and Einstein to explain the motion of electrons around the atom.[37] This was envisioned as a miniature solar system, where an electron moving from a higher energy state (farther away from the nucleus) to a lower energy state (closer to the nucleus) would emit radiation in the form of light. These electrons, however, would have to move in abrupt jumps across space between these orbitals, practically teleporting in the same manner that energy states would in Planck's law, continuing the breakdown of infinitely divisible space (necessary for IVT). Additionally, the emitted light, according to Einstein, would have to move in a singular direction (a consequence of basic transference of momentum, necessary from Newtonian theory) as a wave and particle.[38] This direction, however, would be random.

It was only Schrodinger's succeeding work that explained this, moving quantum theory forward into the modern era. Through his famous wave equation, later simplified and combined with special relativity by Dirac in his own separate equation, Schrodinger shows how electrons move around the nucleus under "a guiding wave of probability."[39] The wave function demonstrates the probability of finding an electron in different areas of space around the nucleus, not exactly where it would be at any given time. It is the fact that the equation shows probability, rather than deterministic certainty, that is revolutionary. Its philosophical effect was extraordinary: determinism, the crucial assumption of classical mechanics, was upset by this utter absurdity. As Richard Feynman later quipped, "no one truly understands quantum mechanics."[40]

Still, however, quantum theory was founded upon the basis of Newtonian theory, despite later contradicting many of its aspects, and the recent successes of special relativity. The development of quantum theory, beginning at this time with Planck and culminating in the wave mechanics of Schrodinger (along with the matrix mechanics of Hesienberg, later shown to be identical to those of Schrodinger), could not have happened without the introduction of statistical chaos in the thermodynamics of Maxwell and Boltzmann. Ironically, Einstein, the grandfather of quantum mechanics

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[34] The Nobel Prize in Physics 1921. NobelPrize.org. Nobel Prize Outreach AB 2023. Sun. 26 Nov 2023.
[35] Einstein, Albert. "On a Heuristic Point of View Concerning the Production and Transformation of Light," reprinted in *CPAE*, vol. 2, doc. 14, pp. 86
[36] Now called photons.
[37] Stone pp. 172-180
[38] Einstein, Albert. "On the Quantum Theory of Radiation," reprinted in *CPAE*, vol. 6, doc. 38, pp. 232
[39] Ibid pp. 276
[40] Richard P. Feynman, The Messenger Lectures, 1964, MIT

through the photoelectric effect, despised what it became as a physics of probability, remarking that "God does not play with dice."[41]

Conclusion to Part I

As Staley writes, "the classical/modern divide had become instead a relationship of historical succession and conceptual incorporation of the old by the new."[42] Einstein's great contributions to science, hailed as a revolution and as era-defining as they became, were themselves preceded by earlier work. Similarly, Planck's creation of the quanta was absorbed as an addition to Newtonian mechanics, and worked well with Einstein's theories, despite being incompatible with IVT. It was only in upsetting determinism, an abandonment of principles greater than Einstein's discarding of absolute space and time, that quantum mechanics became viewed as distinctly modern, different from anything which came before.

Additionally, it is important to note that the sort of isolated conception, rather than non-uniform and progressive development, which would so definitively split two eras is a rare phenomenon in physics. The invention of calculus to describe Newtonian mechanics was itself preceded by another creation, that of analytic geometry. Calculus can also be ascribed to multiple individuals, Newton and his contemporary Gottfried Leibniz. This simultaneous conception shows how a scientific development must be preceded, rather than come about independently. The most recent time (as of writing) the Nobel Prize in Physics was given to a sole individual was in 1992, to Georges Chapak[43], as in many instances, the same discovery was made simultaneously by different scientists "working independently."[44] This can be seen with the theory of quantum electrodynamics developed by Sin-Itiro Tomonaga, Julian Schwinger, and Feynman, for which they collectively won the Nobel Prize in 1965.[45] The regularity of simultaneous independent conception is indicative of a common cause for development, as well as the effectiveness of experimental methods which yield the same results. "Progress of physics is dependent, almost from the first step, on the method of experiment as distinguished from the method of observation."[46] Because of this reliance on experiment, it is impossible for progress in physics to be made independent of previous experiment and discovery, even in theoretical physics.

Part II: The Modern Society
The Decline of Objectivity

Although it was primarily developments within physics that gradually developed the field into its modern form, the effect of changing cultural and philosophical attitudes within Western (mainly European) society also profoundly influenced this change. The great physicists of the time hailed almost entirely from European countries: Germany (Planck, Hesienberg), Austria, (Schrodinger), Switzerland (Einstein, although born in Germany), the Netherlands (Lorentz), France (Louis de Broglie, who made seminal contributions to wave-particle duality), the United Kingdom (Faraday, Maxwell, Dirac), Denmark (Bohr), and Italy (Enrico Fermi). Still others came from places heavily influenced by Europe: the United States (Feynman, J. Robert Oppenheimer, John Archibald Wheeler), or British India (Satyendra Nath Bose).

A clear influence is the prevalence of large scientific institutions and universities to conduct influential research, as well as the presence of an established academic community. At this time, no other areas in the world had these types of institutions to promote scientific research to the same degree. This is not due to any degree of cultural superiority: European and other Western or Western-colonized nations

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[41]Einstein, Albert. 1926, Letter to Max Born, published in 1971, Irene Born (translator), *The Born-Einstein Letters*, Walker and Company, New York
[42] Staley 548
[43] The Nobel Prize in Physics 1992. NobelPrize.org. Nobel Prize Outreach AB 2023.
[44] Kaku pp. 80
[45] The Nobel Prize in Physics 1965. NobelPrize.org. Nobel Prize Outreach AB 2023.
[46] Bumstead pp. 289.

were the only ones with these institutions, having undergone industrialization at an earlier time. With the level of academic investment in different parts of the world at this time, if there were to be great discoveries such as these, it would be most likely for them to happen in Europe.

Yet, as I will show in this section of the paper, it was specifically the shifting cultural attitudes of Western society at that time which resulted in this immense scientific progress. As historian Barbara Tuckman writes,

> "Industrialization, imperialism, the growth of cities, the decline of the countryside, the power of money, and the power of machines, the clenched fist of the working class, the red flag of Socialism, the wane of the aristocracy, all these forces and factors were churning like the bowels of a volcano about to erupt. "Something very great- ancient, cosmopolitan, feudal, agrarian Europe," as a contemporary said, was dying, and in the process creating conflicts, fears, and newfound strengths that needed outlet."[47]

This attitude, that the old world was dying and being replaced by the new, was exemplified by the progressive development of modern physics, where the work of Einstein, Planck, and many successors and collaborators broke down earlier scientific assumptions from the time of Newton. As this is the general attitude of the period, it is not necessary that there be a direct causal link between an event and a certain physicist or group of physicists. Instead, the cultural feeling itself is exemplified by the work of these physicists, showing a sociological effect upon them.

Twilight of the Gods

"So gorgeous was the spectacle on the May morning of 1910," writes Tuckman in *The Guns of August* on the dazzling display of glamor at King Edward VII of England's funeral. Only four years before the First World War it seemed that the old world's order was at a brilliant height, with more than fifty royal heads dressed to the heavens parading through London. "But on history's clock it was sunset, and the sun of the old world was setting in a dying blaze of splendor never to be seen again."[48]

Tuckman's opening to her Pulitzer Prize winning military history of the first month of WWI is indicative of the same attitude she portrays in *The Proud Tower*, quoted above, that of a general feeling at the turn of the twentieth century of the breakdown of old world authority to be replaced by some new development. This is the general thesis of *The Proud Tower*, that "in fact society at the turn of the century was not so much decaying as bursting with new tensions and accumulated energies."[49]

Crisis and transformations in politics, art, and philosophy abounded at this time, with the loudest being the four year tumult over the 1914 assassination of a certain Austrian Archduke. After World War One, the feeling remained, with physics being linked to the changes of the era. At the time of Einstein's general theory of relativity in 1919, the New York Times remarked that the revolutionary nature of this was akin "to Bolshevism enter[ing] the world of science." Columbia professor Charles Lane Poor, a critic of general relativity theory, noted that

> "The entire world has been in a state of unrest, mental as well as physical…This mental unrest is evidenced…by the desire, on the part of many, to throw aside the well-tested authors of government in favor of radical and untried experiments."[50]

Poor, who criticized Einstein's theories on the grounds that it "throw[s] aside the well-tested theories" of Newton (which, it should be noted, Poor taught as a professor of celestial mechanics), believed that they,

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[47] Tuchman, Barbara W. *The Proud Tower: A Portrait of the World before the World, 1890-1914*. 1966. pp. 182
[48] Tuchman, Barbara W. *The Guns of August*. New York City, Ballantine Books, 1994. pp. 3
[49] Tuchman. *The Proud Tower*. pp. XV
[50] "Jazz in Scientific World: Prof. Charles Lane Poor of Columbia Explains Prof. Einstein's Astronomical Theories." *The New York Times*, 16 Nov. 1919.

alongside other new ideas of modern physics, were incorrect empirically, lacking proper proof. Modern physics was indicative of "as great a conflict in the realm of scientific thoughts as there is in the realm of social and political life." Although Poor's critiques have not stood the test of time, especially those asserting that gravitational lensing and the wobbling orbit of Mercury could be explained by as yet unfound derivations of Newton's laws,[51] his sociological analysis does. The article's headline, *Jazz in Scientific World*, connects the new cultural movements of the time with the development of modern physics, particularly those that, like Jazz, abandoned tradition.

Quantum Mechanics and the Weimar Republic

The great discoveries in quantum mechanics, in particular, are notable for occurring almost entirely in Germany after the First World War, with Schrodinger popularizing the wave equation in Berlin in 1925 (although still serving as a professor in Zurich, yet already connected to and soon to move to Berlin). The German state at that time, the Weimar Republic, was plagued throughout its short history with economic and social ills, creating a decadent cultural milieu. "In the aftermath of Germany's defeat the dominant intellectual tendency in the Weimar academic world was a neo-romantic, existentialist 'philosophy of life,' reveling in crises and characterized by antagonism toward analytical rationalist generally and toward the exact sciences and their technical applications particularly,"[52] writes Paul Forman. Mathematician (and later Nazi Party official) Theodor Vahlen commented at the time that "a friendly attitude toward mathematics is so rare that, if we run across it, it really strikes us as especially remarkable."[53] Arnold Sommerfeld, a collaborator and friend of Bohr's, when asked to contribute to an article on the validity of astrology, responded with a dissertation criticizing the predominance of superstition in Germany. "The belief in a rational world order was shaken by the way the war ended and the peace dictated; consequently one seeks salvation in an irrational world order,"[54] he wrote. This illogical new belief was one in acausality, almost as if, to the German people, Germany's loss was so impossible that the universe had to work completely differently to make it comprehensible. Physicists began to embrace this idea in accordance with their environment, this trend "becoming a common phenomenon in the German physical community."[55]

In Forman's analysis of physics in Weimar Germany, he contends that the abandonment of causal determinism was not merely influenced by the social environment, but was rather a deliberate attempt by German physicists to "reconstruct the foundations of their science… as a reaction to their negative prestige."[56] This shift to acausality just so happened, however, to "be precisely what was required for the solution of those problems in atomic physics which were then at the focus of physicists' interest."[57]

This supposes a direct causal link (ironic with the content of the physics it discusses) between the attitudes of the time towards science and the scientific discoveries themselves. While this assumption is intoxicating and demonstrates the sociological impacts of the time upon physics, it is almost too direct, and suggests that scientific theories mainly result from the time and place in which they are developed, rather than being influenced by them yet still primarily originating from scientific evidence. With quantum mechanics specifically, it almost seems like a stroke of luck that the physical world would have agreed with this dominant philosophical attitude.

Rather, the indirect influence of the Weimar environment on quantum physics is far more plausible. Schrodinger's claim that "the solution to our difficulties in atomic physics will depend upon

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[51] These are two of the earliest empirical proofs of general relativity. Poor's more complex analyses of Newtonian mechanics to explain these phenomena are, as of writing, still undiscovered.
[52] Forman, Paul. "Weimar Culture, Causality, and Quantum Theory, 1918-1927: Adaptation by German Physicists and Mathematicians to a Hostile Intellectual Environment." *Historical Studies in the Physical Sciences.* pp. 4
[53] Ibid pp. 14
[54] Ibid pp. 13
[55] Ibid pp. 80
[56] Ibid pp. 7
[57] Ibid pp. 8

'liberation from the rooted prejudice of absolute causality'"[58] shows this, that the breakdown of causality in social thought allowed for physicists to apply that same idea to their work. The great physicists living within the Weimar Republic were still ordinary people, and influenced to question causality by a dominant culture, broke down assumptions in the manner described above. Quoting James Gardner Murphy, Forman writes that physicists "cannot escape the influence of the milieu in which they live. And that milieu at the present time is characterized largely by a struggle to get rid of the causal chain in which the world has entangled itself."[59]

Conclusion

Modern physics was a revolution in human understanding of the physical world, but it was not one that occurred in a single unprecedented leap, like the quantum jumps Planck's theory describes. Rather, the progressive development of modern physics came about in a continuum of superseding ideas which broke down one another, stemming mainly from the work of Maxwell and Newton. Relativity could only have come about from the field equations and the abandonment of absolute space and time, while quantum mechanics only from its statistical predecessor and the similar casting aside of determinism and causality.

In this same way, modern physics was indicative of the reshaping of Western culture and society at this time, and was developed in the midst of a revolution in human affairs. It was this environment which allowed for the breakdown of dogma, whether political, cultural, or scientific, that contributed to modern physics' development.

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