Ryan Dahn is an editor at PHYSICS TODAY. A historian of science, he is working on a biography of the German physicist Pascual Jordan.

NAZIS, ÉMIGRÉS, AND ABSTRACT MATHEMATICS

Ryan Dahn

Today, Jordan algebras are a sprawling mathematical subfield, but the strange story of their discovery amid Adolf Hitler's seizure of power is not widely known.

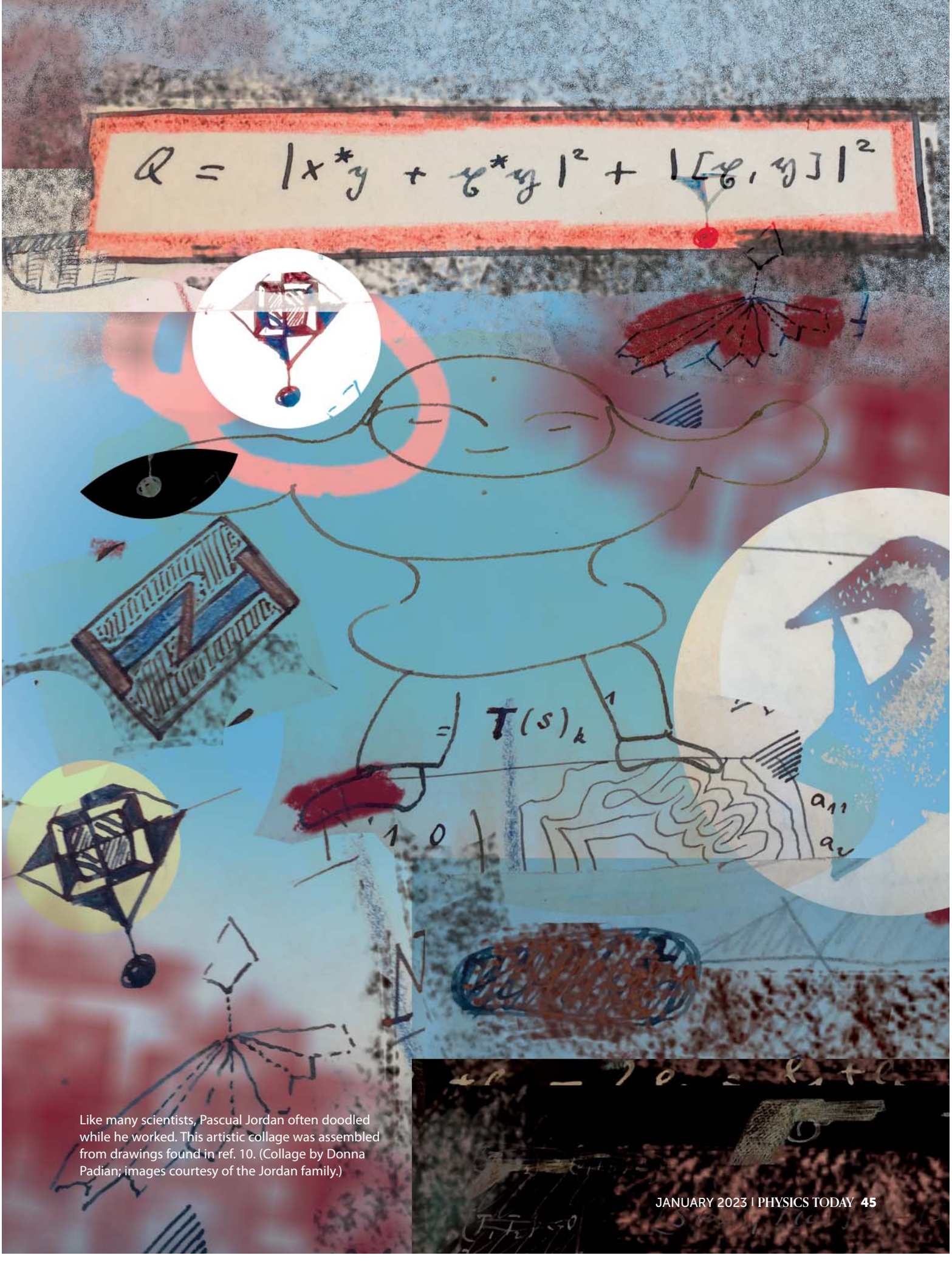
Commemoration is a foundational practice of modern science. Researchers are expected to cite the fundamental work of others in their papers. Phenomena, formulas, effects, and discoveries get named after individuals. Think of Planck's constant, Newton's laws, the Schrödinger wave equation, and the Pauli exclusion principle. When we invoke them, we implicitly commemorate those individuals, whose ideas collectively form what one might call the textbook canon of physics.

One physicist who rarely makes it into that canon is the German theorist Pascual Jordan (1902–80). In 1926, at age 24, Jordan published a paper with Werner Heisenberg and Max Born that outlines the fundamentals of quantum theory.[1] He subsequently authored or coauthored dozens of foundational publications in quantum mechanics and quantum field theory.

But Jordan was also probably the most prominent physicist of his generation to join the Nazi Party. His affiliation with the regime was not merely opportunistic. As early as 1930, three years before Adolf Hitler took power, Jordan was expressing extreme antidemocratic viewpoints in far-right journals under the pseudonym Ernst Domeier. Despite collaborating with many Jewish colleagues, Jordan joined the party in May 1933. He then proceeded to shed his pseudonym and began authoring a series of articles that were laden with Nazi ideology. Aimed at party leaders, the texts argued that supporting modern physics would be the key to winning future wars.[2]

The fact that Jordan is rarely remembered today may seem like the rare example when an odious figure is successfully ousted from the canon. Indeed, many sources claim that Jordan's dubious political activities cost him a chance at the Nobel Prize. But that's not the whole story. Jordan probably was never awarded even a share of a Nobel Prize not so much because of his Nazi ties but because of his severe stutter, which prevented him from building the international reputation necessary to garner nominations, and of the Nobel committee's well-known tendency to award the prize to a lone genius—in the case of quantum mechanics, Heisenberg.

Moreover, Jordan's name did find its way into the canon of pure mathematics, where an entire class of algebras are named after him. And the story behind the birth of that subfield illustrates the value of interrogating the scientific canon. The very moment Jordan was proclaiming his allegiance to the Nazi regime in spring 1933, he was collaborating with his Hungarian Jewish friends John von Neumann and Eugene Wigner on a landmark paper on Jordan algebras.[3]



Like many scientists, Pascual Jordan often doodled while he worked. This artistic collage was assembled from drawings found in ref. 10. (Collage by Donna Padian; images courtesy of the Jordan family.)

Having lived in Germany for years, von Neumann and Wigner fled to the US as the paper was being drafted, but they still collaborated with Jordan after he joined the Nazi Party. Indeed, the seemingly paradoxical history of Jordan's algebra is a quintessential example of how historians have been contending with the thorny question of commemoration well before "cancel culture" entered the zeitgeist.

FIGURE 1. PASCUAL JORDAN, John von Neumann, and Eugene Wigner (from left). The picture of Jordan was taken in the 1930s; the images of von Neumann and Wigner date from after World War II. (Jordan image courtesy of the Voit Collection, Göttingen State and University Library; von Neumann and Wigner images courtesy of the US Department of Energy.)

Nonassociative speculations

The story begins in December 1932, in the dying days of the first German democracy—the Weimar Republic. That month, Jordan, who at the time was the professor of theoretical physics at the University of Rostock, published a short article in a field seemingly distant from his own: the subdiscipline of pure mathematics known as abstract algebra. An algebra generalizes the rules of arithmetic, and its most basic form follows what is known as the associative principle: When you multiply three or more quantities together, it does not matter how you group them when performing the operation. In other words, $(ab)c = a(bc) = abc$.

In his 1932 paper, Jordan described a type of nonassociative algebras, or algebras in which $(ab)c$ is not necessarily equal to $a(bc)$. The new algebras nevertheless retain a weaker form of the associative principle—namely, the power rule of exponents, in which $a^m \cdot a^n = a^{m+n}$.

Why would a physicist delve into abstract mathematics? As Jordan detailed in a second article submitted in December 1932, he hoped to use the new algebra in physics. After all, a form of noncommutative algebra—namely, matrix multiplication—had laid the path for the quantum mechanics revolution in the 1920s. Jordan hoped that nonassociative algebra might analogously serve as a tool to describe quantum electrodynamics. A third paper by Jordan describing how his new algebra could provide a method for generalizing the mathematical formalism of quantum mechanics[4] appeared in March 1933.

Eager to pursue the idea further yet recognizing the limits of his own mathematical talents, Jordan wrote to Wigner, a mathematical physicist who he believed was up for the task. In his letter, which likely dates from December 1932, Jordan asked Wigner if they could meet to discuss his new ideas, and he inquired about the whereabouts of their mutual friend, the brilliant polymath von Neumann (see figure 1).[5]

Wigner invited Jordan to meet him in Berlin, but the two never met in person because Jordan's finances were too "miserable" to afford the trip. Instead, collaboration began via mail. Unfortunately, almost all of Jordan's personal and professional papers dating from before 1945 are lost, so only one side of the correspondence remains—Jordan's letters to Wigner and von Neumann—and even that seems to be incomplete. Nevertheless, by late April 1933, Jordan sent a detailed letter to Wigner on his algebraic ruminations; he enclosed reprints of the three articles he had published on the subject and again implored Wigner and von Neumann to meet with him about his "nonassociative speculations."

An unlikely collaboration

At the time, the situation in Germany was rapidly changing. On 30 January 1933, Hitler was named German chancellor, and by late March, he and his Nazi Party had made Germany a one-party state in all but name. Beginning in April, Nazi authorities started purging Jewish and left-leaning scholars from German universities. It was the start of a decade-long intellectual exodus from Europe that would fundamentally transform the landscape of physics, mathematics, and many other academic disciplines.[6]

Routine correspondence between colleagues quickly took on another role under Nazism: Informal personal networks formerly used to exchange ideas, drafts, and offprints of upcoming articles became vehicles to inquire after and help displaced refugee scholars fleeing persecution. Jordan's letter to Wigner from late April falls into that category. Although most of it deals with their collaborative work, three terse paragraphs at its end are about several colleagues:

> Here in [Rostock] the mineralogical assistant Dr. [Günter] Nagelschmidt has been suspended; otherwise no mathematicians, physicists, or chemists have been affected. Do you know how it stands with [physicist Walter] Gordon and the mathematician [Max] Zorn in Hamburg? I have no idea.
>
> It is really very sad that we have so little prospect of seeing each other within the foreseeable future; there are so many things I would like to talk with you about. But I am fighting a desperate struggle against my financial deficit's tendency to increase monotonically.
>
> Many warm greetings, not only to you, but also to J. [von Neumann], [Leo] Szillard [sic], and all other mutual friends!

Nagelschmidt, Gordon, and Szilard were Jewish scholars working in Germany, and all three emigrated because of Nazi antisemitic laws. Zorn, too, was forced to flee because he had been an active member of the Communist Party of Germany in the Weimar era. The fact that Jordan inquired about Zorn and Gordon and expressed well-wishes to von Neumann and Szilard—another Hungarian Jewish physicist—makes it clear

that he disapproved of at least some aspects of the Nazi purge. His warm tone also reflects the high esteem in which he held his Jewish and left-leaning colleagues. It does not seem a stretch to think that one of the "things" Jordan wished to discuss with Wigner was the dismissal policy.

One wonders why Jordan did not inquire about Wigner or von Neumann's own positions. The two were teaching part-time at universities in Berlin and were also hit by the Nazi purge because of their Jewish heritage. Wigner quickly made plans to emigrate and was officially dismissed on 6 September 1933. Von Neumann was already planning to move to the US before Hitler took power because he had been offered a position at the newly founded Institute for Advanced Study in Princeton, New Jersey, but he accelerated his departure after the Nazi takeover.[7]

It is possible that Jordan expressed concern in another letter that is now lost, or that Wigner informed him matter-of-factly in a lost letter. It is also possible that in spring 1933, with privacy of the mail no longer assured in Germany, Jordan did not want to overtly sympathize with a Jewish colleague who was about to lose his job. After all, it would look bad for an aspiring Nazi to sympathize with a Jewish academic.

The quantum Nazi

The friendly private correspondence with Wigner stands in stark contrast to Jordan's public acclaim for the Nazi takeover. On the rare occasions that he spoke about his actions under Hitler after the war, Jordan insisted that he only joined the party because he thought that doing so would enable him to protect science from Nazi incursions. That excuse is belied by several articles he wrote in 1933 under his Domeier pseudonym—many published in the far-right magazine *Blut und Boden* (Blood and soil; see figure 2)—which make clear that Jordan was euphoric when Hitler toppled German democracy. One of the articles focused on the necessity for Germany to attain economic self-sufficiency so that it could survive a blockade during a future war. Only then could Germany be reborn through a "profound *spiritual renewal* [emphasis in original]."[8]

No one in the scientific community, including Wigner and von Neumann, was aware of Jordan's pseudonym or any of his far-right writings. Yet shortly after Jordan sent the letter to Wigner in late April inquiring about the fate of a few Jewish colleagues, Jordan shed the Domeier pen name and published an endorsement of the Nazi "revolution" under his own name. In that piece, published in the University of Rostock's student magazine on 9 May 1933, he called for the university to be reorganized around the military needs of the "new National Socialist state," urged the student body to assume a "militant character," and insisted that "our life's goal lies . . . in the cratered field of no man's land."[9]

Eight days before that article appeared, on 1 May 1933, Jordan had joined the Nazi Party (see figure 3). The article indirectly establishes the terms of Jordan's Nazism. Even if, as hinted by his letter to Wigner, he privately disagreed with some Nazi antisemitic policies and would have preferred that so-called good Jews like Wigner and von Neumann be allowed to remain undisturbed in Germany, the regime's antisemitism was never a deal breaker for Jordan. Even as colleagues whom Jordan cherished, like Wigner and von Neumann, were dismissed and forced into exile, he vociferously proclaimed his allegiance to the regime. Jordan would maintain those terms with Nazism—even as persecution of the Jews metastasized into genocide—until Hitler's demise in 1945.

FIGURE 2. *BLUT UND BODEN*'S COVER for the November 1931 issue, which featured an article by Jordan authored under his Ernst Domeier pseudonym. *Nebelung* is a "Germanic" name for the month of November that roughly translates to "fogginess." Many proto-Nazi publications like *Blut und Boden* (Blood and soil) emphasized the alleged authenticity of their Germanness by using such Germanic month names, which, they claimed, long predated the standard Roman month names. But that was largely untrue: Names like *Nebelung* were largely 19th-century inventions. (Courtesy of the Siebenbürgen Institute, Gundelsheim, Germany.)

A three-man paper

Amazingly, neither the purge of Jewish academics from German universities nor Jordan's decision to join the Nazi Party had much impact on his feverish exchange of letters with Wigner. As spring turned to summer, one of them (likely Wigner) finally managed to get hold of von Neumann. The three were making rapid progress, and by late July 1933, Jordan made a proposal to von Neumann that the trio publish a three-man paper together, assuming—in a between-the-lines reference to the political situation in Germany—that they could clarify all major remaining problems before Wigner and von Neumann's departure for the US that fall.

Work continued apace. In August 1933 Jordan sent a partial manuscript of the paper, titled "Über eine Verallgemeinerung des quantenmechanischen Formalismus" (On a generalization of quantum mechanical formalism) to Wigner and von Neumann.[10] That draft manuscript is largely unremarkable at first glance; much of it was translated into English and became part 1 of the eventual published paper. But below the surface are traces of the political turmoil in Germany. The byline at the top

of the manuscript, for example, subtly references Wigner's and von Neumann's emigration from Germany by listing them as being "currently in Budapest": The two had stopped in the Hungarian capital before heading to the US.

A bit of historical detective work on the manuscript reveals something even rarer: a tangible trace of Jordan's double identity as Domeier. Jordan had a lifelong habit of reusing paper, and the entire manuscript was drafted on the back of old writings. Much of those scraps consist of discarded calculations. But on the back of page 7 of the manuscript, which discusses a mathematical proof that was largely eliminated in the published article, is the second page of a political essay by Jordan that attacks attempts to reconcile religion with socialism.

The essay is cut off at the bottom where Jordan had cut and pasted text, but by looking through the top layer of paper where he glued the pages together, it is possible to discern "E. Do.," an abbreviation for Ernst Domeier (see figure 4). It is unclear if that Domeier essay was ever published. The first page hasn't survived, so the essay's title is unknown, and its content doesn't correspond with any known published texts under the Domeier pen name. But there are almost certainly more Domeier articles yet to be uncovered: *Blut und Boden* was only one of many far-right journals in which Jordan published under his pseudonym, and those publications are hard to find today. In any event, that manuscript page embodies Jordan's two faces: He drafted a paper coauthored with two Jewish émigrés on the back of one of his proto-Nazi polemics.

A US journal

Despite his German nationalism, Jordan was "very pleased" when Wigner and von Neumann suggested submitting the paper to a US journal that promised to publish quickly, the Princeton-based *Annals of Mathematics*. (Perhaps Jordan also realized that the two likely had little interest in publishing in a German journal after the Nazi takeover.) And Jordan gave his two now-émigré colleagues carte blanche to do whatever was necessary for publication in the *Annals*.

As it turned out, soon after arriving in Princeton in fall 1933, von Neumann and Wigner realized that the higher-dimensional nonassociative algebras Jordan had discovered were not, in fact, suitable for further generalization of quantum mechanical formalism. So it was that despite its title, "On an algebraic generalization of the quantum mechanical formalism," the published paper was purely mathematical in content. Jordan was disappointed, but he remained in awe of his colleagues, as he noted in a letter to von Neumann from fall 1933: "I . . . would like to express how much I am delighted and relieved that you completely settled and resolved the matter in such a fantastically short time. Alone, it would have taken me years—if ever—to come up with it."[11]

And in Princeton, the story of Jordan's algebras took another turn. As Wigner and von Neumann were preparing the manuscript for publication, the classification of a specific case of what Jordan had termed "*r*-number algebras" gave them trouble. They turned to a young visiting fellow at the Institute for Advanced Study, A. Adrian Albert, an American Jewish mathematician, who solved the problem with assistance from von Neumann. Albert quickly wrote up an article on the topic, and it was published directly following the three-man paper in the January 1934 issue of the *Annals of Mathematics*.[12]

For Albert, that was the start of a lifelong interest in *r*-number algebras, which he dubbed "Jordan algebras" in the 1940s. A key figure in the internationally renowned University of Chicago mathematics department, Albert published many articles and advised several doctoral theses on Jordan algebras.[13] He and his school sparked interest in the subfield throughout the US mathematical community. It is probably due to his influence that Jordan, Wigner, and von Neumann's paper has been cited more than 1000 times. Jordan algebras have proven irresistible to mathematicians because they connect abstract algebra with other, seemingly disparate branches of mathematics, such as differential and projective geometry.

Jordan and the international community

Was the three-man collaboration an outlier? After all, it occurred in 1933, just as the Nazis were taking power and before Hitler consolidated control over German society. Surprisingly, it turns out to be one of many examples of how Jordan maintained contacts with the international scientific community before the outbreak of World War II. He coauthored another English-language article with von Neumann that was published in *Annals of Mathematics* in 1935, for example, and also coauthored an article the following year with Ralph Kronig, a physicist based in the Netherlands.[14]

Jordan continued corresponding with von Neumann into the late 1930s—the two even met in person in Cologne, Germany, in 1936 during one of von Neumann's trips to Europe—and he continued exchanging letters with Born, Kronig, and many

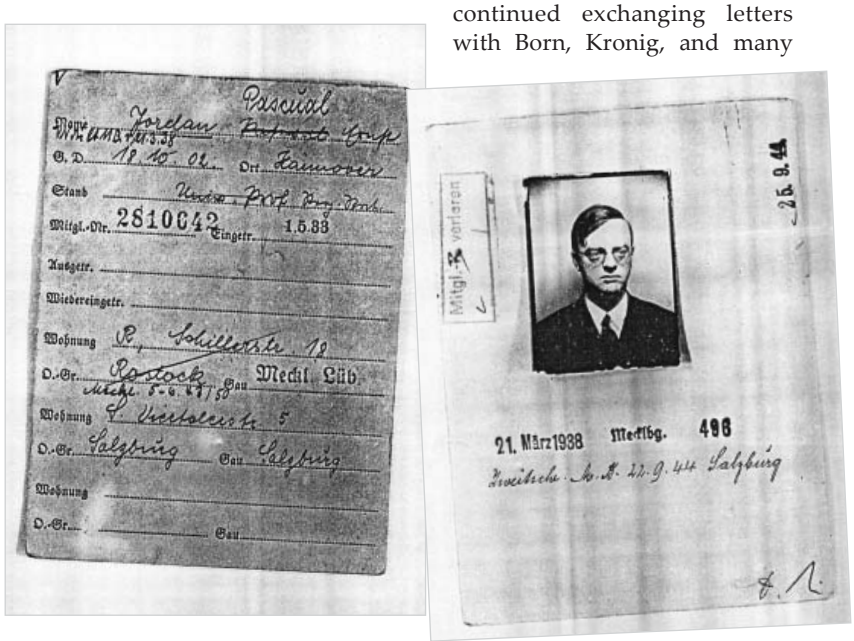


FIGURE 3. JORDAN'S NAZI PARTY membership card, which lists his member number, 2810642, and the date he joined the party, 1 May 1933. That was the same date that a ban on new party members came into effect, which was intended to halt the onslaught of Germans who sought membership after the Nazis seized power in early 1933 and whom party leadership feared were opportunists. (Courtesy of the US National Archives and Records Administration.)

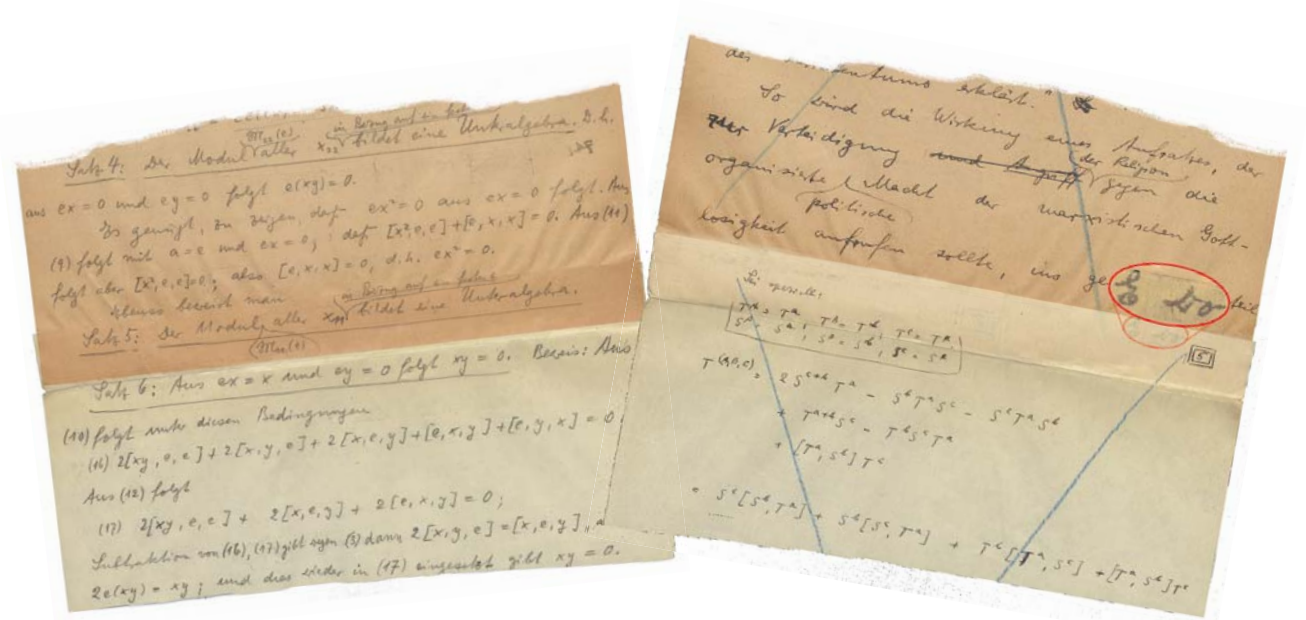


FIGURE 4. FRONT AND BACK sides from page 7 of Jordan's original handwritten manuscript of the three-man paper. The front side of the page contains part of the mathematical article, and the back side is a discarded draft of a political essay by Jordan. On the reverse side, "E. Do." (circled in red), for Ernst Domeier, can be made out where the pages were glued together. (Courtesy of the Jordan family and the Department of Manuscripts and Early Printed Books, Berlin State Library.)

other foreign colleagues until the start of World War II. And even as war began raging in Europe, Jordan corresponded with Max Delbrück, a German biophysicist in the then-neutral US, as late as November 1940. The surviving evidence suggests that Jordan remained accepted in the international scientific community despite staying in Germany and joining the Nazi Party.

How much did they know?

It is likely that many scientists outside Germany were unaware that Jordan had joined the Nazi Party. After all, there was no centralized database of known party members, and information traveled slowly in the 1930s. Although Jordan published a panoply of articles under Hitler that attempted to convince the regime that modern physics could help win future wars, they were largely printed in publications that did not circulate widely outside Germany, and many international colleagues were likely unaware of them. Jordan did mention politics in several popular-science books from the Nazi era that were more likely to be read abroad, but that content may have been viewed as the type of pandering necessary to get a book published in Hitler's Germany.

Of course, colleagues did occasionally stumble across Jordan's pro-Nazi writings. One instance occurred in 1933, when several Jewish colleagues, including Born, James Franck, and Niels Bohr, came across Jordan's paean to the Nazi state in the University of Rostock's student magazine. When they confronted him about such articles, Jordan sent cryptic explanations in return, which often used the vocabulary of physics to draw analogies with the political situation in Germany. His response to Bohr in 1934 is typical:

> I attempted . . . to deliver a contribution to the proof of the general theorem that the value of physics is a quantity that in magnitude and sign is invariant with respect to very general transformations of the external coordinate system. To this end it should be shown that the sign of this quantity can also be proven as positive with a system of axioms that stands in a relationship of complementary exclusion to those axioms from which one would otherwise [be accustomed to] derive this sign.[15]

In essence, Jordan was telling Bohr that he was attempting to prove that physics could be of value to the Nazi dictatorship, in the hope that they would support it financially. On another occasion, he analogized his actions to those taken by Soviet physicists, who, as he saw it, similarly aimed to convince Joseph Stalin's regime to support their scientific endeavors.[16]

And despite what many claimed after the war, those explanations were accepted by many international colleagues at the time. Bohr responded to Jordan's 1934 letter with a similarly cryptic note, but he remained in contact with him and even invited Jordan to a conference in Copenhagen in 1936. Franck, a German Jew who emigrated in 1933, had been one of Jordan's teachers at the University of Göttingen and readily accepted Jordan's explanation for his actions. He told other émigrés like Born who were offended by Jordan's magazine article not to take such publications "seriously."[17]

If physics analogies did not work, Jordan justified his actions by pointing to the city where he taught from 1929 to 1944: ultraconservative Rostock, which was already rabidly pro-Nazi in the Weimar era. Physicist Otto Stern, another German Jewish émigré, ran into Jordan at a party hosted by Bohr in Copenhagen sometime before World War II—probably in 1936, during the conference Bohr had invited Jordan to attend. Stern, who had previously held Jordan's position at the University of Rostock (shown in figure 5) in the 1920s, took Jordan aside during the event and asked him to explain his actions. Jordan responded: "Listen, you were in Rostock, right. You know what it's like there. I couldn't live there at all if I didn't do this [join the Nazi Party]."[18]

Stern was far from repelled by Jordan's explanation: Long after the war, he told an interviewer that he agreed "completely" with Jordan's assessment of Rostock and that one "couldn't hold it against him" for staying in Germany and publishing pro-Nazi texts.[18] Until the start of the war, even many scientists abroad who were aware of Jordan's Nazi ties accepted his justifications.

"Cancel culture" in science

What does it mean when we commemorate a scientist whose behavior would today be considered questionable? Historians have been wrestling with that question for decades, and Jordan is only one of many figures whose actions appear dubious from our vantage point. Isaac Newton was an eager investor in the South Sea Company, which traded in enslaved Africans (see the article by Andrew Odlyzko, PHYSICS TODAY, July 2020, page 30); Erwin Schrödinger would likely today be considered a sexual predator who took advantage of girls; and on a more prosaic level, Wolfgang Pauli was—to put it mildly—a jerk to his colleagues. Even the humanist paragon Albert Einstein expressed opinions in private diaries that today are considered racist.

By interrogating the textbook canon of physics and thereby making the discipline "more human" (see the article by Matt Stanley, PHYSICS TODAY, July 2016, page 38), we see that the questions raised, for example, by the Russian invasion of Ukraine—should scientists collaborate with colleagues that remain in Russia?—are not new. Wigner and von Neumann had to deal with something similar when they collaborated with Jordan back in 1933.

And like many scientists today who may not be aware of the political views of their Russian colleagues (see PHYSICS TODAY, June 2022, page 22), Wigner and von Neumann were likely in the dark about Jordan's political leanings. They probably didn't know he had joined the Nazi Party and were certainly unaware of the Domeier articles, which weren't unearthed until the 1990s. All they knew for certain was that Jordan planned to stay in Hitler's Germany. But in that regard, Jordan was one of many: Almost all German academics whose careers weren't directly threatened by the Nazis stayed in their homeland.

Although it was obvious that Hitler's regime would be repressive toward Jews and political opponents, antisemitism and authoritarianism were commonplace in 1930s Europe. The regime's murderous intentions would not become widely apparent until the *Kristallnacht* pogrom in November 1938, when synagogues were burned across Germany and Austria and when, for the first time, Jews were systematically rounded up and sent to concentration camps.

Most people are human, not heroes. It's easy to judge Wigner and von Neumann for maintaining ties with scholars like Jordan, but they didn't know the Nazi regime had genocidal intentions or that it would start the bloodiest war in history. How do we handle scientists who try to keep their careers afloat even as their society careens into dictatorship and madness? As historians can tell you, there's no easy answer. But that's precisely why it's so important to inject humanity into the textbook canon: The history of physics is a messy business.

I would like to thank Michael Barany for insightful comments that helped shape this article.

FIGURE 5. A COLOR POSTCARD from 1898 depicts the University of Rostock's main building, which is still used today. Jordan was the professor of theoretical physics at the university from 1929–44. (Courtesy of Brück und Sohn Kunstverlag Meißen, CC0 1.0.)

REFERENCES

1. M. Born, W. Heisenberg, P. Jordan, *Z. Phys.* **35**, 557 (1926).
2. R. Dahn, *Isis* **110**, 68 (2019).
3. P. Jordan, J. von Neumann, E. Wigner, *Ann. Math.* **35**, 29 (1934).
4. P. Jordan, *Nachr. Ges. Wiss. Göttingen, Math.-Phys. Kl.*, 1932, 569; *Z. Phys.* **80**, 285 (1933); *Nachr. Ges. Wiss. Göttingen, Math.-Phys. Kl.*, 1933, 209.
5. All the correspondence between Jordan and Wigner quoted in this article can be found in box 96, folder 5, Eugene Paul Wigner Papers, Manuscripts Division, Department of Special Collections, Princeton U. Library. All the unpublished material cited in this article is in German. The English translations are my own.
6. R. Siegmund-Schultze, *Mathematicians Fleeing from Nazi Germany: Individual Fates and Global Impact*, Princeton U. Press (2009).
7. Technical University of Berlin, "Eugene Paul Wigner," *Catalogus Professorum: Professorinnen und Professoren der TU Berlin und ihrer Vorgänger* (Catalogus professorum: Professors of the Technical University of Berlin and its predecessors), accessed 9 November 2022; U. Hashagen, *Inf.-Spektr.* **29**, 227 (2006).
8. E. Domeier, *Blut Boden* **5**, 162 (1933), p. 167.
9. P. Jordan, *Rostocker Universitäts-Zeitung*, 9 May 1933, p. 3.
10. P. Jordan, manuscript (n.d., likely late summer 1933), "Über eine Verallgemeinerung des quantenmechanischen Formalismus," file 124, Pascual Jordan Papers, Department of Manuscripts and Early Printed Books, Berlin State Library.
11. P. Jordan to J. von Neumann (n.d., likely September/October 1933), box 4, John von Neumann and Klara Dan von Neumann Papers, Manuscript Division, Library of Congress, Washington, DC.
12. A. A. Albert, *Ann. Math.* **35**, 65 (1934).
13. A. A. Albert, *Ann. Math.* **43**, 685 (1942); *Trans. Am. Math. Soc.* **59**, 524 (1946). On Chicago's mathematics department, see K. H. Parshall, *Bull. Am. Math. Soc.* **46**, 459 (2009).
14. P. Jordan, J. von Neumann, *Ann. Math.* **36**, 719 (1935); P. Jordan, R. de L. Kronig, *Z. Phys.* **100**, 569 (1936).
15. P. Jordan to N. Bohr (n.d., likely early 1934), folder 158, item 21, Niels Bohr Scientific Correspondence, 1903–1962, Niels Bohr Archive, Copenhagen.
16. P. Jordan to W. Heisenberg (6 June 1934), file 1515/2, Werner Heisenberg Papers, Archives of the Max Planck Society, Berlin.
17. J. Franck to M. Born (18 April 1934), box 1, folder 7, James Franck Papers, Hanna Holborn Gray Special Collections Research Center, U. Chicago Library.
18. O. Stern, quoted in H. Schmidt-Böcking, A. Templeton, W. Trageser, eds., *Otto Sterns gesammelte Briefe—Band 1: Hochschullaufbahn und die Zeit des Nationalsozialismus* (Otto Stern's collected letters—volume 1: University career and the National Socialist period), Springer (2018), p. 57. PT