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Dirk Jan Struik and His Contributions to the History of Mathematics

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This issue of *Historia Mathematica* honors the singular achievements of Dirk Jan Struik, who celebrates his 100th birthday on September 30, 1994. The articles contained herein represent an effort to convey a sense of the exceptionally wide-ranging interests in the history of mathematics that Struik has pursued throughout the course of a truly remarkable career. They address themes related to applications of mathematics, the social and institutional structures that support mathematical research, the philosophical underpinnings of this activity, recent trends in ethnomathematics, and the dialectical unfolding of mathematical ideas themselves. All of these themes have taken center stage at one time or another in Struik's own historical writings.

A distinguished mathematician, learned historian, and engaging speaker, Dirk Struik has also been a particularly effective advocate for the history of mathematics on several different fronts. Even as a nonagenerian he has remained very active as a writer, lecturer, and first-hand witness to many of the 20th century's important events. In recognition of his accomplishments as an historian of mathematics and as a spokesman for the discipline, he was chosen in 1989, along with Adolf P. Yushkevich, as one of the first two recipients of the Kenneth O. May Prize by the International Commission on the History of Mathematics (see *Historia Mathematica* **17** (1990), 1–3, and the responding remarks of Struik and Yushkevich in *Historia Mathematica* **17** (1990), 382–384.)

Dirk Struik is best known among historians of mathematics for his classic bestseller, *A Concise History of Mathematics* [53]. Originally published in 1948, it appeared in 1987 in a fourth revised edition, in which the author treated the mathematics of the 20th century for the first time. Since its initial appearance, this book has probably done more to promote interest in and appreciation for the rich diversity of mathematical ideas and cultures than any other single volume on the history of mathematics. Indeed, its influence has been so widespread that Struik himself has had understandable difficulty keeping track of its dissemination around the globe. According to his latest count, one version or another of his *Concise History* has now appeared in eighteen different languages! (The current list appears under item [53] in his selected publications.)

The following sketch of Dirk Struik's life and work touches upon those aspects connected most directly with his activities as a mathematician and, especially, an historian of mathematics. For an account of how these related to his political

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interests, the reader should turn to the article by Gerard Alberts in this *Festschrift* issue.

THE EARLY YEARS

Struik was born in Rotterdam, where his father taught in a local school. As the oldest of three children, he attended the Hogere Burger School (HBS) in Rotterdam and there fell under the influence of his mathematics teacher, G. W. Ten Dam, who also awakened Struik's early interest in socialism. With Ten Dam's support and after taking a year off to learn Latin and Greek with the help of a tutor (a precondition for admission), Dirk Struik entered Leiden University in 1912. Soon thereafter whole new worlds began to open for him. As a commuter student, travelling by rail between Rotterdam and Leiden, he spent his days soaking up the atmosphere at the Unviersity. More than sixty years later, he still vividly recalled how he and his fellow commuters from Rotterdam, Schiedam, Delft, and The Hague would walk by Boerhaave's statue, then in front of the Academic Hospital, on their way to the main University building located on the Rapenburg, a stately tree-lined canal with old patrician houses on both sides. Struik admired this structure, which had originally served as a medieval nunnery and then as the center of the University, founded in 1575 during the rebellion against Spain. He wandered about the botanical garden, replete with an American tulip tree brought back during the 17th century, attended classes in the main building, and ate sandwiches in a nearby lunchroom overlooking a branch of the Rhine, while he and his fellow students watched the barges slowly pass by [Str, Chap. V, 2].

Yet while Struik was drawn to the charms of Leiden's traditions, he could not help feeling that its atmosphere had something surreal about it. This sense that Leiden's pristine academic life took place in a wholly other world was, no doubt, accentuated by Struik's tenuous connection with the place as a commuting student. Back home in the familiar surroundings of his family in Rotterdam, enjoying the evening meal while reflecting on the events of that day, he could only marvel at this other world, so vivid and yet so remote. The staid formality that permeated the University—where the schedule of courses was still posted in Latin—made him feel at times like a spectator looking in from the outside. As he later described his first years in Leiden:

> No one ever told you which lectures to hear if you wanted to pass your exams; the grapevine took care of that, and you just followed the others who were in the same boat. No deans, provosts, marshals, student advisors, psychologists, and other such academic sages. No fortnightly tests either; there were just two exams in four years, preceded by *tentamina*, one with every professor. There was one man who knew everything, the *pedél*, who was something like a janitor and a dean rolled into one, a very respected man. [113, 7]

Struik aspired to become a high school teacher, which was setting his sights relatively high, namely a step above the social status attained by his father. He never dreamed of entering the world of university scholars, whose social hierarchy resembled that of a caste system with its docents, lectors, and professors. The latter group, the professors at Leiden, seemed like "intellectual royalty" to Struik;

"at them I could only gape, as a mouse gapes at a lion" [113, 7]. With this clear career goal in mind, he studied geometry with Professor Zeeman, whose cousin was the Amsterdam physicist who had discovered the Zeeman effect. Although these lectures amounted to the standard fare in analytic, synthetic, and descriptive geometry, the young Struik lapped it all up. He had discovered a whole sphere of ideas that went far beyond the kind of circle-and-triangle geometry he had been taught in high school.

More influential still were the courses he took with J. C. Kluyver, a distinguished analyst whose work reflected the tradition of Charles Hermite. Most of the students felt intimidated by him, but Struik managed to see beyond his gruff manner and soon learned to appreciate his talents as a teacher. Not that Kluyver was someone a student could really warm up to, as like most Leiden professors he dashed in and out of his classroom and was otherwise seldom seen. Struik described him as an energetic fellow with a graying moustache, a tuft of beard, and a severe expression befitting a *real* mathematician. Kluyver's diction was excellent and he was also a master when it came to neatly filling the blackboard. The students especially dreaded him when he played the role of inquisitor, interrupting his presentation to ask a sarcastic question while quoting Schiller: "Wer wagt es, Rittersmann oder Knapp/ Zu tauchen in diesen Schlund?" ("Who dares, knight or knave/ To plunge into this abyss?") [113, 7].

If the student answered correctly, Kluyver "condescended to a friendly grunt," but when the reply fell short of his expectations he would grin and say "Maar jongetje, meen de dat nu heus?" ("But, my boy, do you really mean that?") Struik knew that Kluyver "scared most students like hell, just as he scared the pants off candidates at teacher's exams," and that he "seemed to enjoy this reputation," as it kept everyone on their toes. Despite these antics, or perhaps in part due to them, Struik took to liking Kluyver, surmising that his bark was worse than his bite [Str, Chap. V, 3].

Struik did not restrict himself to the mathematics offerings at Leiden. He also took courses with the eminent physicist H. A. Lorentz and his colleague W. de Sitter, and eventually he gravitated into the dynamic circle of students drawn together by Lorentz's successor, Paul Ehrenfest. Ehrenfest had burst onto the Leiden scene in October 1912, only to find an academic atmosphere that clashed sharply with his own ideals and personality. In his masterful biography of Ehrenfest, Martin Klein offered this portrait of what he found:

> Contacts in Leyden's carefully stratified academic society were at a minimum. The students resident in the small city were divided into noninteracting groups, foremost among them the elite of the Student Corps, "with their noses high and their pockets full of guilders."[1] The many commuters, from the nearby big cities of The Hague and Rotterdam which had no universities of their own, often spent a minimum of time in the university atmosphere. The professors were something of a caste apart, perhaps to be visited on a Sunday afternoon,

[1] These descriptions were based on communications to M. Klein from D. J. Struik and A. D. Fokker and on Struik's letter of 22 March 1963 to the Christiaan Huygens Society.

> suitably clad in top hat and striped pants. The University Library was first class, but it offered no reading room set aside for students in the sciences where they could find the books, and especially the journals, that they needed, and where students of the various related disciplines could meet and become acquainted in surroundings conducive to intellectual contact. There was no regular colloquium that could bring the students, research men and professors of physics together frequently to hear a report on new research from one of their own group or a visitor from another university. In short, there was no real community of physicists bound together by intellectual and human ties, and Ehrenfest set about to create one. [104, 8–9]

That he succeeded brilliantly can be seen from Gerard Alberts' essay on three of Ehrenfest's students—Struik, Jan Burgers, and Jan Tinbergen—all of whom were deeply influenced by his charismatic personality and his intense commitment to the pursuit of scientific truth. The focal point for Ehrenfest's circle was the scientific club, "Christiaan Huygens," where students of all ages and backgrounds gathered every two weeks to discuss various topics of mutual interest. Ehrenfest himself often attended, and occasionally other docents as well. Freed from the rigid social hierarchy that constrained scientific discourse in a typical Leiden classroom, the atmosphere at these meetings offered many students an opportunity to think about deeper scientific and philosophical questions for the first time.

In May 1913, Ehrenfest opened a second important venue for students of the physical sciences at Leiden, a library and reading room. The idea came from his experiences as a student in Göttingen, where Felix Klein had established such a *Mathematisches Lesezimmer* for students there. In fact, it was in that very place in the fall of 1902 that Ehrenfest's eye fell on a young Russian mathematician, Tatyana Alexeyevna Afannassjeva, whom he married two years later. The Leiden reading room was financed through contacts established by Lorentz, and was named the "Leeskamer Bosscha" after the former head of the Institute of Technology in Delft, Johannes Bosscha.

Struik spent a considerable amount of time reading books in the Bosscha and he regularly attended the meetings of Christiaan Huygens. During these years, he formed warm and lasting friendships with a number of talented fellow students, including Hans Kramers, Dirk Coster, and Jan Burgers, all three of whom went on to become distinguished scientists. Mutual interest in leftist politics also drew him to the historian Jan Romein and Annie Verschoor, who later became Romein's wife. Romein's heterodox approach to Marxism eventually led to his expulsion from the Communistische Partij Nederland (CPN) in 1927, but, as with Struik, Marxist ideas continued to play a fundamental role in his understanding of historical processes. As we shall see, there was a strong affinity not only between Struik's and Romein's understandings of historical materialism but even in their overall conceptions of historical processes.

Struik would have stayed longer in Leiden if he had been given the choice, but by the summer of 1917 his stipend had run out, forcing him to look for a job. Since most of the competition had been conscripted into the army by then, he had no trouble landing a position, and in September of that year he began teaching at the HBS in Alkmaar, about twenty miles north of Amsterdam. The work and

Dirk Struik during his student days

the atmosphere of the school appealed to him, and he soon began contemplating what life would now be like once he had made the initial adjustment to these serene and rather agreeable surroundings. Before he could become fully acclimated, however, he received a tempting new job offer from an unexpected quarter. Out of the blue came a letter from the Delft mathematician, J. A. Schouten, offering him an assistantship there on the basis of a recommendation from Ehrenfest. Struik had, in fact, already met Schouten at meetings of the Amsterdam Mathematical Society, the "Wiskundig Genootschap," and thus he knew about his reputation as a leading authority on vector and tensor analysis. He even had some familiarity with the field itself, as Ehrenfest had discussed it in connection with Einstein's general theory of relativity and the Leiden physicist A. D. Fokker had given a course on the subject. Struik felt torn. Should he give up the security of his present position just so he could work on a doctorate in mathematics at a new and unknown institution? He had made no further progress on the dissertation topic he had been given by Kluyver, whom he visited only occasionally (the latter was an exponent of the "French method" of directing doctoral research, in which the advisor does as little as possible). On the other hand, all of Struik's closest friends at Leiden—Burgers, Kramers, and Coster—had opted to pursue academic careers. After considerable soul-searching and lengthy discussions with his colleagues in Alkmaar, he wrote back to Schouten accepting the offer, and by early December he was already working with him in Delft [Str, Chap. VII].

Jan Arnoldus Schouten was born in 1883 in Nieuwer Amstel, now part of Amsterdam. Like Struik, he attended a Hogere Burger School, and later he took up studies in electrical engineering at the Delft Polytechnical School. After graduating in 1908, he worked for Siemens in Berlin and for a public utility in Rotterdam before returning to study mathematics in Delft in 1912. Two years later he had completed his doctorate with an impressive dissertation [114], which was published as *Grundlagen der Vektor- und Affinoranalysis* and contained a preface written by Felix Klein.

Schouten's engineering background and the fact that he was a "self-made man" undoubtedly appealed to Struik. The field of vector analysis had arisen, after all, in large part from the practical needs of physicists, like P.G. Tait and J.W. Gibbs, and engineers, like Oliver Heaviside. As Struik later noted, on the other hand, professional mathematicians had often tended to scorn this subject, and not without some reason:

> These direct quantities were often poorly defined—what is a vector? well, you know what an arrow is—and both terminology and notation were confusing. There were quaternions, polar vectors and bivectors, axial vectors and bivectors, quantities of the first, second, etc. order, with generalizations as dyadics, tensors, affinors, gap products. There existed a point calculus and there were equipollencies. At least three different national notations were in use, and there was competition between "Grassmannians," "Hamiltonians," and vector analysts, a show already started in the 1890s by the squabble between Heaviside and P.G. Tait on the importance of quaternions versus vectors. [80, 97–98]

Clearly, the time was more than ripe for an effort to get beyond the clutter and to extract some meaning from this madness. Schouten set about to accomplish just that. In fact, he undertook this task with a ready model in hand, namely the "Erlanger Programm" [100] that Felix Klein had set forth as a young man back in 1872. Klein's key notion—that geometry was essentially nothing more than the study of the system of invariants and covariants associated with a given space and a given group of transformations that act on it—had become a fairly conventional idea by 1900. Moreover, the work of Sophus Lie and Elie Cartan had opened the way to a vast new terrain in which group theory, differential manifolds, and tensor calculus enriched one another. On a much more elementary level, Klein had himself indicated how one could apply the ideas set forth in his "Erlanger Programm" to derive the central concepts of vector analysis (see [10, 42–73]).

Schouten, however, went well beyond this, developing a theory in which the study of direct quantities, and their algebraic and analytic properties, was conceived as the invariant theory of an appropriate transformation group. In doing so, however, he was initially unaware of the "absolute differential calculus" or Ricci calculus, despite the fact that Gregorio Ricci-Curbastro and his student Tullio Levi-Civita had presented its key features in a well-known article published in 1901 in *Mathematische Annalen* [111]. Ironically, a young physicist named Einstein did know the Ricci calculus, or at least learned about it from his friend, Marcel Grossmann, before Schouten's work appeared in print [108, 208–298]. Schouten's approach was, by contrast, far less elegant. Even Klein complained about the complicated, nearly impenetrable notation that plagued Schouten's theory, and few mathematicians seem to have mastered this early approach [102, Vol. 2, 45].

By the time Struik joined him in Delft, Schouten was already hard at work developing a new tensor notation, based on his kernel-index method. As Struik described it:

> Like all happy symbolisms (think of Leibniz's notation for the calculus) this tensor notation could in a remarkable way "think for itself." It also brought out a remarkable characteristic of Schouten's vision of mathematics, where algebraic–analytical thinking was accompanied and supplemented by geometric intuition and representation, by "Anschauung" as the Germans say—an approach also typical of such mathematicians as Monge, Darboux, Lie, Cartan, and Klein himself.
>
> Schouten *saw* his tensors and affinors in the plane, in space, even in more than three dimensions, he saw them as arrows, oriented areas and bodies, as rods (*Stäbe*), line complexes, quadrics, leaves on trees, or on the ground, or on strings, like pieces of meat on a spit, as elastic tensions or deformations, as moments of inertia. It was a period, these years of the first World War and after, in which through the influence of Einstein's theories of relativity the tensor calculus became more and more an appreciated tool, not only of visual-minded mathematicians, but also of the purer kind, who began to apply rigor to the foundations. And thus the vector calculus, seen as a section of the tensor calculus, was losing the stigma of its birth and could look the world straight in its face, clothed in the garb of respectability. [80, 99–100]

Two facets of Schouten's work appealed especially to Struik: its close ties with Klein's "Erlanger Programm," which he knew already through Ehrenfest, and its intimate connection with general relativity theory. More than offering a powerful formalism, Schouten's approach to tensor analysis suggested a way to systematize a large portion of pure mathematics. In their first collaborative effort [1], which appeared in 1918, Schouten and Struik investigated connections between geometry and mechanics in the treatment of statical problems in general relativity. In particular, they gave an account of how the precession in the perihelion of Mercury's orbit, the only till then confirmed experimental support for Einstein's theory, could be interpreted by a change of the gravitational tensor induced by the necessary corrective force.

As Struik became increasingly absorbed with tensor analysis, he soon gave up the idea of writing his dissertation under the detached direction of Kluyver. Instead he arranged for the Leiden geometer, W. van der Woude, to serve as his thesis advisor, although the actual work grew out of his collaboration with Schouten. Struik's dissertation, completed in 1922, dealt with the application of tensor methods to Riemannian manifolds. It was published by Springer under the title *Grundzüge der mehrdimensionalen Differentialgeometrie in direkter Darstellung* [7]. As was the custom of the day, the author had to pay for the printing himself, but due to the run-away inflation in Germany at that time this proved an easy matter for Struik.

A second event of decisive importance for Dirk Struik took place a year earlier, while he attended the annual meeting of the *Deutsche Mathematiker-Vereinigung* in Jena. There, he met Saly Ruth Ramler, who had earned her doctorate in 1919 under Gerhard Kowalewski at the Charles University in Prague, probably the first woman to achieve this distinction. The attraction was strong and mutual, and after the meeting they headed off to Dresden, where they managed to see the Sistine Madonna in the Zwinger even though it was past closing hours. Many cards, letters, and rendezvous later, they found themselves in Luxemburg viewing the beautiful castle in Vianden. They decided on that day, Easter Monday, the 17th of April, 1922, to become engaged, and a year later they married in the old Town Hall of Prague, the capital of the newly founded nation of Czechoslovakia [Str, Chap. IX].

Ruth Ramler had not found it easy studying mathematics in Prague. The Charles University, the oldest of all German universities, had more recently become an important place in physics, having attracted figures like Ernst Mach, Albert Einstein, and Philipp Frank to its faculty. Its two best known mathematicians were Kowalewski, who had been one of Sophus Lie's outstanding pupils in Leipzig, and Georg Pick, who had studied in Vienna. As the only woman studying mathematics in Prague, Ramler encountered more than her share of incredulous stares and slighting remarks. When she presented her thesis work on affine reflections and their role in the foundations of affine geometry in Pick's seminar, the Austrian mathematician remarked afterward in perplexed disbelief: "Wissen Sie, Fräulein Ramler, dass Sie Axiomatik machen?" ("Did you know, Miss Ramler, that you're doing axiomatics?) [Str, Chap. IX, 1].

At the time Struik met her, Ruth Ramler was teaching mathematics and physical education at the Deutsches Mädchengymnasium in Pilsen. Beyond her talents as a mathematician, she also loved creative dance. What she did not like about her job, however, was the constant feuds that flared up between the Czechs and Germans or else between the Czechs and Slovaks, as the smoldering tensions between these groups came out in the open during these postwar years. Recalling her reaction, Dirk Struik wrote: "Ruth may have married me for my personal charms, but the fact that marriage with a Dutchman could get her out of quarrel- and clique-ridden Prague also played a role" [Str, Chap. IX, 2].

Adjusting to life in the Netherlands did not come easy either, however. After settling into a flat with her husband in Delft, she began her struggle with the Dutch language, eventually becoming quite proficient in it. She also learned to cook Dutch dishes. But efforts to find some kind of teaching position proved futile in a Dutch society that offered few such opportunities for women. Still, Ruth Struik managed to find some patrons in Rotterdam who were impressed by her grace as a dancer, and so once a week or so she boarded the dilapidated old bus that stopped in front of their home and headed off to give lessons in modern dance. She also wrote occasional articles for the *Prager Tageblatt* on her impressions of the Netherlands [Str, Chap. IX, 3–9].

In the meantime, Struik resumed his collaboration with Schouten, with whom he published their first, rather succinct, exposition of the new tensor methods in differential geometry [8]. Along with Schouten, Lorentz, De Sitter, and Brouwer, he also enjoyed the distinction of being appointed to the editorial committee for the publication of Lobachevsky's collected works. And he also became a *privaat docent* at Utrecht University, an appointment initiated by the Utrecht mathematician Julius Wolff and his physicist colleague L. S. Ornstein. On 12 November, 1923, Struik delivered his inaugural lecture on "The Development of Differential Geometry," and shortly thereafter Ruth prepared a German translation that was published in the *Jahresbericht der Deutschen Mathematiker-Vereinigung* [15].

Already in this lecture, Struik demonstrated the crystal-clear expository style that was to become his hallmark as an historian of mathematics. Beginning with some brief remarks on the contributions of Euler and Monge, he stressed the fundamental importance of Gauss's work on the bending invariants of surfaces. He then discussed Grassmann's *Ausdehnungslehre* with its introduction of *n*-dimensional spaces, and the coordinate-free treatment of Pfaffian problems. Regarding Riemann's revolutionary *Habilitationsvortrag* of 1854, Struik emphasized:

> [i]t is beside the point that Grassmann and Cayley had already passed beyond the boundary of three-dimensionality and that Bolyai and Lobachevsky had gone beyond the Euclideanness of space. Riemann's importance lies deeper. With him comes the clear recognition that one can only speak meaningfully about the systematic structure of differential geometry when certain postulates pertaining to the local properties of space have been fulfilled. What occurred in the development of differential geometry, as Weyl has remarked, is what occurred at nearly the same time in the theory of electricity: the passage from action at a distance in favor of action in the neighborhood of a point. [15, 16–17, my translation]

Struik went on to mention numerous contributions of Sophus Lie that exemplified his profoundly geometrical style. He then turned to the work of leading Italian mathematicians, such as Beltrami and the more analytically oriented Ricci-Curbastro, whom he compared with Grassmann. Most of the remainder of the lecture took up more recent developments connected with figures like Wilczynski, Blaschke, Schouten, and Levi-Civita. In particular, Struik indicated how the new notions of parallel transport and affine connection played a central role in the work of Hermann Weyl and others on unified field theories. Interestingly enough, he said nothing about Cartan's contributions, but in the printed version he added a footnote indicating that Cartan and Schouten had found an elegant way to handle conformal and projective differential geometries.

While still retaining his assistantship in Delft, Struik taught a course at Utrecht in potential theory on the side. His academic future remained, however, very uncertain, and he had few chances of obtaining a position at a school like the one he had taught at briefly in Alkmaar due to his widespread reputation as a communist. Ruth counseled him to "get out from under Schouten," who had a rather domineering personality, but the question remained: how? Their chance came in April 1924 at the Congress on Theoretical and Applied Mechanics co-organized by Jan Burgers. Both Struiks attended the Congress, and Ruth struck on the idea of inviting some of the guests—Richard Courant, Constantin Carathéodory, Theodor von Kármán, Tullio Levi-Civita, and others—to their home. There, over an evening meal, Levi-Civita told them about the newly-established fellowship fund offered by the Rockefeller Foundation, and both he and Courant encouraged Struik to apply. The following September they were on their way to Rome [Str, Chap. IX, 14].

The next nine months were unforgettable ones for Dirk and Ruth Struik, who felt like aristocrats on a grand *Italienreise* in the tradition of Goethe [Str, Chap. X]. They soaked up Rome's cultural riches wherever they went, enthralled with the whole atmosphere of the city, except for the lurking signs of fascism. Struik greatly admired Levi-Civita, whom he regarded as a true internationalist in the spirit of the *Risorgimento*. Oddly enough, though, the two experts on tensor analysis chose a different topic for Struik to research during his stay. Levi-Civita had recently written a paper on the spread of periodic irrotational waves in a canal of infinite depth, and he suggested that Struik tackle the same problem for canals of finite depth. He did, and his preliminary results appeared in the *Rendiconti della Accademia dei Lincei* [14; 17] and subsequently, in more extensive form, in *Mathematische Annalen* [18].

Ruth Struik kept herself busy, too. As it happened, the multitalented geometer Federigo Enriques lived in the same building as Levi-Civita, and when he learned that she had written a doctoral dissertation in geometry he asked her to write a mathematical commentary on Book X of Euclid's *Elements* for the Italian edition he was then preparing. Enriques's pupil, Maria Zapelloni, helped touch up her Italian, and the book came out some years afterward [Str, Chap. IX, 20].

The Struiks met numerous other Italian mathematicians as well during their stay, including Hugo Amaldi, Guido Castelnuovo, Vito Volterra, and Luigi Bianchi. They also spent time with a number of interesting foreigners who happened to be residing in Rome. Szolem Mandelbrojt had come from Paris, where he had studied with Jacques Hadamard, Oscar Zariski came from Kiev to work on his doctorate under Castelnuovo, and Paul Alexandrov was a visitor from Moscow. Alexandrov was particularly glad to be away from home simply in order to escape starving. He told the Struiks that "to do topology at that time you had to convince the authorities that it was useful for economic recovery. So the topologists told them that their field could be of service to the textile industry" [113, 14].

It was during this eventful sojourn in Rome that Struik first began to take a serious interest in the history of mathematics.[2] Besides meeting Enriques, he

[2] Struik's "Sur quelques recherches modernes de géométrie différentielle" [20] aimed to illuminate the historical background of differential geometry, but for a specialized mathematical audience.

talked about the history of mathematics with Ettore Bortolotti and Giovanni Vacca, an expert on ancient Chinese mathematics. Later he became acquainted with the director of the Dutch Archeological Institute in Rome, G. J. Hoogewerff, who suggested that he study the work of Paul van Middelburg, a Dutch Renaissance mathematician who later became a bishop and an advisor on calendar reform at the Fifth Lateran Council of 1512–1517. The Dutch embassy arranged the necessary permissions that enabled Struik to spend his spare time reading Latin incunabula in the Alessandrina and Vatican libraries (his findings appeared in [12, 13, 16]). Finally, he had found a way to put his hard-won knowledge of Latin to some good use!

The Rockefeller Foundation extended Struik's fellowship to a second year, during which time he was to work under Courant in Göttingen. After nearly a year in Rome's sunny and courteous surroundings, the far less easy-going atmosphere in Göttingen came as something of a shock for the Struiks. The town itself seemed quiet and charming enough and for mathematical stimulation Göttingen still remained on top of the world. But, as Struik well remembered, "you had to have a thick skin to survive there" [113, 14]. Those who showed no interest in or talent for sarcastic humor, like Emmy Noether or Erich Bessel-Hagen, often became themselves the butt of cynical or barely well-intentioned jokes.

The weekly meetings of the Mathematical Society, presided over by the illustrious and all-powerful *Herr Geheimrat* David Hilbert, reflected these subterranean tensions, and even world-class mathematicians often dreaded the prospect of speaking before this audience. Seated in rows where everyone seemed to know their place within the established pecking order, the Göttingen mathematicians were famous for pouncing on a speaker after he had finished his presentation. Hilbert, as the presiding chair, always had the first word, and his judicium—often delivered in a flippant, sarcastic tone to amuse the audience—could affect a mathematician's standing in the community considerably. Struik, who had plenty of practice and skill as a public speaker, survived the ordeal unscathed, presenting his recent work on irrotational waves. Others, like his new-found friend, Norbert Wiener, bore scars from this experience for the rest of their lives (see [110, 169–170]).

For a young geometer like Struik, Göttingen was alluring first and foremost as the home of the aged Felix Klein. Through Ehrenfest and later as a result of his collaboration with Schouten, Struik had gained a vivid feel for Klein's central motivating conceptions and a strong sense of the profound influence these ideas had exerted on his two mentors. Beyond this, Klein's style—the sweeping insights connecting such seemingly disparate elements as algebraic forms, Riemann surfaces, groups, number fields, and mechanics—resonated strongly with Struik's sympathy for ideas that reveal the "internal dialectics" of mathematics.[3]

Thus, it was with great disappointment that he learned of Klein's death shortly

[3] The role played by such dialectical processes in mathematics has been stressed by Egbert Brieskorn in [95].

after arriving in Göttingen in June 1925. He and Ruth attended the funeral, along with practically the entire Göttingen academic community and numerous distinguished mathematicians and scientists. After a few short speeches, including one by Hilbert, Struik joined a group of mourners who each threw a spade of earth over the grave. "I felt like I had lost one of my teachers," he later recalled [113, 15]. Little did he realize that his ties with the Kleinian legacy were about to intensify and take on an added new dimension.

This came about through Richard Courant, who approached both Struik and Otto Neugebauer with a proposal to prepare the first published edition of Klein's lectures on the history of 19th-century mathematics. (Neugebauer was then busy finishing his dissertation on ancient Egyptian mathematics [107].)[4] Klein had originally delivered these lectures during World War I, when he was already in retirement. The lectures from the first two semesters had been written up by his youngest daughter, Elisabeth, who took on this task after losing her husband in the early stages of the conflict. During the last three semesters they were prepared by various assistants then working for Klein. None of these earlier *Ausarbeitungen* had circulated widely, however. After the third semester, Klein abruptly shifted into a presentation of the historical background leading up to relativity theory as seen from a formal mathematical standpoint. For this reason, the editors decided to publish Klein's *Vorlesungen über die Entwicklung der Mathematik im 19. Jahrhundert* as two separate volumes.

Both historically and mathematically this project was ideally suited for Struik's tastes. Indeed, only two years earlier Schouten and Struik had delved into the prehistory of certain fundamental identical relations that A. E. Harward had derived in connection with energy and momentum conservation in Einstein's general relativity theory. Harward had indicated that if $R_{\lambda\mu\nu\sigma}$ is the Riemann curvature tensor, then

$$R_{\lambda\mu\nu\sigma;\tau} + R_{\lambda\mu\tau\nu;\sigma} + R_{\lambda\mu\sigma\tau;\nu} = 0.$$

Harward himself conjectured that these identities must have been discovered earlier, a surmise confirmed by Schouten and Struik, who wrote: "[i]t may be of interest to mention that this theorem is known especially in Germany and Italy as Bianchi's Identity" [11, 584]. As Abraham Pais has pointed out, the fact that such eminent mathematicians as Hilbert, Klein, Weyl, Emmy Noether, and of course Einstein himself, had not known this key result posed a major conceptual roadblock for the early development of general relativity theory [108, 275–276].[5]

Struik had studied many of Klein's other lectures before this—again, on Ehrenfest's advice—but nothing like these, which sparkle with all sorts of personal reflections blending mathematical commentaries, sharply drawn biographical sketches, and anecdotal details with brief accounts of the social, intellectual, and

[4] See Noel Swerdlow's obituary [115] for a moving account of Neugebauer's career.

[5] Bianchi had published these identities in 1902, but the contracted form of the Bianchi identities had been derived by Aurel Voss in 1880 and, independently, by Ricci in 1889.

institutional contexts that set the background for the mathematical developments in various countries. Struik's exposure to this novel approach to the history of mathematics pointed him in a surprising new direction. Sixty years later, he wrote:

> [From] . . . Felix Klein's lectures on mathematics in the 19th century, I learned how profoundly the French Revolution had influenced both the form and the content of the exact sciences and engineering, as well as the way they are taught. This was especially due to the establishment of the Ecole Polytechnique in Paris, headed by the mathematician Gaspard Monge. The educational reform, we must note, was for the benefit of the middle classes, not for the *sans culottes*. These facts gave me more confidence in the potential powers of historical materialism in understanding the course of mathematics. . . . [86, 283]

Struik also took advantage of Göttingen's fine University Library to study more of the work of Renaissance mathematicians, including Adam Ries, Christoph Rudolff, Peter Apianus, Michael Stifel, and Simon Stevin. This experience along with his collaborative work on the edition of Klein's lectures laid the groundwork for his later work on the history of mathematics, including his edition of Stevin's mathematical works [60] and his *Source Book in Mathematics, 1200–1800* [77] (see also [50; 59]).

With his Rockefeller Fellowship about to run out, Struik and his wife returned to Delft in August 1926. There, he resumed his collaboration with Schouten and continued to study Renaissance mathematics, including the work of Willem Gillisz van Wissekerke (see [19]), a native of Zeeland like Struik's other newly discovered Dutch mathematician, Paul van Middelburg. However distracting these activities may have been, they offered Struik no real escape from his worries, as he realized that his chances of obtaining a position in the Netherlands, whether within academia or outside it altogether, were very poor. On top of this, Ruth's health was beginning to suffer from the stress of their financial uncertainty [113, 19–20].

Given these dire straits, he began searching for opportunities to go abroad. His brother Anton had already gone to Russia to work on engineering projects, and soon an invitation came from Otto Schmidt, a mathematician and academician in Moscow who soon afterward led a series of Arctic expeditions. In the meantime, Norbert Wiener had managed to arrange for a visiting appointment at M.I.T. Both offers seemed very tempting to Struik, but the first clearly carried more risks, especially in view of Ruth's delicate health. So after lengthy deliberations, they decided to accept the offer from M.I.T., and in late November 1926 they boarded a steamer bound for New York.

MIXING MARXISM AND MATHEMATICS: THE M.I.T. YEARS

The next twenty-five years marked a relatively tranquil interlude in Struik's life. He became a popular M.I.T. professor, the proud father of three girls, and a well-known spokesperson for left-wing causes. During this period, he also continued to couple research in differential geometry with his growing interest in the history of mathematics. Soon after his arrival at M.I.T. he began collaborating with Norbert Wiener on a new relativistic theory of quanta, the results of which

Dirk and Ruth Struik

appeared in [21, 22, 23, 26]. His former mentor, J. A. Schouten, remained, however, as before, his principal mathematical collaborator. This partnership culminated in the late 1930's with the publication of their *Einführung in die neueren Methoden der Differentialgeometrie* [41] in two volumes. On the historical side, Dirk and Ruth Struik coauthored a short note in *Isis* [27] in which they called attention for the first time to the fact that Cauchy and Bolzano both lived in Prague between 1833 and 1835 (they found no evidence of contact between them).

Struik's most substantial historical study from this period appeared in 1933: his two-part "Outline of a History of Differential Geometry," [33], also published in George Sarton's *Isis*. The style he adopted here—mixing biographical, institutional, cultural, and political developments while surveying the most important conceptual and technical breakthroughs—bears a striking resemblance both to Klein's lectures and to his own *Concise History* written fifteen years later. Clearly this study, touching on the works of major figures from Leibniz to Lie, was written with the broadest possible audience in mind.

It was during the 1930s that Struik began to take a serious interest in Marxist approaches to the history of science. As Alberts indicates in his essay, Struik and many of his contemporaries were strongly influenced by the paper [99] Boris Hessen delivered at the 1931 International Congress on the History of Science and Technology held in London. Hessen's Marxist analysis of the social and economic interests that shaped Isaac Newton's scientific program represented perhaps the first serious attempt to bring Newton's work "down to earth." In the wake of this study came the British Social Relations in Science Movement supported by figures such as J.D. Bernal, J.B.S. Haldane, Joseph Needham, Lancelot Hogben, and Hyman Levy. Struik himself later stressed the importance in the 1930s of the publication of Engels' *Dialectics of Nature* and Marx and Engels' *The German Ideology* as well as Lenin's philosophical works for the formation of a self-sufficient Marxist approach to philosophical and scientific issues [86, 285].

In the context of these developments, Struik helped in 1936 to launch the Marxist-oriented periodical *Science & Society*, the first issue of which contained his essay "Concerning Mathematics" [36]. Two years later *Science & Society* carried [39], Struik's review of G.N. Clark's *Science and Social Welfare in the Age of Newton*, a book which was highly critical of Hessen's interpretation of Newton. Struik later described this critique as "a healthy warning against applying historical materialism in a too narrowly economic manner" [86, 287]. A similarly critical view of Hessen's approach animated the work of Robert Merton, whom Struik first met when he was still working on his dissertation in the 1930s (see [90, 227]). (See Alberts' essay, below, for an assessment of Merton's importance for Struik's later work.)

By the early 1940s, Struik felt the time was ripe to draw up a new blueprint for studies in the history of mathematics. He set forth his reflections on this subject in a 1942 article in *Science & Society* entitled "On the Sociology of Mathematics" [43]. Drawing on recent trends in Marxist analyses of the history of science, he called for similar studies directed toward the history of mathematics.

In part, this program was directed against the then dominant approach to the history of mathematics which focused almost exclusively on mathematical problems and/or ideas and the circumstances that led to their "solution" and/or "discovery." Struik always rejected the notion that the history of mathematics can be meaningfully investigated along such narrow Platonic lines. Instead of regarding mathematics as a purely contemplative activity, he argued that it should be seen as a highly abstract science that has gradually emerged as human beings have learned to study a variety of highly complex relationships found primarily in their outside worlds. As such, mathematics unfolds in a dialectical fashion out of a matrix of forces that may be intellectual, social, cultural, economic, etc., in nature.

Given this orientation and his strong predilection for holistic approaches, Marxism clearly had much to offer Struik as a tool for understanding the ways in which a variety of factors shape and mold a scientific milieu and condition certain styles of thought. Yet, he clearly rejected a reductionist view of mathematical knowledge. In a 1956 lecture he emphatically stated that:

> . . . the freedom of the mathematician is not illusory—it is a real one, and one of the most fascinating aspects of our science. But its freedom is the freedom of which the philosopher speaks [here he undoubtedly had Hegel in mind]: the freedom based on understanding of the

laws. The laws of the mathematical game are strict: logical consistency is one of the most important. Experience teaches that in following these laws the mathematician never strays very far out of the world around him. After all, man and his mind are also part of the universe. [58, 3]

Whereas Struik's classic *A Concise History of Mathematics* was conceived as a sweeping overview of mathematics viewed as an integral part of the cultures in which it has flourished, his first real attempt to develop the new sociological program he had fashioned came with *Yankee Science in the Making* [51]. Although both books appeared in 1948, Struik spent considerably more time doing background research in order to write *Yankee Science*. Attracted by New England's scientific traditions, Dirk and Ruth roamed the countryside searching for traces of lost technological treasures, such as the Middlesex Canal, hidden in the woods and nearly forgotten (in the meantime it has been partly restored). Struik read widely and gaining inspiration from Van Wyck Brooks' study of New England literature.[6] Viewing this relatively homogeneous population from the Colonial period through to the early decades of the Republic, he pondered the geography, agriculture, trade, and transportation systems that shaped New England's scientific culture. He considered the role of manufacturing innovations, English cultural connections, Puritan thought and customs, and much else besides. What emerged from Struik's analysis were a number of clear patterns of scientific activity practiced by rather distinct types of individuals. Much of the scientific activity took place in the coastal towns, where shipbuilding and seafaring dominated the local economies. Out of this milieu came the "practical navigators," a tradition that culminated with the work of Nathaniel Bowditch. From the inland farming towns of Connecticut and Worcester County came another scientific type, stemming from the combination of "whittling boy" and "Yankee peddler": the inventor–manufacturer. A third tradition emerged in connection with the construction of new roads, bridges, and canals, as exemplified in the achievements of the civil engineer, Loammi Baldwin. A fourth was inaugurated by academics such as Yale's Benjamin Silliman, Harvard's Louis Agassiz, and M.I.T.'s William Barton Rogers.

Yankee Science in the Making represents Struik's most ambitious undertaking in a sociohistorical vein. Nevertheless, it was but one of many studies guided by the same spirit. For example, he also focused considerable attention on the social, economic, religious, and cultural conditions that shaped Dutch mathematics during the era of the Scientific Revolution (see [40, 59, 90]). A key figure of this period

[6] In a 1991 postscript, Struik recalled how his reading of Brooks' *The Flowering of New England, 1815–1865* helped inspire him to write *Yankee Science in the Making*. He also noted that since the appearance of the 1962 edition of his book, several sites treated therein had been restored: "The old manufacturing section of Lowell . . . has become a historic landmark, the Slater mill in Pawtucket is a museum, and sections of the Middlesex canal have passed into the loving care of the Middlesex Canal Association" [51, 446].

was Simon Stevin (1548–1620), who served as an engineer and general quartermaster under Prince Maurice of Orange during the period when Holland sought to free itself from Spanish rule. In his General Introduction to Part II of *The Principal Works of Simon Stevin* [60], Struik emphasized that when Stevin settled in Leiden in 1581, "[t]he young Republic, at war with Spain and entering a period of great maritime expansion, needed instructors for its navigators, merchants, surveyors, and military engineers. Teachers of mathematics, surveying, navigation and cartography, instrument-markers and engineers found encouragement; their number increased and soon no commercial town was without some of them" [60, 3].[7] With regard to Stevin, whose principal contributions to mathematics—his *Tafelen van Interest*, followed by *Problemata Geometrica, De Thiende, L'Arithmétique*, a *Pratique d'Arithmétique*, and three books on mechanics—were written between 1582 and 1586, Struik emphasized the liberating character of his work. For example, in connection with Stevin's *Tafelen van Interest* Struik noted that before the spread of arithmetical instruction during the sixteenth century powerful financial interests, such as the Baldi and Medici families in Florence and the Welsers and Fuggers in Augsburg, had hired experts who computed such interest tables for them. Stevin himself once said that such tables were "hidden as mighty secrets by those who have got them" [60, 13]. Thus, following Struik's Marxist analysis, Stevin was *consciously* breaking down barriers that led to a new stage of capitalist development.

At the same time, however, Struik paid considerable attention to the conceptual innovations in *De Thiende*, where Stevin introduced the decimal system for handling fractions [60, 4–5; 62]. Within this context, Stevin's work may be viewed as an attempt to liberate arithmetic from its servile bondage to geometry, a tradition dating back to the Greeks. This meant finding an antidote to the engrained view that numbers like $\sqrt{2}$ were "irrationals" or "surds" and, hence, carried a lower status than rational numbers. Struik's analysis went still further in this direction, and he noted how Stevin also strove to overcome the ancient Pythagorean doctrine that the unit of measure, the *μονάς*, is itself not a number [60, 4–6]. In his *L'Arithmetique*, for example, Stevin wrote that the unit is made "of the same material" as a multitude of units, and must, therefore, itself be a number, "just as a piece of bread is bread."[8]

The role of religion has also played a part in Struik's reflections on the character of Dutch contributions to the Scientific Revolution. In "Further Thoughts on Merton in Context" [90], he noted with regret that whereas numerous studies concerned with the influence of Puritanism on English science have been published

[7] Struik noted further that a similar pattern of explosion in mathematical activity had taken place in England, citing E. G. R. Taylor's study, *The Mathematical Practitioners of Tudor and Stuart England,* which found 582 active mathematical practitioners between 1485 and 1715.

[8] Quoted from Jacob Klein, *Greek Mathematical Thought and the Origins of Algebra* [103, 192]. Klein's book analyzes in detail the significance of this conceptual innovation as well as Stevin's role in promoting it.

in the fifty-year period following the appearance of Robert Merton's classic *Science, Technology and Society in Seventeenth-Century England*, no comparable study has examined the influence of religion on Dutch science during the same period. Struik's own findings with respect to this phenomenon suggest that the Arminians, the more moderate sect within the Dutch Reformed Church, sympathized more closely with a "capitalist spirit" than did the more orthodox Calvinist sect, the Gomarists. Struik called attention to the Utrecht theologian and prominent Gomarist, Gisbertus Voetius, who, following Calvin, strongly subordinated scientific findings to Holy Scripture. Still, he cautioned against the tempting, but oversimplified "idea that Arminians were sympathetic and orthodox Calvinists antipathetic to the acquisition of new scientific knowledge," [90, 237] suggesting instead that an undercurrent of "Erasmianism" in Dutch capitalist circles, which often was mixed with some brand of Calvinism, formed the backdrop for the emergence of Dutch scientific achievements.

As the foregoing capsule summary hopefully makes clear, Struik's historical studies were always animated by an intuitive feel for the salient characteristics that contributed to the formation of regional or national styles of scientific thought. He carefully avoided reifying Marxist ideas or employing social and economic categories without paying careful attention to the precise historical conditions that happened to prevail in a particular setting. In fact, his work often evinced scepticism when it came to global theories intended to explain the course of human events. On the other hand, he never shrank from the pursuit of general patterns, however provisional, that could serve as structures for better understanding human history. But these he found by examining the operative forces within a given, well-defined cultural context. Struik's historical materialism, like that of his friend Jan Romein, always served as a means for *doing* history and never as an end in itself. Both were synthesizers on a grand scale, but their search for global patterns was informed by a healthy regard for the irreducible integrity of past historical events.[9]

In 1934 Dirk Struik became a naturalized American citizen, and over the next ten years he took an active part in supporting numerous political causes. These ranged from backing the Spanish Loyalist forces in their battle against Franco's Fascists to working for the Council of American–Soviet Friendship during the war years. Struik made no secret of his Marxist views and his support of militant trade unionism in the tradition of the C.I.O. In 1944 he helped found the progressive-oriented, but short-lived Samuel Adams School in Boston, an institution whose members' activities attracted the attention of J. Edgar Hoover's F.B.I. (see [94]).

[9] For an account of Romein's approach to history, see Harry J. Marks' preface to Romein's *The Watershed of Two Eras. Europe in 1900*, [112, ix–xxxviii]. Chapter XXII on "The Triumph of the Atom" was written by Dirk Struik [73].

During the early stages of the McCarthy era, in an atmosphere that Struik later described as "half reminiscent of Nazi Germany, half of Alice in Wonderland" [94, 34], he remained free to teach his courses while he put the last touches on *Yankee Science* and wrote his *Concise History*. This situation changed abruptly, however, in April 1949 when an F.B.I. informant discussed Struik's "subversive" political activities in testimony given during a well-publicized trial of leading communist figures in New York City. Initially, President Killian and the M.I.T. administration stood behind Struik, and Killian issued a statement in which he noted that the informant's testimony had not charged him with an unlawful act, that Struik had "competently and faithfully" fulfilled his duties as a professor of mathematics, and that he had not attempted to indoctrinate his students with Marxist ideas [94, 38].

Killian's statement seemed to mark the end of this affair, but then the "Struik Case" picked up new momentum when the same informant brought new charges against M.I.T.'s leading communist in a July 1951 hearing before the House Un-American Activities Committee (HUAC). This time he claimed that he had infiltrated the Communist Party in Boston and had discovered that Struik, as a card-carrying member of the CP, had taught Marxism at the Samuel Adams School. By then, Struik and his friend Harry Winner, the former treasurer of the school (which closed in 1948), had both been subpoenaed by HUAC and were obliged to stand before the committee the day after the F.B.I. informant had testified against them. On the advice of their legal counsellors, both refused to answer questions by invoking the Fifth amendment. Struik had to repeat the words: "I decline to answer—basing myself upon the Fifth Amendment" about two hundred times. It was a humiliating experience, as those who chose this course to avoid implicating others were often treated with derision and branded as "Fifth Amendment communists." Afterward, in a private meeting with M.I.T. administrators, Struik defended his case, explaining that he was a Marxist with close ties to communists, but that he was not a member of the party.

Two months later, the next blow fell when a Middlesex County grand jury convened to hear evidence against Struik, Winner, and two others. On 14 September, 1951 all four were indicted on charges of having broken a Massachusetts "Anti-Anarchy Law" which had been enacted in 1919 as part of a series of antisubversive actions. Only once before, in 1926, had a case come up where someone was charged with having violated this law, and the accused went free on that occasion. In this 1951 case the government's key (and, as it later turned out, only) witness was the ubiquitous informant who had testified earlier against Boston's communist "conspirators."

In the meantime a defense committee was set up, headed by Harvard's George Sarton. By the time Struik appeared in court to enter his plea of not guilty, this committee had raised more than enough money to cover bail, set at $10,000, a formidible sum of money in those days. (Struik wrote later: "clearly, I was dangerous, or so the judge thought" [94, 40].) In the wake of these events, the M.I.T.

administration decided to suspend Struik, with salary, during the period of his indictment.

What no one at the time anticipated, however, was just how long that might take. This was mostly due to the fact that the District Attorney had built his case on sand, since he had little more to go on than the F.B.I. informant's testimony. The latter, as it turned out, seemed to think he knew practically *everything* about Bostons' communists. This attitude may have served him well when it came to smearing people's reputations, but the D.A. must have realized that he would not look terribly credible in a courtroom under cross-examination. Beyond this, after being honored by the Governor of Massachusetts, who proclaimed the 27th of November, 1951 "Herbert Philbrick Day," the celebrated F.B.I. informant was eager to "cash in" on his new-found fame by writing a book about his exploits.

Meanwhile, the District Attorney, realizing that he had practically no solid evidence, began stalling the case. Struik's lawyers tried to get the indictments quashed, but their appeals to the State Supreme Court were denied. In liberal circles, Struik's case became a *cause célèbre*. He received countless invitations to speak, and together with Ruth he travelled the country to give talks about a theme then very much on his mind: freedom of speech. At home, he concentrated on his current historical project, the edition of Simon Stevin's mathematical works and, as a substitute for teaching mathematics, his textbook, *Lectures on Analytic and Projective Geometry* [55]. During this time, Struik's colleague and friend, Phillip Franklin, taught a course from Struik's other new textbook, *Classical Differential Geometry* [52].

After dragging on for nearly five years, the indictments against Struik and his "coconspirators" were finally thrown out in 1955. Struik looked forward to the opportunity of taking up his teaching post once again, but then he learned that he would have to stand before a Massachusetts legislative committee which functioned much like HUAC. On the day he was subpoenaed to testify—again following the obligatory appearance of the F.B.I. informant—Struik stated that he would answer all questions, but without giving any names. He then proceeded, against the well-intentioned advice of his lawyer, to speak openly about his views and actions, doing his best to make the committee members look ridiculous. He concluded his testimony by reminding them of Judge Sewall, who presided over the witchcraft trials in Salem and later repented for his actions.

By now the enthusiasm for communist witchhunts had largely run its course. A year earlier, the Senate had shorn Joseph McCarthy of his power, and soon thereafter he died in disgrace. Anticommunism continued to simmer on the nation's stove, but it seemed that the danger of it overboiling had been averted. In the fall of 1955 Struik returned to his classes at M.I.T. and he remained on the faculty until 1960, when he was forced to retire at age 65. He had hoped to receive an emeritus appointment so that he could continue teaching at M.I.T. until he reached age 70, but to no avail. Concerted efforts to find a position at other universities in Texas, Illinois, and Ohio also came to naught. So Struik looked around for possibilities outside the U.S., eventually accepting invitations to teach in Puerto

Rico, Costa Rica, and Utrecht. As a final episode in this chapter of Struik's life, in 1986, on the occasion of his 92nd birthday, he received a certificate of congratulations from the House of Representatives of the Commonwealth of Massachusetts. Struik could not help but enjoy the irony: he, the man who had once been accused of conspiring to overthrow the government, had finally been "forgiven" by the state.

Through the years, Struik met and befriended all sorts of fascinating people, many of them long since deceased. Struik's vivid recollections of teachers, colleagues, friends, and acquaintances provide a rich resource for those with an interest in the often overlooked human side of mathematics and its history (see, for example, [31, 56, 71, 74, 80, 87–89, 91]). Among the numerous tributes he has written in honor of fellow mathematicians, the one for Norbert Wiener [71] is perhaps most revealing since it tells us so much about both men.

Whereas many who knew him fixated on Wiener's eccentricities, Struik looked upon his colleague with awe, and not merely because of his brilliant intellect. He admired him even more for his deep concern for the social consequences of technological innovation, an issue regarding which Wiener's ideas were far ahead of their time.[10] Struik traced the impressive scope of Wiener's accomplishments to his unified vision of science, which originated in the latter's early interest in mathematical logic. "He was a man," recalled Struik, "who not only saw, but lived the unity of the sciences, a unity which embraced philosophy, history and literature. The great discoveries, he used to point out, are made on the border where different sciences, or sciences and arts, meet. His own work in cybernetics is a vindication of this conviction" [71, 34].

Struik mentioned how Wiener loved to read Thackeray, and not just "because he enjoyed a masterful storyteller" but also because the stories evoked a sense of being transported back to an earlier bygone age "in which scientists and craftsmen of the 18th and 19th century lived." Through his father, Wiener learned to love the poetry of Heine, with its mixture of Romanticism and biting irony. Among philosophers, he admired Leibniz, and would "point out how in his cybernetics, the ideas of the philosopher Leibniz, the physicist Gibbs, and the mathematician Lebesgue found a common meeting ground" [71, 35].

Struik had little patience with the standard picture of Wiener as a child prodigy who never really grew up, but he also recognized that his "natural sensitivity had been stimulated by his status as an infant prodigy and the tension caused by the guidance of a strict and all too masterful father" [71, 35]. Still, he emphasized that it was Wiener's concern over the growing efforts of military and political interests to co-opt science rather than personal problems rooted in an unhappy childhood that led to some of his severe depressions in later years.

Recalling his passionate views regarding the moral responsibilities of scientists, Struik wrote:

[10] Struik has been one of the few mathematicians to praise the dual biography by Steve J. Heims, *John von Neumann and Norbert Wiener* [98], precisely for its sensitivity to this issue.

> Wiener could be desperately unhappy about the evil effects, and even evil potentialities, of his work and that of others. He resisted all attempts to enlist him in the war effort . . . or in the employ of private corporations. He must have denied himself access to a fortune. His statement in the *Atlantic Monthly* of January 1947, in which, referring especially to guided missiles, he refused to participate in any enterprise undertaken by the military, received wide attention and made many persons sit up and take notice. [71, 36]

Episodes like this caused Wiener considerable emotional anguish. On the other hand, he was convinced that technology could and should be used to alleviate human suffering. Struik remembered how his colleague once spent several weeks in a hospital recovering from a fall. During this time he struck up conversations with several doctors who were interested in what he had to say about cybernetics and medicine. "Out of these conversations," Struik recalled, "came new ideas on the control of artificial limbs. I have seldom seen Wiener so happy as when he told how he had turned the mishap of his fall into a victory for the handicapped" [71, 36].

Struik saw Wiener as a sterling exemplar of American liberalism, a tradition that he himself admired, but never subscribed to. They conversed about everything from God to politics and love, but Struik never had any delusions that Norbert Wiener would ever find his dialectical materialism very attractive. Still, none of their differences of opinion on this score diminished his respect for Wiener as a social thinker in the least, as evidenced by Struik's account of another episode he shared with him:

> In all such matters, good or bad, he saw deeper than other men. I well remember how upset he was on the day after Hiroshima, and to my remark that war against Japan would now come to a speedy end without much bloodshed (the common feeling at the time and still the official version) he replied that the explosion signified the beginning of a new and terrifying period in human history, in which the great powers had to push nuclear research to a destructive potential beyond anything known in history. [71, 36]

For Struik, Wiener's wisdom simply transcended all conventional boundaries of political thought.

The sheer breadth of Dirk Struik's writings clearly reflects his relentless intellectual curiosity, his sorber optimism, and his marvelous zest for life. But it also reveals another facet of his personality that cannot be emphasized enough: the ability to adapt his message to a given audience and to communicate it as directly as possible. Whether writing for mathematicians, mathematics students, teachers of mathematics, or historians of mathematics, Struik always seemed to find a "wavelength" appropriate for those who were likely to "tune in." His "best-selling" *Concise History of Mathematics* has proven this many times over, for this is not just one book, but many, and can be read from a multitude of viewpoints, both diachronic and synchronic.

After he gave up doing mathematical research around 1950, Struik set his sights on the history of mathematics from the Stone Age (see [66; 84]) to modern tensor analysis [80; 88]. He was trying to get us to look beyond the ramparts of Eurocentrism decades before it became popular to assail them. In his 1963 article on

"Ancient Chinese Mathematics" [64] he introduced mathematics teachers to the work of Yoshio Mikami, Joseph Needham, and others. Ever since his first visit to Mexico in 1935, Struik has taken a passionate interest in Latin American history, and has published several articles on the history of mathematics in the Americas (see [69; 79; 85]). He was also one of the first Westerners to take an early interest in the work of Paulus Gerdes (see his contribution on mathematics in sub-Saharan Africa, below) and others in the area of ethnomathematics (see [86, 296–299]).

If it has become common in certain quarters of late to malign the state of the history of mathematics as a discipline, Struik has offered ample clues for directions with a promising future. His own example suggests that we need not break altogether with past historiographic traditions, as they have much to teach us. In any event, a heightened sense of our discipline's own history and prehistory is today a widely acknowledged *desideratum*. Probably there is no simpler place to start than with Struik's survey of "The Historiography of Mathematics from Proklos to Cantor" [81], which can be warmly recommended to every historian of mathematics, but particularly those starting out in the field.

For most of us who consider ourselves professional historians of mathematics, the questions "why?" or "what for?" occasionally receive some nodding attention, but seldom more. The answers are necessarily personal ones, evoking pleasant memories perhaps of former teachers or first books. If questions like these are difficult to answer, that does not mean one should not try, particularly if the person asking does not have a clue. Dirk Struik's thoughts on this topic can be found in his essay "Why Study the History of Mathematics?" [82]. As for Struik's own favored approach to the subject, one can gain a glimpse of the trends he finds particularly promising in "The Sociology of Mathematics Revisited: A Personal Note" [86].

Dirk Struik was already almost eighty years old when Kenneth O. May launched *Historia Mathmatica* in 1973. For his eightieth birthday he received a special *Festschrift* put together by Robert S. Cohen, John J. Stachel, and Marx W. Wartofsky [97]. This earlier *Festschrift* contains forty-nine articles covering a variety of mathematical, historical, philosophical, and cultural/political themes, a fitting tribute to the breadth of Struik's intellectual concerns and interests. This book also presented a (nearly) complete bibliography of his publications up until 1973 [97, xix–xxvii]. The list of *selected* publications by Dirk Struik that appears below contains all of his major works in mathematics and the history of mathematics. To publish a complete list of everything he has written would simply take up too much space.

Twenty years is a long time, especially for a man like Dirk Struik. A glance at the list below reveals that he is still a "force to be reckoned with," and he would not want it any other way. One can only marvel at a person who has continued to enrich the history of mathematics with lucid narratives, cogent insights, thought-provoking analysis, and fascinating personal reflections right up to the centenary of his birth. Dirk, your life and work have been an inspiration to thousands of people, both living and dead, all over the world, and your influence on the history

Dirk Struik in 1973

of mathematics has been long-lasting and considerable. Whatever else one might say, and perspectives change and vary, all historians of mathematics are likely to agree that our discipline as it exists today would be a far poorer one without you.

SELECTED PUBLICATIONS OF DIRK J. STRUIK

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