STEPHEN SMALE:

The Mathematician Who Broke the Dimension Barrier

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Preface

Stephen Smale* startled the mathematical world in 1957 by proving that, in a theoretical sense, it was possible to turn a sphere inside out. Until Smale's work there was a prevailing intuition that such an act required that the sphere be torn or crimped. Even more sensational were his theorems a few years later, persuading mathematicians that a 6-dimensional world was simpler than a 3-dimensional world. For this work Smale received international acclaim and was awarded the most prestigious prize available to a mathematician. Mathematics, however, is a subject that has stood outside the mainstream of intellectual discourse. The discoveries of its giants have generally been known and appreciated only by those within the field.

Whatever barriers exist to deter entrance into higher mathematics did not prevent Smale's occasional exit. His vision and influence extended beyond mathematics into two vastly different realms. With Jerry Rubin in 1965 he initiated a program of civil disobedience directed at ending the Vietnam War. As a mineral collector Smale accumulated a museum quality collection that ranks among the finest in the world. Despite Smale's unique resumé of diverse accomplishments, the name of this contemporary genius is virtually unknown outside the narrow worlds of mathematicians and mineral collectors. One objective of this book is to bring his life and work to the attention of a larger community.

I first became aware of Stephen Smale when I was a mathematics graduate student in the early seventies. As I began to study the theory of dynamical systems, Smale's name was everywhere. He had set the agenda

*pronounced as snail with an m.

for development, made the important conjectures, and proved the big theorems. John Franks, a former student of Smale, was my thesis advisor, making Smale my academic grandfather. Reading papers on dynamical systems and working on my thesis problem, I was continually struck by Smale's insight into the subject. Not only had he identified the structures that I was struggling to assimilate, but he had seen how they might fit together into a theory. By that time Smale himself had moved on to mathematical economics, leaving behind a rich collection of problems for his progeny.

Smale's mathematics is distinguished by its breadth as well as its depth. It was his work on the theory of computation that inspired me, in the mid-eighties, to shift my own research in that direction. At Smale's invitation I visited Berkeley for a semester in 1990. During that period we became better acquainted. I learned that he had been a communist during the McCarthy era. More surprising was that, in addition to his ambitious research program, the sixty-year-old mathematician had just recently begun devoting considerable energy to making high quality photographic prints of his minerals. One night at dinner he confided to me that the biggest driving force in his life at that instant was the hope that he might someday be known as a great photographer. I immediately thought "Why isn't it enough to be acknowledged as a great mathematician?"

I wanted to know more about Smale's life and what he had accomplished with his remarkable mind. Ten years earlier Smale had begun to write an autobiography, focusing on his protest activity. Unfortunately he only completed a portion of the project. Reading the chapters whetted my appetite for more. Since my childhood I have enjoyed the biography genre, but there are few biographies of mathematicians. Thinking of Smale as a possible subject, it became clear why the life stories of mathematicians are rarely recorded. To place their lives in perspective requires some appreciation of their theorems. Biographers are not trained in mathematics, and mathematicians do not learn to write biographies. It was unlikely that a suitable author would emerge to write Smale's biography.

Although I am foremost a mathematician, I became intrigued by the notion of working on a Smale biography project. Smale is a significant figure in intellectual history and his story should be recorded and known. Few people have any idea as to what research mathematicians do, or even the intellectual skills and personal qualities that contribute to success in this mysterious subject. The life of Steve Smale offers a case study in the development of a great mathematician. This book examines what made him that rare individual who succeeded in proving profound theorems. Additional perspective is provided by comparing Smale's approaches to politics, minerals, and other endeavors.

Several factors made me hesitate to write this book. My admiration of Smale's mathematics and antiwar work raised a concern that I was not sufficiently objective. There were doubts about my qualifications as well as a reluctance to delve into his personal life. In the final analysis these issues were outweighed by my genuine interest in Smale's life and the realization that biographers, while struggling for objectivity, are never indifferent to their subjects. When informed of my intentions, Steve was gracious, making himself and his papers available to me. I believe, however, that he may have doubted that this project would be completed.

My goal has been to produce a book that makes Smale accessible to nonmathematicians. Not to provide the details of his proofs, but rather to convey an appreciation for the problems he attacked. One of the challenges is the vertical nature of mathematical knowledge—where each concept depends on several others which themselves depend on still others and so on in long cascades. In the twelve chapters of narrative there is little technical discussion, but there are a few selected localities with intuitive descriptions of abstract mathematical concepts. To illustrate more of the flavor of Smale's work, appendices are included at the back of the book. These sections explore, at varying levels of sophistication, the nature of four mathematics problems to which Smale made significant contributions. The presentation is directed at nonmathematicians and mathematicians whose expertise is outside the topic under discussion. The appendices are not essential to the text nor do they encompass the full range of Smale's mathematics. Readers may wish to skip them entirely or read a portion before moving on to the next section.

7. The Summer of 1966

A. Another Berkeley subculture

The Berkeley campus impact of the Free Speech Movement extended beyond the new freedoms on political activity. Previously, there had been a sharp demarcation between faculty and graduate students. In the post-FSM environment, such class distinctions became less formal, and a more collegial relationship emerged. Some professors had difficulty adjusting to the new campus culture, but this was not the case for Smale and Hirsch. Both had already accepted a peer status in sitting around Jerry Rubin's apartment, planning Vietnam Day.

When Smale shifted his energy back to mathematics in late 1965, he was well positioned to assume a new role as faculty mentor. Berkeley had a large number of talented mathematics graduate students, each needing a thesis advisor. Smale was not only a politically correct choice, but he also possessed the currency which was most vital to a graduate student: good problems. Steve had launched a major program for the development of dynamical systems, offering enough interesting conjectures and questions to sustain a small army of mathematicians. Hirsch and a young faculty member named Charles Pugh joined the steady stream of graduate students enlisting each year. They quickly developed a subculture within the mathematics department, facilitating discussion and interaction. Somehow the excitement of mathematical discovery comfortably integrated with the social and political transformation occurring around them.

Among the first graduate students to join the group were Mike Shub, Jacob Palis from Brazil, and Nancy Kopell. All would go on to distinguished mathematical careers of their own. However, for the last seven months of

1966, their early progress was challenged as Smale was temporarily away from the Berkeley campus. During this period the students benefited from each other, as well as Hirsch and Pugh who generously gave of their time in guiding Smale's charges. Steve's own plans called for a summer in Europe, followed by a residency at the Institute for Advanced Study. The European phase included mathematical sojourns and conferences, as well as travel with his family. The highlight would occur in August when Steve was one of the eminent mathematicians invited to deliver a plenary address at the International Congress of Mathematicians in Moscow.

B. The Nobel Prize and the Fields Medal

In 1897 Zurich hosted the first International Congress of Mathematicians. Over 200 attended the three day meeting that was to feature lectures by four outstanding mathematicians. Henri Poincaré was scheduled to deliver the first talk, but illness necessitated his paper being read by a substitute.[1] The second Congress, three years later in Paris, extended the format to an entire week. Again there were a few invited *plenary* addresses to the entire gathering, separated by smaller sessions broken down by field. This structure of the International Congress of Mathematicians remains today. The meetings have occurred every four years since, excepting the war periods and a one year delay of the 1982 Warsaw meeting due to the political upheaval in Poland. Other more specialized or localized mathematics conferences occur frequently, but none possess the scope and prestige of the ICM.

The number of plenary speakers has increased to approximately fifteen per Congress, but the honor of delivering these hour lectures remains among the highest status available to a mathematician. Ironically, the most influential lecture in the history of mathematics was a nonplenary talk at the 1900 Paris ICM. In his address "Mathematische Probleme" and a subsequent paper, David Hilbert of Germany described 23 unsolved problems, setting an agenda to challenge mathematicians for the new century.

During the early twentieth century, Europe was the center for mathematical research. Promising American scholars often traveled across the Atlantic for graduate and/or postdoctoral work, studying under the European masters. Naturally, the ICM tended to select venues that were convenient to its audience and the plenary speakers. The emerging North American school finally attracted the 1924 meeting, originally scheduled for New York but actually held in Toronto.

The Canadian mathematician J. C. Fields organized and raised the money for the Toronto ICM. Fields received his Ph.D. from Johns Hopkins in 1887, one of the foremost American programs of his day. After a short period of teaching in the United States, Fields went to Europe and

further refined his mathematical knowledge. During his ten years abroad, Fields developed an important friendship with the influential Swedish mathematician, Gösta Mittag-Leffler. In 1902 Fields accepted a position at the University of Toronto, where he remained until his death.[2]

Fields' time in Europe coincided with the founding of the Nobel Prizes. When the wealthy Swedish scientist Alfred Nobel died in 1896, the world was shocked to learn the substance of his will. Nobel left most of his estate to endow the annual award of prizes to those who "have conferred the greatest benefit on mankind."[3] He designated five separate disciplines for recognition: physics, chemistry, physiology or medicine, literature, and peace. While the will was short on implementation details, the $40,000 magnitude of the prizes dwarfed the salaries of academicians. Prestige quickly followed the wealth, and the prizes became the most coveted awards of the twentieth century.

Following the Toronto ICM meeting, Fields sought to remedy the omission of mathematics from the Nobel list. Due to Fields' successful fundraising, the 1924 Congress had produced a surplus. Fields managed to direct the money toward a prize in mathematics, which he conceptualized in a memo just prior to his death in 1932.[4]

> It is proposed to found two gold medals to be awarded at successive International Mathematics Congresses for outstanding achievement in mathematics...
> It would be understood, however, that in making the awards while it was in recognition of work already done it was at the same time intended to be encouragement for further achievement on the part of the recipients and a stimulus to renewed effort on the part of others...
> One would here again emphasize that the medals should be of a character as purely international and impersonal as possible. There should not be attached to them in any way the name of any country, institution or person.

Fields designated additional endowment funding from his estate, permitting stipends to accompany the medals. At the 1932 ICM in Zurich, the concept was approved and a committee was designated to select the honorees for the following Congress. In the opening session of the 1936 Oslo ICM, King Haakon VII presented the first awards.[5] The winners were 29-year-old Helsinki born Lars Ahlfors of Harvard University and 39-year-old Jesse Douglas of New York and the Massachusetts Institute of Technology. The Fields Medal, as it became known despite the intentions of its creator, featured a profile of Archimedes.

Both the Fields and Nobel winners receive a gold medal and accompanying honorarium. Mathematicians describe the Fields Medal to laypeople as

the "Nobel Prize of mathematics." This characterization (similar to a college calling itself the Harvard of some region or genre) contains a great deal of information. The prestige of the Nobel is appreciated by everyone, but the standing of the Fields Medal is restricted to the world of mathematics.

The iconification of the Nobel Prize among science awards owes to its seniority and the lottery-magnitude of its stipend. When the first Nobels were awarded in 1901, physicist Wilhelm Röntgen and chemist J. H. van't Hoff each received a payment in excess of $40,000 in the currency of the time. Seventy years later, mathematicians were taking home a $1500 stipend with the Fields Medal. Although the financial reward of the Fields Medal failed to measure up to that of the Nobel, among the mathematical community it was a prize of comparable honor.

Another contrast between the Fields and Nobel awards has been the age of the recipients. While Fields made no mention of a specific age requirement, he did suggest that the medal both reward prior work and encourage future achievement. In interpreting this intention, every Fields selection has designated recipients who were under the age of 40. Nobel's desire was to reward the greatest past accomplishment. Röntgen and van't Hoff were 56 and 49, respectively.

Why is there no Nobel Prize in mathematics? It is a natural question, especially for a mathematician who annually observes, perhaps with some envy, the fuss surrounding the announcement of the Nobel winners. The question provides the title for a short article by Lars Gårding and 1962 Swedish Fields Medalist Lars Hörmander.[6]

While the author of this book was in graduate school, he was told that the Swedish mathematician Mittag-Leffler had had an affair with Nobel's wife. It is a fairly common experience for American mathematics graduate students to hear this story from another student or a faculty member, possibly at a precolloquium gathering, party, lunch, office discussion, or even in a classroom.[7] Despite the fact that Nobel never married, the legend continues to spread as part of the socialization of mathematicians. In a field with little in the way of prurient substance, it is easy to understand the persistence of the myth. To a young (typically male) mathematician, defensive of the nerdish image of his chosen profession, there may be some satisfaction in believing that less glory is available because of the sexual exploits of an ancestor. However, it is a profession with an extraordinarily high standard of verification. Inadequately supported mathematical claims are frequently the object of ridicule, and the Nobel's wife story is *trivial* to debunk.

Gårding and Hörmander refer to the above story as the French-American version. When a mathematical statement is shown invalid, one might try to adjust the hypothesis or conclusion so as to be consistent with the data. For

example, in some tellings of the story, there is a triangle with an unnamed woman who is not specified as Nobel's spouse. Other formulations omit the woman, but maintain that Nobel rejected mathematics in order to deprive Mittag-Leffler of an opportunity at the award. Gårding and Hörmander refer to this as the Swedish version.[8]

The theory that Nobel's action was motivated by animus toward Mittag-Leffler is difficult to prove or disprove. Gårding and Hörmander state that there is no basis for the theory. Crawford reached the same conclusion following her intensive study of the establishment of the Nobel Prize.[9] A statement from J. L. Synge, an associate of Fields and the executor of his estate, suggests that Fields accepted the allegation. "Perhaps I should insert here something that Fields told me and which I later verified in Sweden, namely, that Nobel hated the mathematician Mittag-Leffler and decided that mathematics would not be one of the domains in which Nobel Prizes would be available."[10]

Considering the historical context of these stories, the Swedish version may well have originated out of the political battles waged by Mittag-Leffler. In 1881 Mittag-Leffler joined the faculty of the Högskola in Stockholm, three years after its founding. Mittag-Leffler, who was well connected in the European mathematical community, set out to boost the profile of mathematics at his new institution. Two of his most successful ventures occurred in the areas of publication and personnel. Shortly after his arrival at the Högskola, Mittag-Leffler began a mathematical periodical, *Acta Mathematica*, which rose to become among the most important outlets for the dissemination of mathematical research. Under Mittag-Leffler's influence, the Högskola attracted some of Europe's leading scholars to long and short term residencies.[11] The Russian mathematician Sonya Kovalevsky joined the faculty in 1884.[12] When Kovalevsky contemplated returning to St. Petersburg, Mittag-Leffler solicited the wealthy Nobel, among others, for funds to endow a chair for Kovalevsky at the Högskola. That Mittag-Leffler made such a request in 1890, suggests the absence of enmity at that stage. In examining the correspondence, Crawford concluded "The polite letters that Nobel and Mittag-Leffler exchanged during their lifetime seem to belie the assumption of a rift between the two."[13] Nobel declined the request, and Kovalevsky died the following year.[14]

> The building up of the Högskola was an arduous process that caused a series of conflicts culminating in the mid-1890s. Since these conflicts are thought to have influenced Nobel when he formulated his last wishes as well as to have affected the manner in which these wishes were carried out, they deserve brief mention here. The underlying cause of the disagreements at

> the Högskola were the conflicting views of two factions as to the basic aims of the institution. One faction, led by Mittag-Leffler, consistently supported *Lehrfreiheit*, that is, the view that the Högskola should be devoted to free learning and research at the highest level and not concern itself with exam or degree requirements. The other, led by Pettersson and including Arrhenius and Bjerknes, wanted to see the Högskola develop into a full-fledged university with the right to grant degrees in the same range of subjects as the state universities. The election of Pettersson as rector in 1893, followed by that of Arrhenius, who held this post from 1897 to 1901, were significant victories for this group. They were won, however, only after head-on confrontations with the old guard led by Mittag-Leffler. Pettersson's reelection as rector early in 1895 only occurred after a drawn-out fight during which the Högskola for a short while, partly as a result of Mittag-Leffler's machinations, found itself with *three* rectors, two of whom had been duly elected by the council of teachers at two successive meetings, the third having been appointed temporarily by the governing board. This episode was followed only four months later, in May 1895, by a row over the appointment of Arrhenius to the newly created chair in physics. In an effort to block Arrhenius, Mittag-Leffler succeeded in having Lord Kelvin called in as one of the three experts judging Arrhenius's competence. Kelvin's opinion was predictably negative, but was transmitted to Mittag-Leffler in a personal letter rather than, as called for by the rules of appointment (*sakkunnighetsinstitutionen*), in a formal opinion addressed to the Högskola. This made it possible for Pettersson, the new rector, to disallow it...
> In Stockholm's small intellectual community, where practically everybody knew someone in the press, these conflicts received considerable attention from the newspapers, which made much of "the trouble at the Högskola."

The political struggles at the Högskola peaked between the drafting of the penultimate and final versions of Nobel's will, dated March 14, 1893, and November 27, 1895, respectively. In the earlier version, the Högskola was among the beneficiaries with a modest bequest.[15] The final will omitted the Högskola entirely, but it was only one of several changes.

Nobel, the inventor of dynamite, held a deep interest in the movement toward world peace. In early 1893 he broached the idea of a peace prize in a letter to Bertha von Suttner, one of the most influential people in his life. Two months later Nobel produced a will which stipulated 20 percent

of his estate for various named individuals including relatives, 16 percent for specified institutions including the Högskola, and 64 prcent to endow a prize fund. While the leaders of the Högskola quarreled, Nobel further developed his notion of prizes. These ideas were implemented in the final will, along with drastic revisions in the allocations. Each individual was left a specific amount, summing to substantially less than the one fifth share of the previous version. All of the remainder was to endow prizes in the five areas of physics, chemistry, physiology or medicine, literature, and peace. No institution was included, except to administer the prizes.[16]

When the contents of the will were revealed after Nobel's death, it was a shock to virtually everyone, including his relatives and even his personal assistant Ragnar Sohlman who was designated as one of the two executors.[17] Who could have guessed? There was nothing like the Nobel Prize then in existence, and Nobel had been discreet about his plans, except with Bertha von Suttner. Von Suttner occupied a unique role in Nobel's life. They had met when von Suttner sought a job many years earlier. Nobel was strongly attracted to her, but she was already involved in a complicated relationship that soon led to marriage. Nobel remained fascinated by von Suttner and they did maintain a correspondence. Von Suttner founded a peace organization and authored the novel, *Lay Down Arms!* In 1905 she was awarded the Nobel Peace Prize.

Why is there no Nobel Prize in mathematics? The immediate answer is that it was not among the five areas designated by Nobel in his final will nor, as with economics, was it added later. Why then was mathematics excluded from the list? Nobel clearly wanted to make a big splash and promote those activities which "have rendered the greatest service to mankind." Under these criteria, peace and medicine were obvious choices. Given his own scientific work, it is likely that discoveries in physics and chemistry would have grabbed his attention. Finally, literature had an important aesthetic value to Nobel. Since he was so secretive about his plans, one can only speculate about his motivation, or lack of it, with regard to mathematics. Gårding and Hörmander assert that "the thought of a prize in mathematics never entered Nobel's mind."[18] Whether or not this was the case, it seems likely that mathematics would have ranked, in priority, behind the other five. Too many prizes might have diluted their impact, and cases could be made for other disciplines as well. Simply put, there was no compelling reason to include mathematics.

However, the Swedish and French-American explanations did originate somehow, and do continue to circulate. The contentious environment of the Högskola was ripe for allegations of blame.[19]

> Although it is not known how those in responsible positions at the Högskola came to believe that a *large* bequest was forthcoming, this indeed was the expectation, and the disappointment was keen when it was announced early in 1897 that the Högskola had been left out of Nobel's will of 1895. Recriminations followed, with both Pettersson and Arrhenius letting it be known that Nobel's dislike for Mittag-Leffler had brought about what Pettersson termed the "Nobel flop."

Thus the predicate of the Swedish version had an early origin, and was employed by Mittag-Leffler's opponents to explain the disinheritance of the Högskola.

Mittag-Leffler's posture toward the award winners was hardly that of a scorned party. Each year he hosted a dinner in honor of the laureates.[20] Moreover, Mittag-Leffler was intimately involved in the selection process for physics and chemistry. Nobel had left these decisions in the hands of the Swedish Academy of Sciences to which he and Mittag-Leffler both belonged. There were three stages in the selection process: nomination, review by standing committees of the Academy, and consideration by the entire Academy. Although Mittag-Leffler never served on either the physics or chemistry committee, he did manage to exert his influence on each of the three stages. He was especially active in choreographing nomination campaigns, even attempting to disguise his involvement from his enemies.[21]

Mittag-Leffler's greatest efforts were on behalf of Poincaré. The absence of a Nobel Prize in mathematics was no deterrent to Mittag-Leffler. Poincaré's work covered a broad spectrum, ranging from abstract topology to mathematical physics. Mittag-Leffler began a tactical campaign to obtain a Nobel Physics Prize for Poincaré.[22] At the turn of the century, the Academy physicists were disposed toward the applied side of their discipline. To reach Poincaré required a significant shift in emphasis. Mittag-Leffler planned a series of moves to steadily push the theoretical envelope. The first successful step in his program was the 1902 award shared by H. A. Lorentz. The effort ended with Poincaré's death in 1912, at which point he had the distinction of receiving the most nominations of any nonwinner.[23]

We hypothesize the following chronology for the Nobel–Mittag-Leffler stories. The omission of mathematics from Nobel's list reflected the priorities of the benefactor. When the Högskola was passed over, Mittag-Leffler's opponents seized the opportunity to place the blame on him, fabricating the notion of Nobel's animus. As Mittag-Leffler plotted to manipulate the physics awards toward mathematicians, the story's consequence evolved, changing Nobel's retribution from the Högskola to mathematics. Stipulating this Swedish version, it is easy to imagine the story being spruced up in

numerous retellings, eventually leading to the French-American version with Nobel's (nonexistent) wife.

C. International Congress of Mathematicians in Moscow

The original Fields plan called for two medals to be presented at each of the quadrennial ICMs. Following the inaugural award in 1936, there was a 14 year hiatus in the Congresses, due to World War II and its aftermath. During this period many leading European mathematicians migrated to the United States.[24] Europe's loss was America's gain, and the center of mass of the mathematical world abruptly shifted westward. In 1950 the ICM resumed in Cambridge, Massachusetts, where the second Fields Medals were presented. Below is a list of the subsequent ICMs, along with the Fields Medal winners, their age, country of birth, and institutional affiliation.[25]

1950 Cambridge, MA

Laurent Schwartz, 35, France, University of Nancy

Atle Selberg, 33, Norway, Institute for Advanced Study

1954 Amsterdam

Kunihiko Kodaira, 39, Japan, Princeton University

Jean-Pierre Serre, 37, France, College de France

1958 Edinburgh

René Thom, 34, France, University of Strasbourg

Klaus Roth, 32, Germany, University of London

1962 Stockholm

Lars Hörmander, 31, Sweden, Stockholm University

John Milnor, 31, USA, Princeton University

Smale was fortunate to have had early mathematical contact with several of the Fields Medalists. In large measure this was via his thesis advisor Raoul Bott. It was Serre's work that was the topic of the topology seminar at Michigan. During Smale's last year as a graduate student, he met Serre while visiting his advisor at the Institute for Advanced Study in Princeton. Thom learned of Smale's thesis results directly from Bott. At the Mexico City conference in 1956, Steve met Thom, who was also on his way to the University of Chicago for the following term. At Chicago, Smale attended Thom's lectures on transversality. While that mathematical tool played an

important role in Smale's future work, there was also a vital interaction. At that time Steve was a fresh Ph.D. embarked on his first major result, and Thom was about to win the Fields Medal. These were two young mathematicians who possessed an abstract mathematical power beyond most people's comprehension. Thom appreciated Smale's ideas. That interest provided direct support to Smale as well as boosting his profile at Chicago.

Milnor was also at Mexico City. Just 25 years old, that year he published the result that won him the Fields Medal in 1962.[26] When Steve went to the Institute for Advanced Study in 1958, he attended Milnor's lectures at Princeton. Consider then that among the six Fields Medalists in the 1954–62 period of Steve's thesis and early professional work, Smale was intimately acquainted with the ideas of three of them, immediately after their discoveries.

Smale wanted his own Fields Medal. With the higher dimensional Poincaré Conjecture in 1960 and the h-cobordism theorem in 1961, Steve knew that he had the credentials. He thought 1962 "was the logical time I would have gotten the Fields Medal."[27] The Stockholm Congress was also a logical time for Milnor who, like Smale, had profoundly influenced the course of topology. Other mathematical areas offered their candidates as well, and a committee was charged with the task of selecting just two winners. It was a purely qualitative problem. Considering all the mathematicians in the world under the age of 40, who had done the best mathematics? How do you compare seminal results in topology, as well as with those in analysis or algebra? The committee chose Milnor and the Swedish analyst Hörmander.

Not winning was a tremendous blow to Smale. He attributed his loss, in part, to mathematical politics.[28] Comparisons between Milnor and Smale were inevitable. They were the two brilliant, young, American topologists with the most outstanding theorems. Unlike Smale, Milnor's mathematical gifts became apparent at an early stage of his life. The New Jersey native attended Princeton University and then joined its faculty. With the Institute for Advanced Study and the University, the city of Princeton had a special prestige in the mathematical world. Milnor had the more influential backers. Steve had followed an unconventional path to the top and was deprived of full credit for his work on the Poincaré Conjecture. It was not the sort of profile that attracted unanimous enthusiasm from the mathematical establishment.

With the Nobel Prize, Steve would have had another opportunity the following year, but the next Fields Medals were to be awarded in 1966. That year Steve's European summer tour began in Paris. The French left were organizing a Vietnam protest against the United States. It was called Six Hours for Vietnam and followed much of the Michigan teach-in format with speeches, movies, songs, and breakouts into parallel seminars. Among

those endorsing the rally were Jean Paul Sartre and Fields Medalist Laurent Schwartz.[29] Schwartz had a long record of political activity, having opposed his country's policies in Algeria and Vietnam. When Smale sought to globalize the Vietnam protest in 1965, he solicited Schwartz' support, receiving an enthusiastic response. While Smale's role as an antiwar leader had evaporated since the Oakland march of the previous October, he remained a prominent opponent of the War. Steve had already planned to spend the summer in Europe with a vigorous schedule of mathematical endeavors. When Schwartz invited him to speak, Smale decided to begin his time abroad with the Paris rally. Joining Steve on the platform were officials from North Vietnam and China. Smale recalled the experience.[30]

> The *Salle de la Mutualité*—I remembered that great old hall on the left bank for the political rallies I had attended there fifteen years earlier. Now there were several thousand exuberant young people in the audience, and I was at the microphone. My French was poor and since my talk could be translated I decided to speak in English. I still wasn't at ease giving non-mathematical talks; even though I had scribbled out my brief talk on scratch paper, I was nervous.
> There was a creative tension in that atmosphere that inspired me to communicate my feelings about the United States in Vietnam. As I was interrupted with applause my emotional state barely permitted me to give the closing lines: "... As an American, I feel very ashamed of my country now, and I appreciate very much your organizing and attending meetings like this. Thank you." Then I was led across the stage to M. Vanh Bo, the North Vietnamese representative in Paris; we embraced and the applause reached its peak.

A reporter covering the rally observed:[31]

> Indeed Professor Smail [*sic*] of the University of California got almost as big a hand as Monsieur Vanh Bo of North Vietnam. Such is the sentimentality of the left. Even the chant that followed Smail's speech—"U.S. go home! U.S. go home!"—was obviously a left-handed tribute.

After the Paris speech, Steve resumed his mathematics mode.[32] A few days later he and René Thom drove to a conference in Geneva. While en route Thom, a member of the Fields Committee for the 1966 ICM, disclosed that Smale was to receive the award in Moscow. Steve had attained the status he deserved and craved. It was an extraordinary feeling. His place in mathematical history was secured.

Clara and the children joined Steve in Switzerland. The Smale family remained in Geneva until the end of July. During that time Steve was in residence at the University of Geneva except for a week at a Bonn mathematics conference. Smale had a remarkable capacity to effectively immerse himself in his current interest. The previous summer he was completely devoted to stopping a war. In Geneva he was doing mathematics, and the conditions were highly favorable. The University had a fine mathematics department, providing stimulating interaction. There were no teaching or administrative responsibilities. The locale offered nice settings for family outings. Finally there was the satisfaction that he was soon to receive the Fields Medal.

When Steve was a child, his father enjoyed taking the family on automobile excursions around the country. Now Steve had the opportunity to explore Europe with his own family. The Fields Medal presentation was scheduled for August 16, the opening day of the ICM. The Smales rented a camper and, during the first two weeks of August, drove from Geneva to Athens, camping and touring Yugoslavia and Greece along the way. Smale planned to fly from Athens to Moscow on August 15, participating in the ICM while his family remained in Greece.

Unbeknownst to Smale, his whereabouts were a hot topic in the Bay Area. In early August the House Committee on Un-American Activities (HUAC) sought to subpoena Steve for testimony later in the month. Some members of Congress were disturbed by the troop train demonstrations and other activities, which they construed as aiding military opponents. Pending legislation was directed at prohibiting such activities. The HUAC scheduled hearings on the bill, issuing subpoenas to various antiwar leaders.

In the fifties, the prospect of subpoenas provoked dread among members of the Old Left. Recipients, such as Chandler Davis, suffered blacklisting and jail. At that time Steve's leftist activities narrowly escaped the public scrutiny of the HUAC. Now, as the former cochair of the VDC and leader of the troop train protests, he was too prominent. Moreover, the HUAC always had a thing for college professors. Subpoenas were issued for Smale, Jerry Rubin, and several others. The HUAC was soon to learn that they had lost their power of intimidation. The first indication was the posture of the Berkeley community toward the subpoenas. Among the radicals, subpoenas were coveted as recognition of one's standing. When Stew Albert lamented his failure to attract the solicitation of the HUAC, Jerry Rubin diagnosed his condition as "subpoenas envy."[33]

Serving Steve was problematic. At the time he was somewhere in Yugoslavia, on a roundabout course to the ICM in Moscow. Investigation by the *San Francisco Examiner* turned up a few facts which they interpolated

with a fictional motive. The story ran under the headline "UC Prof Dodges Subpoena, Skips U.S. for Moscow."[34]

> Dr. Stephen Smale, University of California professor and backer of the Vietnam Day Committee and old Free Speech Movement, is either on his way or is in Moscow, The Examiner learned today.
> In leaving the country, he had dodged a subpoena directing him to appear before the House Committee on Un-American Activities in Washington.

Steve was, in fact, headed to Moscow, and he did not receive the subpoena. However, he was unaware of its existence and there was absolutely no linkage between the recent subpoena and the long planned trip to the Moscow ICM. Mathematical colleagues rallied to Smale's defense. The following day an article in the *San Francisco Chronicle* set the record straight, chiding the *Examiner's* "somewhat exaggerated published report." However, it is the nature of such corrections that they fail to completely erase the original distortions.

Back in Athens, Clara dropped Steve at the airport on August 15, and drove off with the children. He was ticketed on a flight to Moscow, excited about the Fields Medal ceremony of the following day. The euphoria was interrupted by a trip into a bureaucratic twilight zone. Customs detected some irregularity with Smale's passport.[35]

> Slowly I began to understand. When we had come across the Greek border, customs had marked in my passport that we were bringing in a car. (The government was concerned that we would sell the car without paying taxes.) Now the Greek officials were not letting me leave the country without that car. The customs officials were adamant.

Unable to produce the car, Smale was prohibited from boarding the only Athens-Moscow flight of the day. Imagine Steve's frustration. A last moment technicality was depriving him of the greatest moment of Fields acclaim. Eventually Steve obtained the assistance of an American embassy official who successfully intervened on his behalf. Smale was on a plane the following day, and the timing was tight.[36]

> I arrived late in Moscow and rushed from the airport to the Kremlin where I was to receive the Fields Medal at the opening ceremonies of the International Congress. Without a registration badge the guards at the gate refused me admission to the palace. Finally, through the efforts of a Soviet mathematician

> who knew me, I obtained entrance and found a rear seat. René Thom was speaking about me and my work:
> "*si les oeuvres de Smale ne possedent peut-etre pas la perfection formelle du travail definitif, c'est que Smale est un pionnier qui prend ses risques avec un courage tranquille*;"

Steve had just missed the opportunity to formally receive the award, but he did hear Thom's tribute to his risk taking. An anonymous gift permitted the award of four Fields Medals in 1966. The other winners were:[37]

Michael Atiyah, 37, England, Oxford University

Paul Cohen, 32, USA, Stanford University

Alexander Grothendieck, 38, Germany, University of Paris

Moscow was an interesting selection as host city. It was the home of some of the world's best mathematicians, but the severe travel restrictions imposed by their government prohibited many of them from attending congresses and conferences in the west. The 1966 Congress was a truly international gathering. Over 4000 mathematicians participated in the technical program at Moscow University, smashing the attendance records from all previous Congresses. Especially notable was the large Soviet delegation.

The communist government repressed various forms of intellectual inquiry. Earlier that year the cases of two Soviet writers, Yuli Daniel and Andrei Sinyavsky, had attracted international attention. Satirical works by these men were smuggled out of the country and published in the West under pseudonyms. The authors were indicted and tried for the crime of producing "anti-Soviet propaganda, harmful to the Soviet people."[38] In February 1966 Daniel and Sinyavsky were convicted and sentenced to five and seven years of forced labor, respectively.

Smale had visited Moscow and Kiev five years earlier, when he lectured on the horseshoe and sketched some of his ideas for dynamical systems. During the visit he interacted with a number of young Soviet mathematicians and was struck by their prodigious talent. In 1966 the development of dynamical systems was hitting its stride with independent investigations underway in Berkeley and the Soviet Union. At the Congress Smale was able to renew his discussions with the Russians. The stimulation was not restricted to mathematical endeavors.

Despite the Daniel–Sinyavsky case, there was a degree of freedom in the country. Smale, through his Russian mathematics friends, became connected with a network of anticommunists.[39] Among this group of writers, artists, mathematicians, and other intellectuals there was contempt for Soviet policies. Not only did they express their solidarity for Daniel and Sinyavsky,

but they supported the United States' intervention in Vietnam. Smale was shocked to encounter the latter manifestation of anticommunism.[40]

During the previous year Smale and Laurent Schwartz had collaborated to internationalize opposition to the Vietnam War. Now Smale had moved to the background, but Laurent Schwartz continued the effort. The Moscow ICM provided an opportunity to petition mathematicians from around the world. A Japanese mathematician conceived the International Appeal Against the War in Vietnam and Schwartz pushed the idea. Prior to the Congress, Schwartz enlisted the help of Chandler Davis (HUAC Class of 1954). Davis' vita included being fired at the University of Michigan, 6 months of jail time, being hired by the University of Toronto, and his own organization of antiwar efforts. He was already planning to attend the ICM, excited about the opportunity of meeting Vietnamese mathematicians. Davis liked the concept of a Moscow petition, recalling "the idea was to initiate the Appeal at the Congress, to agree on the wording, and collect tons of signatures."[41] Following the Congress, the document was to circulate around the world, gathering opposition to the War. There was some discussion of seeking endorsement of the resolution by the Congress as a whole, but the notion was quickly rejected. The structure of the program was not conducive to such initiatives and there appeared little prospect for success.

To conduct the Appeal at the meeting required some infrastructure, such as a meeting room and duplication machinery. Securing these facilities in a totalitarian state was problematic. Although the Appeal's mission was in line with Soviet policy, there was a reluctance to permit political activity outside of rigid government control. I. Petrovski, president of the Congress and rector of Moscow University, refused a request for a room by a Schwartz–Davis led delegation. Mimeograph machines were even further out of the question. Access to these vital propaganda tools was severely restricted.

With the assistance of some Soviet mathematicians, Davis and Schwartz secured a meeting room. This time they did not request official sanction, but Davis was certain that the authorities were aware of the plans, and elected to look the other way. Invitation was by word of mouth and attracted about 80 people. Schwartz chaired the meeting, and there was discussion of the appeal's wording.[42]

It remained to print and duplicate the petition. In 1966 Moscow, there were no Kinko's. The only mimeograph facilities were under government control. Already rejected by the Soviets, Davis solicited the help of another government. At the North Vietnamese embassy, Davis typed and the Vietnamese mimeographed.[43]

Smale was among the proponents and signatories of the statement condemning United States actions in Vietnam. There were other political activities at the Congress, including petitions associated with Smale's HUAC subpoena. Timing constraints limited the effectiveness of these efforts. While Schwartz had circulated preliminary appeals prior to the Congress, few participants were even aware of the subpoena in advance. Smale, himself, learned of it on the plane to Moscow, receiving the information from a mathematician who boarded during a stop in Hungary.

The antiwar efforts of Schwartz, Davis, and Smale were acknowledged in a moving gesture. They were the guests for a banquet hosted by four Vietnamese mathematicians at the Congress. The dinner took place in a dormitory where the Vietnamese prepared their own native cuisine. Mathematicians from different countries often overcome cultural barriers by sharing their scientific interest. Here the bond was much stronger. There was a devotion to a common cause that somehow was multiplied with the mathematics. The banquet was a memorable experience.

The Vietnamese conceived the dinner, but the guests devised a complementary agenda, planning to issue a press release afterward. However, the banquet set in motion a chain of events that led to a greater political statement, spotlighting Steve. Smale recalled:[44]

> At the banquet, I was asked to give an interview to a reporter named Hoang Thinh from Hanoi. I didn't know what to say and struggled with the problem for the next day. I felt a great debt and obligation to the Vietnamese—after all, it was my country that was causing them so much pain. It was my tax money that was supporting the U.S. Air Force, paying for the napalm and cluster bombs. On the other hand, I was a mathematician, with compelling geometrical ideas to be translated into theorems. There was a limit to my ability to survive as a scientist and weather further political storms. I was conscious of the problems that could develop for me from a widely publicized anti-U.S. interview given to a Hanoi reporter in Moscow. In particular, I knew that what I said might come out quite differently in the North Vietnamese newspaper, and even more so when translated back into the U.S. press.
>
> This was the background for my rather unusual course of action. On the one hand, I would give the interview; on the other hand, I would ask the American reporters in Moscow to be present so that my statements could be reported more directly. I would give a press conference on Friday morning, August 26.

At the ICM Smale faced the problem of whether to give an interview to Thinh, the Moscow correspondent of the North Vietnamese Press Agency. His analysis and solution exhibit parallels to his mathematical style. As a mathematician Steve liked to undertake *hard* problems which had resisted the attacks of others. Frequently he succeeded in finding an innovative solution, employing techniques from completely different areas of mathematics. After the fact, his methods seem natural, but nobody else thought to apply them. While other mathematicians were failing with conventional techniques, Smale understood the problem in a new fashion, and blazed his own trail. To succeed in this manner requires audacity and profound mathematical power.

When confronted with the interview request, most people would have seen two choices: decline or accept. Steve was inclined to accommodate the reporter, and, in the process, make his own political statement. However, there were serious qualms. Smale was a person who had lost faith in communism a decade earlier, and he never trusted his own country. He was sufficiently pragmatic to recognize the dangers of distortion from North Vietnamese and American filters, especially when composed in that order. A third party observer at the interview might have provided some insurance, but the above sequence could still play out. Furthermore, Smale wanted to direct his future energy toward mathematics rather than clarifying his politics. Neither conventional solution was appealing, but Smale was rarely constrained by convention. How many people would have elected to conduct a press conference in Moscow in 1966? The thought process did not require the intellectual power of his mathematical work, but it was a creative solution.

The logistics of holding a press conference presented a major problem. In Moscow the emphasis was on government control. Recall that Davis and Schwartz were unable to officially obtain a meeting room for discussion of the appeal. Even when there was an expectation of shared goals and interests, the government permitted no slack for free expression. Smale ruled out any official request, but there was concern that the Soviets might treat the press conference as a subversive act.

Steve wanted to create a situation that maximized his physical safety and minimized the potential for distortion of his remarks. These priorities called for an open venue, a diverse audience, and short notice. The steps of the University were easily accessible to ICM participants. In addition to Hoang Thinh, Smale invited the American and Soviet press, as well as various friends and colleagues.

The next move was up to Thinh. Smale's unilateral change in the arrangements, from interview to press conference, shifted the dynamic from a

North Vietnamese production to a Steve Smale show. If Thinh were to participate in a public demonstration, unauthorized by the Soviets, there was potential embarrassment for both the North Vietnamese and USSR governments. Late Thursday, Thinh responded. He declined to participate in the press conference, rather, providing his list of questions and requesting written responses.

Thinh's interview overture had begun the whole process. With his withdrawal, the press conference might have been cancelled. However, Smale was determined to go ahead with his condemnation of United States' policy in Vietnam. A press conference in Moscow was in the best tradition of the Rubin–Smale-led VDC. An audacious act to attract the press, who would then communicate the message.

With the press conference scheduled for the following morning, Steve worked on the message.[45]

> As I wrote down my words attacking the United States from Moscow, I felt that I had to censure the Soviet Union as well. This would increase my jeopardy, but, having just received the Fields Medal and being the center of much additional attention because of HUAC, I was as secure as anybody. If *I* couldn't make a sharp antiwar statement in Moscow and criticize the Soviets, who could?

That night Steve discussed his ideas with Chandler Davis who recalled Smale's demeanor: "He was really happy about the opportunity. His attitude was of trying to take the most advantage of it by getting things absolutely clear."[46] Davis cautioned that the attacks on the Soviet Union and the United States might cancel each other out, blunting the criticism of American policy in Vietnam.

On Friday morning, a small group gathered on the steps for the press conference. Chandler Davis, Moe Hirsch, Bob Williams, and Berkeley department chair Leon Henkin were among the mathematicians joining the American reporters in attendance. Other mathematicians passed by on their way to the final day of the Congress. Steve had constructed the situation so as to afford protection. If the Soviets forcibly terminated the press conference, the American reporters were on the scene to report a big story. A more diplomatic effort was unlikely to stop a veteran of VDC maneuvers. Just prior to the opening, a woman from Novosti, a Soviet press agency, requested a private interview. Smale agreed, but deferred their meeting until after the press conference. Then he read the following statement, handwritten on two sheets of paper.[47]

> This meeting was prompted by an invitation to an interview by the North Vietnamese Press. After much thought, I accepted, never having refused an interview before. At the same time, I invited representatives from Tass and the American Press, as well as a few friends.
> I would like to say a few words first. Afterwards I will answer questions.
> I believe the American military intervention in Vietnam is horrible and becomes more horrible every day. I have great sympathy for the victims of this intervention, the Vietnamese people. However, in Moscow today, one cannot help but remember that it was only 10 years ago that Russian troops were brutally intervening in Hungary and that many courageous Hungarians died fighting for their independence. Never could I see justification for military intervention, 10 years ago in Hungary or now in the much more dangerous and brutal American intervention in Vietnam.
> There is a real danger of a new McCarthyism in America, as evidenced in the actions of the House Un-American Activities Committee. These actions are a serious threat to the right of protest, both in the hearings and in the legislation they are proposing. Again saying this in the Soviet Union, I feel I must add that what I have seen here in the discontent of the intellectuals on the Sinyavsky–Daniel trial and their lack of means of expressing this discontent, shows indeed a sad state of affairs. Even the most basic means of protest are lacking here. In all countries it is important to defend and expand the freedoms of speech and the press.

Following his statement, Smale responded to the questions submitted by Thinh urging immediate withdrawal of United States forces from Vietnam. "At this point, a middle-aged Russian woman hastened up to the professor, touched him on the right arm and told him that Vladimir G. Karmanov, the secretary general of the mathematics conference wanted to see him immediately for an "urgent" discussion."[48] The second interruption, more intrusive than the first, was deflected in the same manner. Smale agreed to see Karmanov, following the completion of the press conference. A short time later, Smale had fielded the remaining questions. The press conference was over, and Steve moved on to his commitments with the two Soviet women. Karmanov's representative was the more assertive, ushering Smale to meet the secretary general at his nearby office. Following along was an entourage that included the other woman, curious reporters, and concerned mathematicians.

Despite the purported urgency of the meeting with Karmanov, the conversation was devoid of substance, mathematical as well as political. Karmanov played the role of a director of tourism. He presented Steve a coffee table book, featuring pictures of the Kremlin and text in German. Instead of asking about the press conference, Karmanov was anxious to learn what sights Steve had seen or might wish to see, making available an automobile and guide. The meeting ended amiably with Steve declining the tour.

What followed is a bit murky. Steve reluctantly agreed to accompany the Novosti representative to an unspecified location for their interview. He was then escorted, at a fast pace, to a waiting car, as Soviet bodyguards brushed off the press and mathematicians. Steve recalled: "I felt pressured and a little scared. But all the while I was treated not just politely, but like a dignitary. It was hard to resist."[49] The scene was out of a Hollywood movie script. Steve's automobile drove off at high speed with the American reporters in hot pursuit. Where were they taking him? Hirsch "thought the worst" when Steve was put in the car.[50] The excursion ended at Novosti headquarters where there was another hour of small talk, but no interview. Finally Steve was returned to the Congress at his own request.

The Congress was concluding, but there were questions for Steve from reporters and his very relieved friends. What happened and what were the agendas behind the two meetings? The press conference placed the authorities in a quandary. Unaware of what Steve planned to say and unable to prevent it diplomatically, his statement was a worst case scenario. The first step in damage control was to isolate Smale from the reporters and prevent further mischief. Firmness replaced finesse in the trip from Karmanov to Novosti. The process bought some time during which the problem may have been considered at a higher level. In any event, no further action was taken. Smale returned to his hotel room late that night, without incident. The following morning he made his scheduled 7:00 am flight to rejoin Clara and the children in Athens.

The Saturday *New York Times* carried the story, with accompanying photograph, at the bottom of the front page. The well written article provided accurate coverage of Smale's press conference and adventure in Moscow. However, the headline and picture caption gave a false impression. In the photograph, Steve was shown between a pair of larger men. The caption "CALIFORNIAN GETS ESCORTED TOUR: Dr. Stephen Smale, center, being led to car in Moscow after his news conference was halted when he criticized the Soviet Union" was juxtaposed with the headline:

American Critical in Soviet—Briefly

Together, the picture and headline implied that the Soviets had ended the press conference prematurely. The portion of the story appearing on the

front page, while correct, was also consistent with that inaccurate portrayal. To learn the complete story, one needed to read the continuation on page 13. The *Washington Post* headline, "Russians Halt Speech by U.S. Professor," was followed by the sentence: "Soviet authorities ended a press conference abruptly yesterday when an American professor, who is a leader of the anti-Vietnam-war movement, compared U.S. "aggression" with Russia's brutal intervention in Hungary."[51]

Smale had included the American press in order to secure both his safety and the accurate dissemination of his message. While both were achieved, the papers failed to correctly convey the actual sequence of events. As a result, the distorted impression prevailed.

Although the news appeal of the story might have been enhanced by the image of the Soviets shutting down Smale's speech, the historical value was in the substance and setting of the statement. It was a remarkable speech. The world was polarized in communist and anticommunist camps. Smale saw parallel tragedies in each system that were concealed from their respective constituencies by Cold War denial. He paired the United States' aggression in Vietnam with the Soviet invasion of Hungary. The efforts of the HUAC were compared with Daniel–Sinyavsky and communist repression. All of this conveyed in two lucid paragraphs by an American in Moscow.

D. The HUAC hearings

On August 16, the day that Smale received the Fields Medal, a HUAC subcommittee began hearings on *Bills to make punishable assistance to the enemies of U.S. in time of undeclared war*.[52] The legislation had been introduced by the subcommittee chair, Representative Joe Pool of Texas. Pool organized the hearings into two stages. First was an investigative phase to establish the problem. Among those scheduled for testimony were informants, radicals, and government officials. Topics included the troop train demonstrations and efforts to provide medical support for the North Vietnamese and Viet Cong armies. Once the stage was set with the egregious acts of the antiwar movement, congressmen and government officials would discuss the merits of Pool's legislation. It was to be a two-act HUAC production, exposing communists along the way.

The power of the HUAC had diminished considerably since the fifties. At that time the HUAC ran the show and even lawyers were reluctant to accompany a witness. In 1966 the radicals saw the hearings as an opportunity to make their case against the HUAC and the War. Rather than defend themselves against attacks by HUAC members, they planned to launch their own offensive, seizing control of the production. Supporting the witnesses were a new breed of lawyers.

Prior to the hearings, there were some legal controversies. That the *Examiner* learned of Smale's subpoena, implied a violation of the House's nondisclosure rules. On another front, the American Civil Liberties Union filed suit to enjoin the HUAC from holding the hearings. On August 15, a federal judge issued the injunction. The surprise ruling raised its own constitutional questions on separation of power between the legislative and judiciary branches. Pool's plans to defy the court order became moot when an appeals court panel quashed the injunction, just before the hearings began on Tuesday.[53]

The hearing room and halls were filled with antiwar demonstrators. The HUAC was going to have an overtly hostile audience. Just after the hearing commenced, a woman screamed from the entrance door. It was Jerry Rubin's attorney, Beverly Axelrod. Unlike the deferential lawyers of the fifties, Axelrod forewent the normal decorum to seek admission for herself and her client. Rubin entered, dressed in a Revolutionary War uniform, passing out pamphlets explaining the symbolism.

Rubin's wardrobe and demeanor ended any pretense that the hearing was a dignified proceeding. It was going to be a spectacle, in the tradition of the VDC rather than the HUAC. Rubin's willingness to appear as a clown and sacrifice personal dignity was an unusual form of courage, conceded even by his Berkeley detractors. Throughout the first day, the hearings were interrupted by belligerent demonstrations. There were 17 arrests, including two of the witnesses. Spectators painted slogans on the wall. Rubin became a hero of the radical youth culture, inspiring a new left style that would set a standard for outrageous courtroom contempt.

On day two Pool stuck with the HUAC game plan, but it was not working. A witness proudly announced that he was a communist. Lawyers often ignored admonitions from the chair and aggressively pursued their arguments. There were 21 arrests, highlighted by that of attorney Arthur Kinoy who was dragged from the room as he screamed in protest. A picture on the front page of the *New York Times* showed a marshal gripping Kinoy by the neck.[54] The other attorneys and some witnesses departed in protest, leaving the remaining clients without representation.

The HUAC subpoenaed the district attorney of Alameda County as a friendly witness to describe the activities of the VDC. Testifying in his place was the deputy district attorney, Edwin Meese III. Meese was 30 years old, early in a legal and political career that would lead to the attorney generalship under Ronald Reagan. Meese's testimony gave high marks to the VDC's organization and planning. When the committee's counsel requested that he describe the troop train protests, the following discussion occurred.[55]

Mr. Nittle. Mr. Meese, would you describe the incident or incidents concerning the troop trains?

Mr. Meese. The troop train demonstrations, which is probably the best known of the activities, took place on the 5th of August 1965, the 6th of August 1965, and the 12th of August. On the 5th of August, the demonstrations were led by Stephen Smale, who is one of the witnesses that I believe the committee is familiar with. I believe he was to be subpoenaed as a witness, but was not able to be served, if I understand correctly.
And a man by the name of Paul Ivory. Stephen Smale is a member of the faculty in mathematics at the University of California, and Paul Ivory, who is an assistant professor, Jerry Rubin–

Mr. Rubin. I object. I would like to make a statement. I am without counsel because of the way my lawyer was treated. I want to represent myself.

Mr. Nittle. I ask that this witness be seated until the end of the presentation of this witness.

Mr. Rubin. I want to make a statement. I want to represent myself.

Mr. Nittle. I ask that this man be removed.

Mr. Ashbrook. Mr. Chairman, he cannot be removed.

Mr. Rubin. My name is Jerry Rubin. It has just been introduced in the record without notice, I want to make a statement about it. I am now representing myself, apparently.

Mr. Ichord. Mr. Chairman, I would suggest that the gentleman be seated. He will be called tomorrow and have the opportunity to deny—

Mr. Rubin. I am representing myself.

Mr. Ichord. —to refute in any way any allegations made against him.

Mr. Rubin. I am sorry. My name was just introduced by this gentleman into the record without my knowing about it, and I would like to make a statement.

Mr. Pool. What do you want to say?

Mr. Rubin. First, I want to introduce myself. My name is Jerry Rubin. I would like to make an explanation as to why I am wearing the uniform of the American Revolution of 1776.

Mr. Pool. I don't care to hear that.

Mr. Rubin. I am wearing it because America is degrading its 1776 ideals.

Mr. Pool. I am giving you the opportunity to make an objection and I am trying to be fair with you, so state your objection.

Mr. Rubin. I am making this objection.

Mr. Pool. What is your objection?

Mr. Rubin. I am making it right now.

Mr. Pool. What is your objection?

Mr. Rubin. Would you wait one second and let me say it?

Mr. Pool. Real fast.

Mr. Rubin. I want to do it—

Mr. Pool. Your way.

Mr. Rubin. This gentleman has just mentioned my name and introduced into evidence.

Mr. Pool. What is your objection?

Mr. Rubin. And I have not been informed previously that he was going to make statements about myself that may defame my character; previously, so far, what he said about the Vietnam Day Committee has been, I think, complimentary, but he may be going to make statements, and has not yet, and I have not been informed that my name was to be introduced. That's my first objection.
My second objection is that I do not—that I want the right to cross-examine Mr. District Attorney Meese.

Mr. Pool. You have been named in the newspapers on many occasions, and I don't think you are surprised by this statement.

Mr. Rubin. This is a little different than a newspaper.

Mr. Pool. And your second objection—

> Mr. Rubin. I want the right to cross-examine.
>
> Mr. Pool. —that you want the right to cross-examination; that is overruled also.
>
> Mr. Rubin. This gentleman is making statements about me.
>
> Mr. Pool. I overrule both objections. You have no others, so just be seated.
>
> Mr. Rubin. This is quite a courtroom.

Rubin's interruption was in a similar vein to that of Kinoy earlier in the day. This time Pool was more indulgent. Meese then resumed his testimony which he concluded on the following morning. The subcommittee was delighted with Meese's performance, lavishing praise on the witness.[56]

The hearing was a confrontation between the HUAC and the new left. If press coverage determined the score, and it was vital to both sides, then the radicals were winning the battle. The *New York Times* front page coverage focused on the original injunction, demonstrations, and Kinoy's arrest. Meese's testimony on the Oakland Army Terminal was buried in two brief paragraphs at the end of the continuation.[57] Worse yet, the radicals appeared to enjoy the proceedings, even boasting of communist involvement.

It was time to move on to the legislative phase, but several subpoenaed radicals remained to be called. Following Meese's testimony, Pool adopted a new strategy, exploiting the walkout of the attorneys. As much as the HUAC wanted to hear the remaining radicals, it was only fair to defer their testimony until November, permitting them to secure new counsel. However, Pool made the mistake of offering the deferral individually, rather than invoking it unilaterally. A couple of witnesses were called and accepted the deferral, but then Stuart McRae countered the HUAC move. McRae insisted on testifying and resumed the attack from the left.

By the following day, August 19, the radicals had fully regrouped and decided to testify. The phrase "hostile witness" was especially appropriate, as the radicals directed insults and obscene gestures at the committee members. Each of the witnesses responded that they were members of the Progressive Labor Party (Chinese communist). Two of the radicals were dragged out of the room when they refused to leave the stand. Pool had had enough. He ended the investigative phase, excusing the remaining witnesses, much to the chagrin of Jerry Rubin. When Rubin persisted in his attempts to testify, Pool ordered his ejection.[58]

The legislative phase went more smoothly. Congressmen, generals, and Meese expressed enthusiasm for Pool's bill. The final witness was Deputy

Attorney General Ramsey Clark, who, like Meese, would later become attorney general. Clark expressed opposition to the bill, stating that existing state and federal statutes provided more than adequate protection.

Smale felt ambivalent over missing the hearings. One year earlier he would have been anxious for a platform to push his antiwar agenda. In 1966 he would have enjoyed the experience, but was content to do mathematics and avoid the aggravation that accompanied a HUAC appearance. Besides, he still had the subpoena credential. It is difficult to speculate on how a Smale appearance might have impacted the chaotic hearings. Certainly he would not have worn a Revolutionary War uniform. Looking back he said "I would have used the situation to express my points of view on the War and troop trains. I would not have clowned around, but I would not have felt bound by the strictures the committee lays down for witnesses."[59]

The HUAC had been in decline since the midfifties, and the August hearings accelerated its demise. Congress had a genteel self-image and the raucous hearings were an embarrassment. Even Senate Republican leader Everett Dirksen observed that Congress had fared poorly.[60] In an editorial, the *New York Times* called for "radical surgery" to abolish the HUAC.[61]

Subsequent years saw an increase in opposition to the HUAC, concurrent with the strengthening of the left by the antiwar movement. In 1969 the HUAC attempted to rehabilitate its image with a change of name to the House Internal Security Committee. The mission was only altered slightly and the makeover did little to deter its opponents. Congressman Robert Drinan, a Jesuit priest from Massachusetts, secured membership on the committee with the express intent of seeking its abolition. Still the House Internal Security committee managed to obtain appropriations for several years. Finally in 1975, following the post-Watergate Democratic congressional election gains, the last vestige of the HUAC was purged from the House.

Mathematical Appendix B: Everting the Sphere

In 1957 Smale submitted a manuscript to the *Transactions of the American Mathematical Society*. The ten page paper, entitled "A Classification of Immersions of the Two-Sphere," appeared in the February 1959 issue. Among the results was the following theorem:

Theorem B. *Any two C^2 immersions of S^2 in E^3 are regularly homotopic.*

A consequence of Theorem B is that the sphere can be turned inside out. To understand why this is the case requires an examination of the mathematical terms. The symbol E^3 is just another notation for R^3, Euclidean 3-space. Different mathematical symbols or terminology sometimes arise for the same structure. There is no clearinghouse for mathematical jargon, and duplication may result from independent discovery or an effort at improvement. The symbol S^2 represents the surface of the unit sphere.

A C^2 immersion of S^2 in R^3 is a function with domain S^2 that assumes values in R^3 and satisfies some additional conditions. Prior to describing the extra constraints, consider some examples of functions from S^2 into R^3. Figure B.1 shows the resulting images in R^3. The functions may be described as follows:

a. Identity: each point of S^2 is mapped to itself.

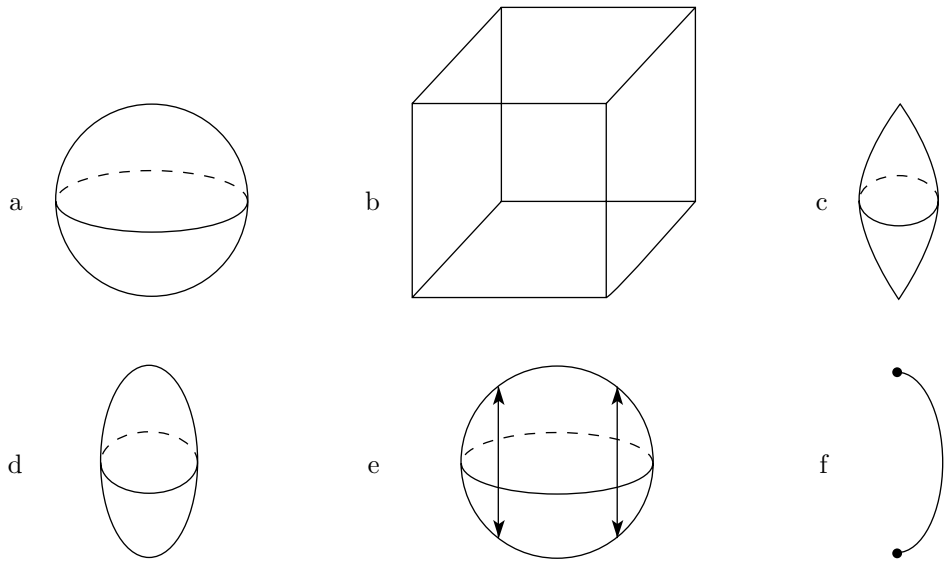

Figure B.1. Some images of functions from S^2 to R^3.

b. Circumscribed box of side length 2: each point of S^2 is mapped out to the point of the box that lies on the same radial ray from the origin.

c. Teed up football with pointed ends: another radial projection.

d. Teed up football with rounded (ellipsoidal) ends: yet another radial projection.

e. Reflection about equator: fixes equator and switches northern and southern hemispheres.

f. Semicircle: all points of a given latitude map to the point on the prime meridian at that latitude.

Notice that at each point on the graph of a, d, and e, there is a well defined tangent plane. However, at the corners of the box and at the pointed ends of c, there is no single tangent plane. In example f there is a tangent line to each point, but no tangent plane. To be a C^2 immersion of S^2 in R^3 requires that there exist a tangent plane at each point and more. Certainly b, c, and f fail. The adjective C^2 imposes a technical condition that nearby tangent planes relate to each other in a smooth manner. We stipulate that a, d, and e meet all the criteria of a C^2 immersion of S^2 in R^3.

The following approach generates a family of immersions. Beginning with the identity map, deform the image by symmetrically pushing down at the north pole and up at the south pole. With a bit of care, the resulting map is a C^2 immersion. Let g_s denote the result of pushing each pole by s units. Figures B.2a and B.2b show $g_{.2}$ and $g_{.5}$. With g_1, the north and south

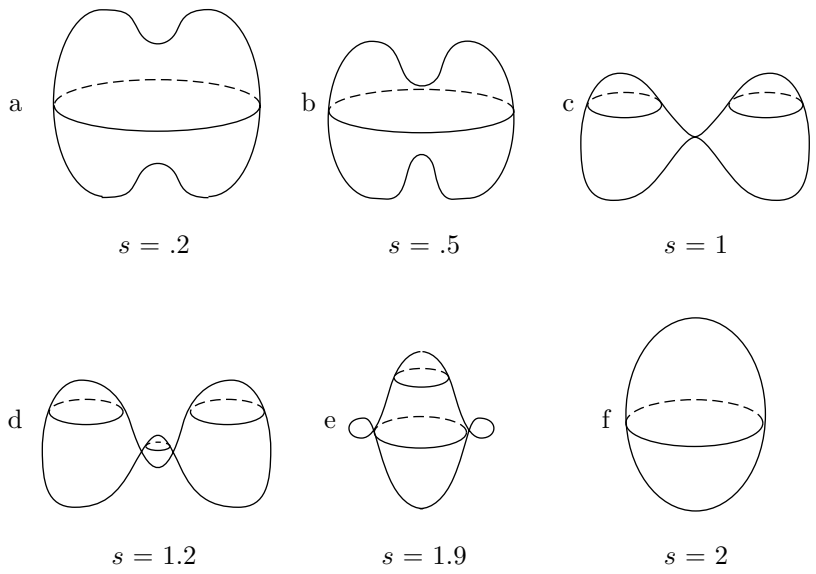

Figure B.2. A homotopy from the identity to reflections on the sphere that is not regular.

poles are mapped to the origin. Immersions permit the image to cross itself, provided all the other conditions are met. With $g_{1.2}$ and $g_{1.9}$ there is a circle of intersection, where points from the northern and southern hemisphere are mapped inside the equator. When $s = 2$, g_2 is the reflection from B.1e.

Now consider the family of maps g_s as s goes through the real numbers from 0 to 2. Each g_s is a C^2 immersion. For g_0, the identity from B.1a, think of the inside of the sphere having the color red and outside as blue. As s increases the sphere is deformed. When s passes 1 and the sphere goes through itself, portions of the red push outside. By the time $s = 2$, the outside is red and the inside is blue. In some sense this process, called a homotopy, turned the sphere inside out. However, it does not meet the mathematical standard for a regular homotopy. The difficulty lies with the crimping that occurs near the equator as s gets close to 2. To be a bit more precise, consider what happens to the tangent planes near the west pole. The tangent plane at the west pole is vertical for each g_s. Nearby, there are points (at the top of the crimp) where the tangent plane is horizontal. As s gets closer to 2, a point with a horizontal tangent plane approaches the west pole. When $s = 2$, the only horizontal tangent planes are at the north and south poles. It is the sudden evaporation, at $s = 2$, of the horizontal tangent planes that violates regularity of the homotopy. To be a regular homotopy each g_s must be an immersion, which they are, but additionally the tangent planes must change continuously with the deformation. We can not have horizontal tangent planes move into vertical ones.

Summarizing the previous paragraph, the family g_s is a homotopy of immersions from the identity to the reflection. It is not a regular homotopy. The mathematical criterion for turning the sphere inside out is that there exist a regular homotopy between the identity and the reflection. The exercise with g_s gives some of the flavor of mathematical research: a promising attempt that fails to evert the sphere. Next the mathematician might attempt to rehabilitate the homotopy in some manner so as to address the regularity problem. Remember, the failure of g_s to evert the sphere does not preclude the existence of a different homotopy that is regular. When the g_s example resisted remedy, a mathematician might seek a different, likely more complex, deformation. Another possibility to consider, prior to Smale's work, was that no eversion existed (i.e., the identity and reflection are not regularly homotopic). Some support for this point of view came from the analogous lower dimensional problem of regular curves in the plane (immersions of S^1 in R^2) where the Whitney–Graustein theorem was applicable. There the identity and reflection have different winding numbers and are not regularly homotopic.

With no candidate for a regular homotopy, the conventional wisdom was that none existed. Most mathematicians would have pursued that course. Smale's Theorem B established that the identity and reflection, as well as any other C^2 immersion of S^2 in R^3, were regularly homotopic. However, the statement of the theorem provides absolutely no clue as to the nature of the deformation. Sometimes that type of information is present in the proof. To follow this thread we first note that Smale's Theorem B was essentially a corollary of his more complicated Theorem A.

Theorem A resolved the problem of regular homotopy for C^2 immersions of S^2 in R^n. The solution involved taking a certain set of $n \times 2$ matrices (rigorous mathematical aside: those with rank 2), known as Stiefel manifolds, $V_{n,2}$. Next he considered an algebraic topology structure on $V_{n,2}$, denoted $\pi_2(V_{n,2})$. Theorem A established a 1-1 correspondence between $\pi_2(V_{n,2})$ and the distinct regular homotopy classes of C^2 immersions of S^2 in R^n.

In the Theorem B situation, $n = 3$. From Theorem A there is a 1-1 correspondence between $\pi_2(V_{3,2})$ and the number of different regular homotopy classes of C^2 immersions of S^2 in R^3. Now for the interdisciplinary beauty of mathematics. The algebraic topology question as to the nature of $\pi_2(V_{3,2})$ was already answered. The set $\pi_2(V_{3,2})$ consisted of just one element. Thus there was only one regular homotopy class of C^2 immersions of S^2 in R^3, implying that the identity is regularly homotopic to the reflection.

The enterprise of obtaining an explicit eversion by backtracking through Smale's mathematics is already daunting. At the very least, it requires understanding some algebraic topology of Stiefel manifolds as well as Smale's

proof of Theorem A. In any event, a careful examination of these topics[1] provides little, if any, insight into the nature of a comprehensible eversion. However, consider the impact of Theorem B on a mathematician seeking to construct an eversion. Prior to Smale's work, the existence of an eversion was a long shot that had not yet been ruled out. After Theorem B, there definitely was one out there, just waiting for discovery. Despite the drastic increase in the expected return of the problem, it was several years before Arnold Shapiro devised his complicated solution.

Most conceptualizations of the eversion involve the *antipodal map*, rather than reflection across the plane of the equator. The antipodal immersion is defined by mapping each point of the sphere to its diametrically opposite companion. In functional notation, antipodal $(x, y, z) = (-x, -y, -z)$ and reflection $(x, y, z) = (x, y, -z)$. Note that performing a sequence of three reflections in z, y, and x yields the antipodal map. By Smale's theorem each of these immersions is regularly homotopic to the others.

Understanding an actual eversion remains a challenge. A variety of visual aids* have been produced including pictures,[2] films,[3] and wire models.[4]

In mathematics the proof is the substance, but the theorem is the hook. Although Smale's proof of theorem A employed tools and followed a choreography similar to that of his thesis, the two works elicited entirely different reactions. This was because Steve's thesis appeared to be a mundane extension of Whitney–Graustein, but the existence of the eversion was an intriguing shock that provoked interest in exploring the methods. Soon Smale extended the work from the two sphere S^2 to higher dimensional spheres. In his article, "The classification of immersions of spheres in Euclidean spaces,"[5] he classified immersions of S^k into R^n, for $k < n$, in terms of the algebraic topology of the Stiefel manifold $V_{n,k}$.

Over the years a common misconception has developed among mathematicians that Smale turned the sphere inside out in his thesis. History is rarely a vital part of mathematical education and the folklore is replete with inaccuracies and incorrect attributions. This theme is explored further in Chapter 4.

*The image on the book cover is a frame from the video "Outside In" generated at the Geometry Center of the University of Minnesota and distributed by A K Peters, Ltd.