

JULIA ROBINSON **And Hilbert's Tenth Problem**

A documentary film by
George Paul Csicsery



Julia Robinson (1919-1985)

A one-hour biographical documentary, *Julia Robinson and Hilbert's Tenth Problem* tells the story of an important American mathematician against a background of mathematical ideas.

Julia Robinson, a pioneer among American women in mathematics, rose to prominence in a field where often she was the only woman. Julia Robinson was the first woman elected to the mathematical section of the National Academy of Sciences, and the first woman to become president of the American Mathematical Society. Her work, and the exciting story of the path that led to the solution of Hilbert's tenth problem in 1970, produced an unusual friendship between Russian and American colleagues at the height of the cold war. In this film, Robinson's major contribution to the solution of H10 triggers a tour of 20th century mathematics that moves from Paris in 1900, through the United States, to the Soviet Union and back. Following the passionate pursuit of an unsolved problem by several individuals in different countries adds to the emotional intensity of the mathematical quest.

The film covers important events in the history of modern mathematics while conveying the motivations of mathematicians, and exploring the relationship between mathematical research and the development of computers. The key protagonists and advisors to the project are recognized as the most prominent in their fields.

Julia Robinson's story, and the presence of prominent women in mathematics in the film, should inspire young women to pursue educational opportunities and careers in mathematics.

The Project

Julia Robinson and Hilbert's Tenth Problem is a video portrait of Julia Robinson, the first woman elected to the mathematical section of the National Academy of Sciences, and the first woman to become president of the American Mathematical Society. The biographical documentary features a heroine, captivated by the lure of unsolved mathematical problems, who rises against formidable obstacles to assume a leading role in her field. Robinson's pursuit of these problems, and one in particular—Hilbert's tenth problem—brought her face to face with critical developments in 20th century mathematics. The film presents Robinson's life in the context of the 70-year search for a solution to the tenth problem.

Julia Robinson's work hinged on the ideas of key protagonists in the history of mathematics and logic: David Hilbert, Alfred Tarski, Alan Turing, and Kurt Gödel, among others. The film interweaves the personal story of this important figure in American mathematics with the discovery of new ideas that led to the development of computers.

Background

In Paris, on the morning of Wednesday, August 8, 1900, David Hilbert, the most scientifically charismatic mathematician of his time, proposed to his fellow mathematicians a list of problems, the solving of which he felt would make for great mathematical progress during the coming century. The story of H10 and its solution is nested within this biographical film about Julia Robinson.

Hilbert asked for a general method of ascertaining whether a polynomial equation with whole number coefficients has a solution. Three American mathematicians—Martin Davis, Hilary Putnam, and Julia Robinson—were “captured” very early in their respective careers by Hilbert's tenth. In their own words, “it would not let them go.” Julia Robinson told her sister, Constance Reid, that she did not want to die without *knowing* the answer, even if she herself did not solve the problem. Then, in 1970, a 22-year-old Russian mathematician named Yuri Matiyasevich put in place the last, necessary piece for the solution. The negative answer to Hilbert's question turned out to be a solution with significant implications for the development of computer science.

Three of the four mathematicians involved in solving H10 are in the film. Fortunately, Julia Robinson's place in the film is filled by her biographer and sister, Constance Reid, who also wrote highly acclaimed biographies of David Hilbert and of other modern mathematicians, including E. T. Bell.



Constance Reid

Treatment and Style

We meet Julia Robinson through shots of a three-year-old girl (Eva Liddle) as she squats under a giant saguaro cactus in the Arizona desert. A closer look reveals that she is lining up stones in neat rows, creating sequences of numbers. This reenacted moment is recalled by Robinson's sister, closest friend, and biographer, Constance Reid, who plays a central role in Julia's story, and in the film.

The introductory sequence segues into a series of statements by prominent mathematicians and collaborators appraising Julia's skill as a research mathematician, and her accomplishments late in life as a pioneer and role model for women in American mathematics. A key person in this section is Carnegie-Mellon Professor Lenore Blum, a leading mathematician who has written about Julia Robinson and her work. Blum conveys some of the film's most important themes concerning the struggles of American women in mathematics. One of the tensions in the film is a debate over whether or not Julia Robinson suffered discrimination because she was a woman in a field dominated by men. On some questions there are contradictory statements from different sources. For example: 1.) Julia was prevented from holding a tenured position until late in life primarily because the mathematics department at the University of California, Berkeley, discriminated against women; and 2.) freedom from academic responsibility gave her the time she needed to pursue what really interested her—pure research instead of teaching.

The thread of these comments returns to the film's main theme of Julia's interest in unsolved problems, and to her decades-long obsession with Hilbert's tenth problem (H10). Throughout the film, the three living mathematicians who were involved in its solution, describe their work in the context of her contribution.

Where did Julia Robinson's passion for mathematics come from, and how was it nurtured?

Robinson's childhood is presented through her father Ralph Bowman's beautiful black and white photographs of the Bowman family's life, and scenes filmed with Constance Reid in present-day San Diego. Locations include early years in the desert near Phoenix, Arizona, the home on Point Loma where Robinson suffered the illness that changed her

life and drastically affected her mathematical career. Following a series of childhood illnesses that kept her out of school during her early teens, Julia developed an early fascination with numbers. This led to a pursuit of mathematics at San Diego High School. One question raised by the film: did disease and isolation prepare her for being the only girl in her mathematics class, and for a life of being different?

During the 1930s, Julia was clearly an exception. Girls in the United States did not pursue scientific studies. "What are we going to do with a girl like that?" asked her stepmother in a comment about Julia's unflagging interest in science and mathematics. It is a line Constance Reid likes to quote. She recounts the story on stage at the 1999 San Diego High School graduation ceremony.

Throughout the film, Reid's presence provides an echo of Julia Robinson herself, describing Robinson's decisions, feelings, and motives, as Robinson confided these to her sister. Reid's collection of papers and photographs further enrich the film with authentic archival materials. Robinson's own words, taken from papers, speeches, letters, and from the autobiography, *Julia, a Life in Mathematics*—dictated to Constance Reid before Robinson's death in 1985—are brought to life through two surviving clips of Julia Robinson's own voice, and readings by narrator Danica McKellar.

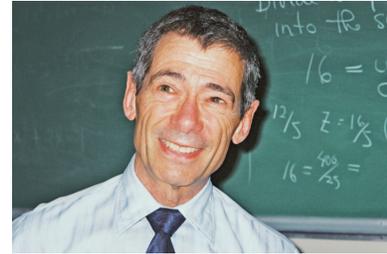
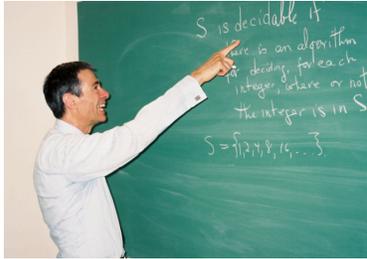
Julia Robinson's 1939 transfer from San Diego State College to the University of California at Berkeley was the key to the direction of her future work. At age 22 she married one of her teachers, the mathematician Raphael Robinson. When she went into a deep depression upon learning that having children was too risky, due to lingering damage to her heart from the rheumatic fever she had suffered from as a child, Raphael reminded her that she need not despair; "there is still mathematics."

Julia had the good fortune to study and work among some remarkable refugees from Nazi-occupied Eastern Europe, including Alfred Tarski, a towering figure in mathematics and logic. In 1948 she earned her Ph.D. under Tarski. It was Tarski who first drew her attention to H10. As Robinson wrote, "the problem has occupied the largest portion of my professional career. It was Tarski, talking to Raphael, who started me off. Tarski wondered whether one could prove that the powers of two cannot be put in the form of a solution of a Diophantine equation. Raphael mentioned the problem to me when he came home. And I began to work on it without saying anything to Tarski."

Hilbert's belief that there was a unified theory of mathematics, and that it would be discovered piece by piece, is addressed by mathematicians who will explain why the tenth problem commanded such compelling interest to Julia Robinson and the others who worked on it.

Hilbert's tenth problem (H10), stated in a more accessible way, asks the following: *Given a Diophantine equation with any number of unknown quantities, devise a process according to which it can be determined whether the equation is solvable in whole numbers.*

Discussing H10 requires both verbal and graphic explanations of key mathematical ideas, such as Diophantine equations. The explanations were filmed in interview and classroom presentation style with mathematician Steven Givant, Bjorn Poonen, and Kirsten Eisenträger. An animated sequence of a Turing machine was designed by Andrea Hale.



Steve Givant explains Hilbert's Tenth Problem

Why H10 was an important problem is discussed in relation to the development of computability, and requires explanations of the concepts of solvability and unsolvability. If a problem is unsolvable and a computer is set to try and solve it, the computer will work into eternity without finding a solution.

Nearly 50 years after Hilbert had asked whether a problem had a solution or not, the question began to consume Julia Robinson. On the east coast, Martin Davis and Hilary Putnam also became obsessed with H10 about the same time as Julia Robinson. Martin Davis describes his early interest in the problem and his exciting collaboration with Hilary Putnam.



Martin Davis



Hilary Putnam

"For me the best part of the summer of 1954, which I spent at the Moore School, was getting to know Hilary Putnam, who was living in the same prefab housing complex for graduate student and junior faculty families," wrote Davis. "To my surprise, he was interested in Hilbert's tenth problem and proposed that we collaborate." Putnam and Davis began working together in earnest in 1957. Hilary Putnam recalls the collaboration this way: "What I remember from that summer is not so much the mathematical details as

the sheer *intensity* with which we worked. I have never in my life been so absorbed in a mathematical problem, and I'm sure the same was true of Martin."

Davis and Julia Robinson first met at the International Congress of Mathematics in 1950. It was a meeting at which no representatives from Iron Curtain countries were present. As Martin Davis and Constance Reid explain in the film, the political wall between East and West during the cold war began to take a toll on the exchange of scientific information. As the story of the solution to H10 unfolds, the audience will see how the passionate pursuit of knowledge by several mathematicians on both sides of that wall succeeded in bridging political barriers. "We mathematicians are all from one country," wrote Robinson.

Davis, Putnam, and Robinson concluded that the solution to H10 required a proof that listable sets and Diophantine sets were the same. They made some progress, but finding a proof eluded them. Every year Julia made a wish that it did not matter to her who solved the problem, but that she wanted to know the answer before dying.

For a time, Julia Robinson's political beliefs took over her life. She was involved in the fight over the controversial loyalty oath imposed on faculty members at the University of California at Berkeley. And in the mid-1950s she committed herself entirely to working on Adlai Stevenson's unsuccessful presidential campaigns.

Following the disappointments of politics, Julia returned to mathematics. Martin Davis and Hilary Putnam tell the story of how she joined them in the famous Davis, Putnam, Robinson paper of 1961. But H10 was stubborn. Martin Davis went so far as to joke at one of his presentations that he believed a young Russian who was yet to be born would eventually solve the problem.

During this time Julia continued to suffer the lingering effects of her childhood illnesses. "By the time the joint paper was published (November 1961) my heart had broken down just as the doctor in San Diego had predicted; and I had to have surgery to clear out the mitral valve. One month after the operation I bought my first bicycle," she tells us.

Yuri Matiyasevich first heard about Hilbert's tenth problem at the end of 1965 when he was a sophomore at the Department of Mathematics and Mechanics at Leningrad State University, and he too became captivated with the challenge of searching for a solution. He read Julia Robinson's 1952 paper, but was unable to make any meaningful progress.

In an interview filmed in Gent in 1999, Matiyasevich described his early involvement in H10, and his tenacity in sticking with the problem in the face of disapproval and ridicule by peers and teachers. "One professor began to laugh at me. Each time we met he would ask: 'Have you proved the unsolvability of Hilbert's tenth problem? Not yet? But then you will not be able to graduate from the university.'"

"Then one day in the autumn of 1969, some of my colleagues told me: 'rush to the library. In the recent issue of the *Proceedings of the American Mathematical Society* there is a

new paper by Julia Robinson!" But I was firm in putting Hilbert's tenth problem aside. I told myself, 'It is nice that Julia Robinson goes on with the problem, but I cannot waste my time on it any longer.' So I did not rush to the library. But somewhere in the mathematical heavens there must be a god or goddess of mathematics who would not let me fail to read Julia Robinson's new paper. Because of my early publications on the subject, I was considered a specialist on the tenth problem, and so the paper was sent to me to review. Thus I was forced to read Julia Robinson's paper, and Hilbert's tenth problem captured me again."



Yuri Matiyasevich in 1999

In the interview, Matiyasevich revealed the process of discovery that followed. "On the morning of January 3, I believed I had a solution of Hilbert's tenth problem, but by the end of that day I had discovered a flaw in my work. But the next morning I managed to mend the construction. I wrote out a detailed proof without finding any mistake and asked Sergei Maslov and Vladimir Lifshits to check, but not to say anything about it to anyone else. I had planned to spend the winter holidays with my bride at a ski camp, so I left Leningrad before I got the verdict from Maslov and Lifshits. For a fortnight I was skiing, simplifying my proof, and writing the paper."

Matiyasevich's proof involved the use of Fibonacci numbers, an idea that is relatively easy to illustrate. The film includes a sequence explaining the Fibonacci numbers and their history, as well as an aside about Fibonacci and the reproduction of rabbits. The DVD of the film features the classic 1996 film by Beau Janzen, *Fibonacci and the Golden Mean*, as an extra feature.

As Matiyasevich himself declares, his solution depended crucially on Julia Robinson's earlier work. She had set up the final piece of the problem by solving a number of other things first and by presenting a hypothesis that he followed. "I tried to convey the impact of Julia Robinson's paper on my work by a rather poetic Russian word, which seems to have no direct counterpart in English; roughly it means, 'as if blown by the wind,'" Matiyasevich wrote.

It was 1970 and Matiyasevich was 22 years old. In his own black and white 8mm home movies, we can see him typing away on a portable manual typewriter. The films also contain one of Matiyasevich's first talks about the solution to H10. He has generously made the footage available to this film.

Constance Reid and Martin Davis describe how John McCarthy's notes taken at a lecture in Novosibirsk about Matiyasevich's result made their way to the United States, to Julia and to Martin. Julia's emotional reaction is conveyed by readings from a letter she wrote Matiyasevich upon learning that H10 had been solved

Without ever having met, Matiyasevich and Robinson forged a unique relationship during a period when U.S.-Soviet relations were strained. The correspondence between Robinson and Matiyasevich that flourished tells of the excitement that each of them felt at having contributed to an achievement as momentous as the solution of a Hilbert problem. They went on to work on other problems by mail. Their letters reveal the creation of a strong emotional bond. Matiyasevich is often overcome by emotion as he reveals that Julia Robinson became the most important person in his life.

He also describes how difficult it was for him to develop and sustain a lengthy correspondence with Julia Robinson and other American colleagues when Soviet censors were monitoring his mail.

Robinson and Matiyasevich finally managed to meet at a conference in Bucharest, Romania in 1971, and Matiyasevich took his home movie camera. The footage he shot there contains the only known filmed images of Julia and Raphael Robinson, and of Alfred Tarski.

Recognition of Julia Robinson's contributions to mathematics finally resulted in an appointment to the mathematics department at the University of California. In 1976 she was elected to the National Academy of Sciences. It was the first of many honors she amassed, including presidency of the American Mathematical Society (AMS), election to the AAAS, and a MacArthur award.

Julia Robinson quickly became the most prominent woman in American mathematics. It was a role she had not sought: "All this attention is gratifying but also embarrassing. What I really am is a mathematician. Rather than being remembered as the first woman this or that. I would prefer to be remembered, as a mathematician should, simply for theorems I have proved and the problems I have solved."

Constance Reid's relationship with Julia Robinson is another theme that unfolds as the film progresses. By the end of the story it is clear that Reid's career as a highly renowned biographer of mathematicians is a part of Julia Robinson's legacy. This is pointedly illustrated by Reid's account of Julia Robinson's bout with leukemia and death in 1985, and of the circumstances leading to Julia's autobiography.

Evaluations of Julia Robinson's life and mathematical achievements from several people in the film are interwoven as a sequence of anecdotes and telling statements. Lenore Blum, Martin Davis, Anita and Solomon Feferman, Steve Givant, Yuri Matiyasevich, and Bjorn Poonen, and Dana Scott are key commentators.

Robinson's role in breaking down the academic barriers in mathematics faced by American women into the 1970s and beyond is addressed by Lenore Blum, a founder of American Women in Mathematics. It also reverberates in the presence of a young woman named Anna Salamon, who was filmed in 1999 because she had been awarded the annual Julia Robinson Prize in Mathematics at San Diego High School.

Among the women inspired by Julia Robinson who appear in the film is Kirsten Eisentraeger, a mathematician who has pursued research into a generation of problems based on H10.

Project History

At the beginning of 1999, Constance Reid went to St. Petersburg, Russia, to celebrate her birthday and the anniversary of the solution of H10 with Yuri Matiyasevich and his family. The documentation of this trip initiated the project's production phase. Production was resumed in San Diego in June 1999. The material includes scenes from Julia Robinson's childhood with Constance Reid as interviewee and guide; the award ceremony at San Diego High School at which the Julia Robinson Prize in Mathematics was presented by Reid; and interviews with three students who had won the prize. In November 1999, two days of filming at a workshop on Hilbert's tenth problem held in Gent, Belgium provided key interviews with mathematicians Yuri Matiyasevich, Martin Davis, Alexandra Shlapentokh, and Jan Denef.

During 2001 and 2002, in-depth interviews about Julia Robinson's life and Hilbert's tenth problem were conducted with Lenore Blum in Washington, D.C., with Constance Reid in San Francisco, and with Anita and Solomon Feferman in Palo Alto. During 2006 and 2007, interviews and explanations of the mathematics behind H10 were filmed with mathematicians Kirsten Eisenträger, Steve Givant, Bjorn Poonen and Dana Scott.

On February 7, 2006, Stanford University's Institute for Research on Women and Gender hosted a forum, "Proof and Prejudice: Women in Mathematics," on the experiences of women mathematicians, the barriers to women in math, the achievements of women, and math culture in general. A newly edited sample reel of footage from the film was shown at the program. Producer George Csicsery participated on an hour-long panel on Julia Robinson as a role model for women.

See (<http://www.stanford.edu/group/gender/NewsAndEvents/MathForum.html>). One unexpected result of this conference was that Hollywood actor and mathematician Danica McKellar was also on the panel and became interested in Julia Robinson's story. Almost two years later Danica McKellar became the film's narrator.



Kirsten Eisentraeger

A reenactment, with Eva Liddle (below) playing a young Julia Robinson, was filmed in the desert near Phoenix, Arizona in April 2006.



- A 45-minute rough was screened at the Boston Museum of Science on March 15, 2007, as part of a Conference on Hilbert's Tenth Problem held by the Clay Mathematics Institute. (See: <http://www.claymath.org/events/h10/>)
- The same cut was featured at a sneak preview at the Urania kino in Berlin, Germany on March 26, 2007 as part of the MathFilm Festival 2007. (See: <http://www.dmv-gdm-2007.math.hu-berlin.de/filmprogramm.php>)

These sneak previews provided audience feedback to help determine the final structure and editing of the film.

The completed film was first screened at the Joint Mathematics Meetings in San Diego, California on January 7, 2008, courtesy of the Clay Mathematics Institute. Several key participants were present, including Constance Reid, who was celebrating her 90th birthday, and Martin Davis.

Project Supporters

Julia Robinson and Hilbert's Tenth Problem was made possible by a grant from Margaret and Will Hearst, and by generous support from the Clay Mathematics Institute. The project is sponsored by Film Arts Foundation, a 501 (c) 3 non-profit arts organization based in San Francisco.

Production team

GEORGE PAUL CSICSERY (Producer/Director) Csicsery has directed 23 films—dramatic shorts, performance films and documentaries, including *N is a Number: A Portrait of Paul Erdős* (1993), a one-hour documentary about the renowned wandering mathematician. *Invitation to Discover* (2002), *porridge pulleys and Pi* (2004), and *The Right Spin* (2005), were made for the Mathematical Sciences Research Institute. Csicsery produced, directed, and edited *Where the Heart Roams* (1987), a widely distributed feature documentary about romance writers and their fans, and *Hungry for Monsters* (2003), a feature documentary about recovered memories and false accusations, and *The Thursday Club* (2005), a documentary about retired policemen involved in quelling antiwar riots in the 1960s. *The Right Spin* (2005) was a 30-minute DVD about astronaut Michael Foale and saving the Mir space station, produced for Math Awareness Week. He has worked on films by Errol Morris (*Gates of Heaven*) and Barbet Schroeder (*Koko*). He began working on *Julia Robinson and Hilbert's Tenth Problem* in 1998.

CONSTANCE REID: Her books on David Hilbert and other mathematicians (Bell, Courant) are considered outstanding. She is essential to the film as Julia Robinson's sister and the author of her biography, "JULIA, A Life in Mathematics." Constance Reid is at the core of the project as subject, and as the principal source of biographical and historical information. Her participation and contributions of photographic and audio materials, and documents were indispensable.

CHARLES L. SILVER (Writer/Researcher) A student of Julia Robinson and Alfred Tarski at UC Berkeley, where he earned his Ph.D. in philosophy, Silver has taught mathematics, computer science, and philosophy at a number of universities. He edited and consulted on several films, among them *Gates of Heaven* (supervising editor), *A Brief History of Time* (about the life and the physics of Stephen Hawking), and *N is a Number: A Portrait of Paul Erdős*. He is the author of "From Symbolic Logic to Mathematical Logic" (1994). His expertise in both the story of Julia Robinson, and documentary film conceptualization combines two areas that have helped to guide the production of the film from his initial suggestion of the topic through its completion.

JOHN SHARAF (Cinematographer) has been a news and documentary cinematographer since 1976. He regularly shoots for all major American television networks, “Nightline,” “60 Minutes,” “20/20,” and CNN. His credits include two Academy award-winning documentaries, —*Gravity Is My Enemy* and *Number Our Days*.

SKIP SWEENEY (Cinematographer) is founder of Video Free America in San Francisco. He has made numerous films of his own, and has worked as cinematographer and editor for over 35 years.

TAL SKLOOT (Editor) has edited numerous feature films and Emmy winning documentaries. His credits include Orion Pictures, LucasFilm, 20th Century Fox, Warner Brothers, PBS, KQED, Frontline, Pulse Films, Zala Films, DLB Films and The National Endowment For The Arts. Tal is a graduate of the American Film Institute and an adjunct faculty member at the Diablo Valley College film department.

DANICA MCKELLAR (Narrator) is best known as “Winnie Cooper” from *The Wonder Years* and “Elsie Snuffin” on *The West Wing*. In August 2007, Danica was named “Person of the Week” by *ABC World News with Charles Gibson* for her latest role: author of her bestselling book “MATH DOESN’T SUCK: How to Survive Middle School Math Without Losing Your Mind or Breaking a Nail.” Prior to the book, this summa cum laude graduate of UCLA earned a degree in Mathematics and a place in Britain’s esteemed *Journal of Physics* and the *New York Times* for her work on a mathematical physics problem which now bears her name (The Chayes-McKellar-Winn Theorem). Danica’s deep love of mathematics, her respect for Julia Robinson, and her desire to provide role modeling for girls inspired her to take part in this documentary project.

MARK ADLER (Composer) Mark's feature film scores include Paramount Classics' "Focus," the Miramax film "Picture Bride," the Wayne Wang films "Eat A Bowl of Tea" and "Life Is Cheap," numerous National Geographic Specials, and three Oscar-nominated feature documentaries. In 1999 he won a Primetime Emmy for his work on HBO's "The Rat Pack." Other TV movie scores include Hallmark Entertainment's "Forbidden Territory: Stanley's Search for Livingstone," starring Aidan Quinn and Nigel Hawthorne (for which he received a 1998 Primetime Emmy nomination), "Flowers For Algernon" starring Mathew Modine, and two Hallmark Hall of Fame productions. In 2000 he composed the new theme for the long-running PBS series, "American Experience." He also wrote and produced source music for the Philip Kaufman films "The Unbearable Lightness of Being," and "Henry and June," and was involved as a producer in the recreation of indigenous Brazilian music for the Saul Zaentz production "At Play in the Fields of the Lord." He composed original music for "The Road To Memphis," directed by Richard Pearce as part of the Martin Scorsese-produced series, "The Blues." This range of experience has resulted in an eclectic musical style, often drawing on jazz, folk, world music, and traditional orchestral idioms. He is also a member of the Music Peer Group Executive Committee of the Academy of Television Arts and Sciences, where he currently serves on the National Awards Committee.

ANDREA HALE (Animation/Assistant Editor) graduated from San Francisco State University's Department of Cinema in 2007. She has produced several animated shorts independently.

Mathematicians and historians

LENORE BLUM is well known for her work in increasing the participation of girls and women in mathematics, and was instrumental in founding the Association for Women in Mathematics, serving as its President from 1975 to 1978. She has worked in model theory and differential fields (logic and algebra) and in developing a theory of computation and complexity over the real numbers (mathematics and computer science). She is co-author of "Complexity and Real Computation," with F. Cucker, M. Shub, S. Smale (1997). She is currently at Carnegie-Mellon University. Among the most important women in American mathematics today, Lenore Blum has addressed Robinson's significance for women in mathematics. She is also familiar with all aspects of the mathematics to be discussed in the film.

MARTIN DAVIS is best known for his pioneering work in automated deduction and his contributions to the solution of H10. His book "Computability and Unsolvability" has been called "one of the few real classics in computer science." Another key subject, Martin Davis is one of the four people who worked hardest on H10.

KIRSTEN EISENTRAEGER is an Assistant Professor of Mathematics at the Pennsylvania State University. Her research interests are in number theory and arithmetic geometry. One direction of her research focuses on questions of decidability and undecidability in number theory, and she has worked on generalizations of Hilbert's Tenth Problem.

STEVEN GIVANT is chair of the Department of Mathematics and Computer Science at Mills College. He worked with Alfred Tarski (one of Julia Robinson's teachers) on research in logic and the foundations of mathematics, and has specialized in designing ways to motivate and prepare undergraduate women for graduate school in the mathematical sciences. Givant is an inspiring teacher with a gift for translating difficult concepts to students in the classroom. His knowledge of the protagonists in the story, and of the mathematical concepts involved, makes him the ideal person to deliver the materials verbally on camera.

ANITA BURDMAN FEFERMAN, a biographer of mathematicians, is the author of a biography of Alfred Tarski. Her insights on Tarski, and on the Robinsons, provide a valuable non-mathematical human perspective in the film.

SOLOMON FEFERMAN, an expert on mathematical logic and the foundations of mathematics, theoretical computer science, philosophy of mathematics and the history of twentieth-century logic, is Professor of Mathematics and Philosophy at Stanford University. He is also Julia Robinson's scientific biographer. He was interviewed on the

significance of Robinson's work, her relationship to Alfred Tarski, and other important aspects of the story.

YURI MATIYASEVICH solved Hilbert's tenth problem. He is Director of the Laboratory of Mathematical Logic at the Steklov Institute of Mathematics, St. Petersburg, Director of the Euler Institute for Mathematics, and Professor (on leave) of Computer Software at the St. Petersburg State University in Russia. A central character in the story, Matiyasevich is a key subject, and has donated rare footage and photographs to the project, including the only known images of Julia Robinson on film.

BJORN POONEN is Professor of Mathematics and a Vice Chair for Undergraduate Affairs at the University of California at Berkeley. He is one of the new generation of researchers actively working to extend the results on H10 to rings other than the ring of integers, using modern methods from number theory and algebraic geometry.

HILARY PUTNAM, Cogan University Professor in the Department of Philosophy at Harvard University, worked on Hilbert's tenth problem with Martin Davis and Julia Robinson. Putnam co-wrote with Julia Robinson about H10, and shares the story of his own long involvement with the problem.

DANA SCOTT, Professor Emeritus of Computer Science, Mathematical Logic, and Philosophy at Carnegie Mellon University, was an undergraduate at the University of California, Berkeley, 1950-1954. There he came under the influence of the Tarski School and was a close friend of Julia and her husband until their deaths. He is a fellow of the Academia Europea, American Association for the Advancement of Science, American Academy of Arts and Sciences, Association for Computing Machinery, British Academy, Finnish Academy of Sciences and Letters, New York Academy of Sciences, and U.S. National Academy of Sciences.



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With

**Martin Davis
Yuri Matiyasevich
Hilary Putnam
Constance Reid**

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**Lenore Blum
Jan Denef
Kirsten Eisenträger
Anita Burdman Feferman
Solomon Feferman
Steve Givant
Eva Liddle
Daria Matiyasevich
Nina Matiyasevich
Jan Mestdagh
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Home movies of David Hilbert
filmed in the 1920s by Richard Courant
courtesy of Ernest Courant

Archival footage of mathematical
presentation in Russia,
film of Julia Robinson,
and Yuri Matiyasevich childhood photos
courtesy of Yuri Matiyasevich

Archival footage from 1950 - 1956
courtesy of Absolutely Archives

Still photos of Julia Robinson,
Constance Reid, Arizona, Point Loma,
and San Diego by Ralph Bowman
courtesy of Constance Reid

Hilbert Radio Address
courtesy of Gunther Cornelissen

Photo of 1955 Caltech
Number Theory Conference
courtesy of Tom Apostol

Davis, Matiyasevich, Robinson photo
courtesy of Louise Guy

Additional still photos courtesy of
Sigmund Csicsery
Martin Davis
Hilary Putnam
Anita and Solomon Feferman

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