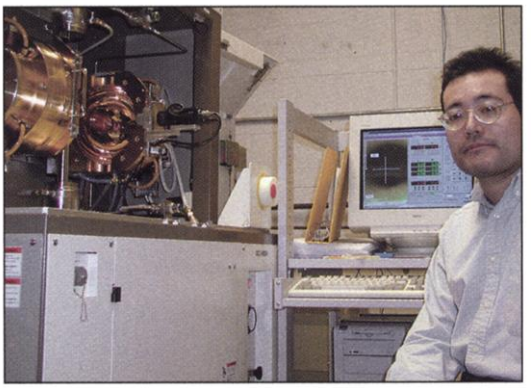
the hires (41) come from abroad, and a scant 2% (eight) made the shift from industry. Stevenson says there is no evidence that the occupants of the new chairs were about to fly the coop, and he frets that the bulk of future appointments will involve more interuniversity poaching. "The net effect will be that we are paying the same people a lot more for no discernible improvement in output," he predicts.

Stevenson also believes that people in the social sciences and some natural sciences are disadvantaged by CFI's requirement that another body put up 60% of a project's cost, because it's generally much harder for natural and social scientists to find external sources of funding. Accordingly, the social sciences have garnered only 2% of CFI funding (a mere four projects), although they represent 53% of the country's faculty members, whereas the 18% in the health sciences have won 45% of the pot. This imbalance has exacerbated resentment among social scientists, says Humanities and Social Sciences Federation of Canada president Patricia Clements: "Of course, there is a division on the campus. While the Minister of Justice was visiting the clean room in the new engineering building, people in the humanities center are phoning the janitor for the fifth time to fix the dripping tap."



**Growth industry.** Postdoc Shuichi Wakimoto and the floating zone crystal growth furnace, one of several new University of Toronto facilities with funding from CFI.

Birgeneau rejects that gloomy assessment of the programs' impact. Even if tiering occurs, he says, peer review ensures that the money is well spent. In addition, he argues that a rising tide lifts all academic boats: "The fact is that, because of these increased resources, we're attracting better graduate students and providing them with a better graduate education." The result, Birgeneau says, is that even "second-tier institutions" can choose from a wider selection of well-trained faculty members.

But Frederick Lowy, head of Concordia University in Montreal, feels that the gap has grown large enough and that the government now needs to strike "a better balance between capacity building and rewarding of existing research strength." Otherwise, he warns, "those universities without research potential will not be able to provide as good an education as those [that] do."

He and others had hoped to address such concerns during forthcoming national consultations on Ottawa's long-overdue white paper on innovation. But they were delayed after the chief sponsor, Industry Minister Brian Tobin, unexpectedly packed his bags last month. Tobin's successor, Allan Rock, is expected to pick up the project this spring.

–WAYNE KONDRO

Wayne Kondro writes from Ottawa.

MATHEMATICS IN FILM

# *Beautiful Mind*'s Math Guru Makes Truth = Beauty

**As mathematics consultant to the hit film about a troubled genius, Dave Bayer learned to balance a whole new set of equations**

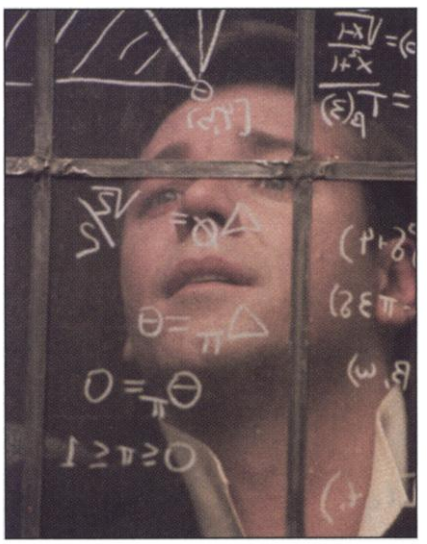
Early in the film *A Beautiful Mind*, Russell Crowe, playing the brilliant young mathematician John Forbes Nash, strides into a classroom at the Massachusetts Institute of Technology to teach his first undergraduate class in vector calculus. The 1950s-era students are wearing coats and ties; Nash, who hasn't even bothered to don a shirt over his undershirt, makes no effort to hide his resentment of them and of his teaching duties. Hurling the assigned textbook into a wastebasket, he writes a series of equations on the blackboard and announces that the rest of the course will be devoted solely to solving the problem they represent—a task, he says, that will take some of them "all your natural lives."

It's a pivotal moment. The student who later rises to the challenge—unsuccessfully—is Nash's future wife Alicia (played by Jennifer Connelly), who will nurse him through 3 decades of mental illness and share his triumph when he receives the Nobel Prize. Like many key scenes in the film, though, the one that launches their journey together mixes fact and invention. Though Alicia Larde did take John Nash's advanced calculus course, he never threw out such a challenge.

So when director Ron Howard needed a mathematical problem for the scene, he couldn't just pluck one out of someone's 50-year-old class notes. Instead he asked Dave Bayer to make it up—to invent the math that Nash *would* have written if such a scene had actually taken place. Some mathematicians or math historians might have balked, but for Bayer—an algebraic geometer at Barnard College in New York City who was moonlighting as *A Beautiful Mind*'s mathematical consultant—it was all in a day's work. "For me, movies are dream sequences," Bayer says. "But even the wildest dream sequences are anchored in reality."

Bayer's task was to forge the anchors. It is a job, Bayer says, that Howard and his team took very seriously. "They have found that real life is much more surprising than anything people can make up," he says. "Audiences can tell when the mathematics is real, and they want it to be real."

If a scientific consultant does his or her job well enough, the viewers won't even notice it. And indeed, the ambitious portrayal of mathematics in *A Beautiful Mind* has done nothing to prevent audiences from appreciating its compelling love story. It has been one of the five top-grossing movies in the United States every week since its release, and on 20 January it won four Golden Globe awards, including best drama.



**Obsessive.** *A Beautiful Mind* depicts a man immersed in mathematics.

Bayer came to the picture by a circuitous route. In 2000, he had written a review of the Broadway play

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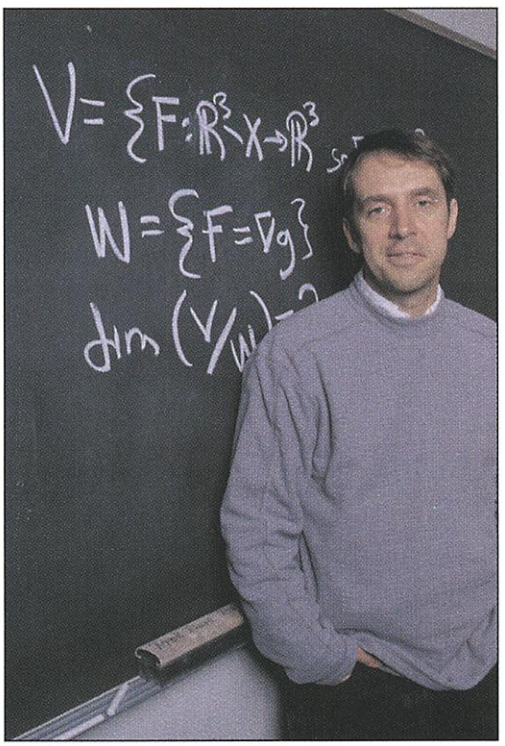
*Proof* for *Notices of the American Mathematical Society*. As a movie and theater aficionado, he wanted to draw his colleagues' attention to a play that treated mathematics seriously. The review found its way to Howard, who liked what he read. The director offered Bayer an interview, which went well enough that he hired him on the spot. Once Bayer was on board, Howard outlined his main concerns about the role of mathematics in the film: How could such an intensely internal subject be captured visually? Could mathematics reflect Nash's descent into mental illness and his slow emergence?

Answering those questions took months of intense effort. "It may look glamorous sitting around a table at the Golden Globes," Bayer says (he himself watched at home), "but the truth is an amazing amount of work goes into every second of film." Between February and June 2001, when the movie wrapped, Bayer put in several hundred hours of work on top of his regular teaching schedule. The insane hours are part of the job, he says; he credits his fascination with moviemaking for carrying him through: "If you didn't have that fascination, you'd walk on day three." His work included writing every one of the countless formulas and computations that cover blackboards and windows throughout the film, apart from a few that Crowe wrote on-camera. Bayer also consulted on set design and props.

The classroom scene was the pièce de résistance, Bayer says. He approached it as if he were the actor playing Nash, by putting himself into the character's shoes. "This is someone who really doesn't want to teach the mundane details, who will home in on what's really interesting," he says. Such a mathematician, Bayer says, would have posed a problem that led into a field of active research, perhaps something that he was thinking about himself—a question that let him "feel the gravitational pull of deep ideas." Yet at the same time, the problem had to be accessible enough so that Connelly's character, a bright physics student, might concoct a plausible, although incorrect, solution.

The problem Bayer finally chose (see photo) was a more complicated version of a classical physics problem: determining whether a static electric field (the F in lines one and two) necessarily has a potential function (indicated by g). If the "electric field" is allowed to be infinite or simply nonexistent at certain points (collectively indicated by X), the question becomes physically unrealistic but mathematically very rich. The answer depends not only on the geometry of the set X, but also on one's assumptions about the field F, as the fictional Nash explains to Alicia rather brusquely when she offers her stab at a solution.

Bayer acknowledges that he was also playing to the cognoscenti. "For years I had heard mathematicians boasting that they could solve the blackboard problem in *Good Will Hunting* [a 1997 movie about a mathematical prodigy] while it was still on the screen," Bayer says. "It would thrill me to no end to have someone with a lot of hubris whispering to their neighbor 'I know what the answer is' and then have it be wrong in the same way as Jennifer's." Ideally, though, Bayer would like even the most savvy viewers not to think about it. "If you put enough effort into making the math credible, at a certain point you win the war," he says. "They're caught up in the movie and barely have time to recognize it's a problem in de Rham cohomology."




**Mathematical haiku.** Dave Bayer's terse calculus problem plays a key role in the film.

More subtly, Bayer also orchestrated mathematics to trace the ups and downs of Nash's struggle with schizophrenia. In the movie, at the time of his breakdown Nash is working on a famous still-unsolved problem called the Riemann Hypothesis, and he continues to work on it as he recovers. Bayer carefully crafted Nash's work so that in the depths of his illness it verges on arithmetical gibberish but later becomes a plausible attack on the problem.

Bayer's advice even extended to acting. In the scene in which Nash breaks down while delivering a public lecture on the Riemann Hypothesis, Bayer noticed that the extras in the audience looked bored. It was understandable, after an early start and long hours of costuming—but it was wrong. If the onlookers thought Nash might really have a proof of the Riemann Hypothesis, they should have started out on the edge of their seats, only to grow increasingly bewildered as they realized that Nash was babbling. Bayer moved to alert one of Howard's assistants. "Ron, who has eyes in the back of his head, was there like a shot, asking me, 'What is it, Dave?' " Bayer recalls. "Then he gave the extras better directions than I could ever have on how to play the scene."

As an unexpected bonus, Bayer wound up on camera himself. Near the end of the movie, he appears as one of Nash's fellow professors who approach him in the Princeton faculty club and lay their pens on his table as tribute. The "pen ceremony" scene is fiction, but it is one of the most moving scenes in the movie and, Bayer says, a beautiful example of the way a good director creates emotional truth. Other "professors" in the scene include members of the film crew. Their sentiment was genuine, Bayer says, the scene their tribute to Crowe for the bravura performance they had just seen him give.

Bayer himself expected little recognition for his work beyond a mention in the closing credits. Instead, he says, he had braced himself for criticism from his fellow mathematicians. "He realized he might get pilloried," says Henry Pinkham, a mathematician and dean of graduate studies at Columbia University in New York City, who consulted for the 1997 film *The Mirror Has Two Faces*, about a lovelorn Columbia University mathematics professor. "He saw the script and the fact that it took serious liberties with Nash's story. He did a fantastic job, given the constraints." Indeed, although some critics grumble that *A Beautiful Mind* exaggerates the competitive atmosphere of postwar Princeton and leaves out important parts of Nash's life and work, the mathematics in the film has come through peer review with flying colors.

The best-informed critic of all seems to be satisfied. John Nash, who has seen *A Beautiful Mind* several times, wrote to Bayer that he appreciated the "bona fide sophistication" of the math in the movie—although he added that in the film's portrayal of his later work, the fictional Nash seems to know some things that "the real Nash (me)" never did.

**–DANA MACKENZIE**

Dana Mackenzie is a writer in Santa Cruz, California.

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