Opinion

Two Views: How Much Math Do Scientists Need?

On April 5, 2013, The Wall Street Journal *published an essay by the Harvard biologist E. O. Wilson, "Great Scientist ≠ Good at Math". Berkeley mathematician Edward Frenkel responded to it in* Slate *on April 9, 2013. We reprint the two essays below, with permission from* The Wall Street Journal *and* Slate.

Great Scientist ≠ Good at Math

E. O. Wilson Shares a Secret: Discoveries Emerge from Ideas, Not Number-Crunching

For many young people who aspire to be scientists, the great bugbear is mathematics. Without advanced math, how can you do serious work in the sciences? Well, I have a professional secret to share: Many of the most successful scientists in the world today are mathematically no more than semiliterate.

During my decades of teaching biology at Harvard, I watched sadly as bright undergraduates turned away from the possibility of a scientific career, fearing that, without strong math skills, they would fail. This mistaken assumption has deprived science of an immeasurable amount of sorely needed talent. It has created a hemorrhage of brain power we need to stanch.

I speak as an authority on this subject because I myself am an extreme case. Having spent my precollege years in relatively poor Southern schools, I didn't take algebra until my freshman year at the University of Alabama. I finally got around to calculus as a thirty-two-year-old tenured professor at Harvard, where I sat uncomfortably in classes with undergraduate students only a bit more than half my age. A couple of them were students in a course on evolutionary biology I was teaching. I swallowed my pride and learned calculus.

I was never more than a C student while catching up, but I was reassured by the discovery that superior mathematical ability is similar to fluency in foreign languages. I might have become fluent with more effort and sessions talking with the natives, but being swept up with field and laboratory research, I advanced only by a small amount.

Fortunately, exceptional mathematical fluency is required in only a few disciplines, such as particle physics, astrophysics and information theory. Far more important throughout the rest of science is the ability to form concepts, during which the researcher conjures images and processes by intuition.

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Everyone sometimes daydreams like a scientist. Ramped up and disciplined, fantasies are the fountainhead of all creative thinking. Newton dreamed, Darwin dreamed, you dream. The images evoked are at first vague. They may shift in form and fade in and out. They grow a bit firmer when sketched as diagrams on pads of paper, and they take on life as real examples are sought and found.

Pioneers in science only rarely make discoveries by extracting ideas from pure mathematics. Most of the stereotypical photographs of scientists studying rows of equations on a blackboard are instructors explaining discoveries already made. Real progress comes in the field writing notes, at the office amid a litter of doodled paper, in the hallway struggling to explain something to a friend, or eating lunch alone. Eureka moments require hard work. And focus.

Ideas in science emerge most readily when some part of the world is studied for its own sake. They follow from thorough, well-organized knowledge of all that is known or can be imagined of real entities and processes within that fragment of existence. When something new is encountered, the follow-up steps usually require mathematical and statistical methods to move the analysis forward. If that step proves too technically difficult for the person who made the discovery, a mathematician or statistician can be added as a collaborator.

In the late 1970s, I sat down with the mathematical theorist George Oster to work out the principles of caste and the division of labor in the social insects. I supplied the details of what had been discovered in nature and the lab, and he used theorems and hypotheses from his tool kit to capture these phenomena. Without such information, Mr. Oster might have developed a general theory, but he would not have had any way to deduce which of the possible permutations actually exist on earth.

Over the years, I have co-written many papers with mathematicians and statisticians, so I can offer the following principle with confidence. Call it Wilson's Principle No. 1: It is far easier for scientists to acquire needed collaboration from mathematicians and statisticians than it is for mathematicians and statisticians to find scientists able to make use of their equations.

This imbalance is especially the case in biology, where factors in a real-life phenomenon are often misunderstood or never noticed in the first place. The annals of theoretical biology are clogged with mathematical models that either can be safely ignored or, when tested, fail. Possibly no more than 10 percent have any lasting value. Only those linked solidly to knowledge of real living systems have much chance of being used.

If your level of mathematical competence is low, plan to raise it, but meanwhile, know that you can do outstanding scientific work with what you have. Think twice, though, about specializing in fields that require a close alternation of experiment and quantitative analysis. These include most of physics and chemistry, as well as a few specialties in molecular biology.

Newton invented calculus in order to give substance to his imagination. Darwin had little or no mathematical ability, but with the masses of information he had accumulated, he was able to conceive a process to which mathematics was later applied.

For aspiring scientists, a key first step is to find a subject that interests them deeply and focus on it. In doing so, they should keep in mind Wilson's Principle No. 2: For every scientist, there exists a discipline for which his or her level of mathematical competence is enough to achieve excellence.

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Don't Listen to E. O. Wilson

Math Can Help You in Almost Any Career. There's No Reason to Fear It

E. O. Wilson is an eminent Harvard biologist and best-selling author. I salute him for his accomplishments. But he couldn't be more wrong in his recent piece in *The Wall Street Journal* (adapted from his new book *Letters to a Young Scientist*), in which he tells aspiring scientists that they don't need mathematics to thrive. He starts out by saying: "Many of the most successful scientists in the world today are mathematically no more than semi-literate … I speak as an authority on this subject because I myself am an extreme case." This would have been fine if he had followed with: "But you, young scientists, don't have to be like me, so let's see if I can help you overcome your fear of math." Alas, the octogenarian authority on social insects takes the opposite tack. Turns out he actually believes not only that the fear is justified, but that most scientists don't need math. "I got by, and so can you" is his attitude. Sadly, it's clear from the article that the reason Wilson makes these errors is that, based on his own limited experience, he does not understand what mathematics is and how it is used in science.

If mathematics were fine art, then Wilson's view of it would be that it's all about painting a fence in your backyard. Why learn how to do it yourself when you can hire someone to do it for you? But fine art isn't a painted fence, it's the paintings of the great masters. And likewise, mathematics is not about "number-crunching", as Wilson's article suggests. It's about concepts and ideas that empower us to describe reality and figure out how the world really works. Galileo famously said, "The laws of Nature are written in the language of mathematics." Mathematics represents objective knowledge, which allows us to break free of dogmas and prejudices. It is through math that we learned Earth isn't flat and that it revolves around the sun, that our universe is curved, expanding, full of dark energy, and quite possibly has more than three spatial dimensions. But since we can't really imagine curved spaces of dimension greater than two, how can we even begin a conversation about the universe without using the language of math?

Charles Darwin rightfully spoke of math endowing us "with something like a new sense." History teaches that mathematical ideas that looked abstract and esoteric yesterday led to spectacular scientific advances of today. Scientific progress would be diminished if young scientists were to heed Wilson's advice.

It is interesting to note that Wilson's recent article in *Nature* and his book claiming to show support for so-called group selection have been sharply criticized, by Richard Dawkins and many others. Some of the critics pointed out that one source of error was in Wilson's math. Since I'm not an expert in evolutionary theory, I can't offer an opinion, but I find this controversy interesting given Wilson's thesis that "great scientists don't need math."

One thing should be clear: While our perception of the physical world can always be distorted, our perception of the mathematical truths can't be. They are objective, persistent, necessary truths. A mathematical formula means the same thing to anyone anywhere—no matter what gender, religion, or skin color; it will mean the same thing to anyone a thousand years from now. And that's why mathematics is going to play an increasingly important role in science and technology.

One of the key functions of mathematics is the ordering of information. With the advent of the 3-D printing and other new technology, the reality we are used to is undergoing a radical transformation: Everything will migrate from the layer of physical reality to the layer of information and data. We will soon be able to convert information into matter on demand by using 3-D printers just as easily as we now convert a PDF file into a book or an MP3 file into a piece of music. In this brave new world, math will be king: It will be used to organize and order information and facilitate the conversion of information into matter.

It might still be possible to be "bad in math" (though I believe that anyone can be good at math if it is explained in the right way) and be a good scientist—in some areas and probably not for too long. But this is a handicap and nothing to be proud of. Granted, some areas of science currently use less math than others. But then practitioners in those fields stand to benefit even more from learning mathematics.

It would be fine if Wilson restricted the article to his personal experience, a career path that is obsolete for a modern student of biology. We could then discuss the real question, which is how to improve our math education and to eradicate the fear of mathematics that he is talking about. Instead, trading on that fear, Wilson gives a misinformed advice to the next generation, and in particular to future scientists, to eschew mathematics. This is not just misguided and counterproductive; coming from a leading scientist like him, it is a disgrace. Don't follow this advice—it's a self-extinguishing strategy.

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