

progressed, many more kinds of numbers would be invented: imaginary, irrational, transcendental, and complex, to name a few. They each have specific and sometimes unique applications to the physical world that we have discovered around us from the dawn of civilization.

Those who study the universe have been around from the beginning. As a member of this (second) oldest profession, I can attest that we have adopted, and actively use, all parts of the number line for all manner of heavenly analysis. We also routinely invoke some of the smallest and, of course, largest numbers of any profession. This state of mind has even influenced common parlance. When something in society seems immeasurably large, like the national debt, it's not called biological or chemical. It's called astronomical. And so one could argue strongly that astrophysicists do not fear numbers.

With thousands of years of culture behind us, what has society earned on its math report card? More specifically, what grade do we give Americans, members of the most technologically advanced culture the world has ever known?

Let's start with airplanes. Whoever lays out the seats on Continental Airlines seems to suffer from Medieval fears of the number 13. I have yet to see a row 13 on any flight I have taken with them. The rows simply go from 12 to 14. How about buildings? Seventy percent of all high-rises along a three-mile stretch of Broadway in Manhattan have no thirteenth floor. While I have not compiled detailed statistics for everywhere else in the nation, my experience walking in and out of buildings tells me it's more than half. If you've ridden the elevator of these guilty high-rises you've probably noticed that the 14th floor directly follows the 12th. This trend exists for old buildings as well as new. Some buildings are self-conscious and try to conceal their superstitious ways by providing two separate elevator banks: one that goes from 1 to 12 and another that goes upward from 14. The 22-story apartment building in which I was raised (in the Bronx) had two separate banks of elevators, but in this case, one bank accessed only the even floors while the other bank accessed the odd. One of the myster-

FEAR OF NUMBERS

e may never know the circuit diagram for all the electrochemical pathways within the human brain. But one thing is for certain, we are not wired for logical thinking. If we were, then mathematics would be the average person's easiest subject in school.

In this alternate universe, mathematics might not be taught at all because its foundations and principles would be self-evident even to slow-achieving students. But nowhere in the real world is this true. You can, of course, train most humans to be logical some of the time, and some humans to be logical all of the time; the brain is a marvellously flexible organ in this regard. But people hardly ever need training to be emotional. We are born crying, and we laugh early in life.

We do not emerge from the womb enumerating objects around us. The familiar number line, for example, is not writ on our gray matter. People had to invent the number line and build upon it when new needs arose from the growing complexities of life and of society. In a world of countable objects, we will all agree that $2 + 3 = 5$, but what does $2 - 3$ equal? To answer this question without saying, "It has no meaning," required that somebody invent a new part of the number line—negative numbers. Continuing: We all know that half of 10 is 5, but what is half of 5? To give meaning to this question, somebody had to invent fractions, yet another class of numbers on the number line. As this ascent through numberdom

ies of my childhood was why the odd bank of elevators went from floor 11 directly to floor 15, and the even bank went from 12 to 16. Apparently, for my building, a single odd floor could not be skipped without throwing off the entire odd-even scheme. Hence the blatant omission of any reference to either the 13th or the 14th floor. Of course, all this meant that the building was actually only 20 stories high and not 22.

In another building, which harbored an extensive subterranean world, the levels below the first floor were B, SB, P, LB, and LL. Perhaps this is done to give you something to think about while you are otherwise standing in the elevator doing nothing. These floors are begging to become negative numbers. For the uninitiated, these abbreviations stood for Basement, Sub-Basement, Parking, Lower Basement, and Lower Level. We surely do not use such lingo to name normal floors. Imagine a building not with floors labelled 1, 2, 3, 4, 5, but G, AG, HG, VHG, SR, R, which obviously stand for Ground, Above Ground, High Ground, Very High Ground, Sub-Roof, and Roof. In principle, one should not fear negative floors—they don't in the Hotel de Rhone in Geneva, Switzerland, which has floors -1 and -2, nor are they afraid at the National Hotel in Moscow, which had no hesitation naming floors 0 and -1.

America's implicit denial of all that is less than zero shows up in many places. A mild case of this syndrome exists among car dealers, where instead of saying they will subtract \$1,000 from the price of your car, they say you will receive \$1,000 "cash back." In corporate accounting reports, we find that fear of the negative sign is pervasive. Here, it's common practice to enclose negative numbers in parentheses and not to display the negative symbol anywhere on the spreadsheet. Even the successful 1985 Bret Easton Ellis book (and 1987 film) *Less Than Zero*, which tracks the falling from grace of wealthy Los Angeles teens, could not be imagined with the logically equivalent title: *Negative*.

As we hide from negative numbers, we also hide from decimals, especially in America. Only recently have the stocks traded on the New York Stock Exchange been registered in decimal dollars instead

of clunky fractions. And even though American money is decimal metric, we don't think of it that way. If something costs \$1.50, we typically parse it into two segments and recite "one dollar and fifty cents." This behavior is not fundamentally different from the way people recited prices in the old decimal-averse British system that combined pounds and shillings.

When my daughter turned 15 months old, I took perverse pleasure in telling people she was "1.25." They would look back at me, with heads tilted in silent puzzlement, the way dogs look when they hear a high-pitched sound.

Fear of decimals is also rampant when probabilities are communicated to the public. People typically report odds in the form of "something to 1." Which makes intuitive sense to nearly everyone: The odds against the long-shot winning the ninth race at Belmont are 28 to 1. The odds against the favorite are 2 to 1. But the odds against the second favorite horse are 7 to 2. Why don't they say "something to 1"? Because if they did, then the 7 to 2 odds would instead read 3.5 to 1, stupefying all decimal-challenged people at the racetrack.

I suppose I can live with missing decimals, missing floors to tall buildings, and floors that are named instead of numbered. A more serious problem is the limited capacity of the human mind to grasp the relative magnitudes of large numbers:

Counting at the rate of one number per second, you will require 12 days to reach a million and 32 years to count to a billion. To count to a trillion takes 32,000 years, which is as much time as has elapsed since people first drew on cave walls.

If laid end to end, the hundred billion (or so) hamburgers sold by the McDonald's restaurant chain would stretch around the Earth 230 times leaving enough left over to stack the rest from Earth to the Moon—and back.

Last I checked, Bill Gates was worth \$50 billion. If the average employed adult, who is walking in a hurry, will pick up a quarter from the sidewalk, but not a dime, then the corresponding amount of money (given their relative wealth) that Bill Gates would ignore if he saw it lying on the street is \$25,000.

These are trivial brain exercises to the astrophysicist, but normal people do not think about these sorts of things. But at what cost? Beginning in 1969, space probes were designed and launched that shaped two decades of planetary reconnaissance in our solar system. The celebrated *Pioneer*, *Voyager*, and *Viking* missions were part of this era. So too was the *Mars Observer*, which was lost on arrival in the Martian atmosphere in 1993.

Each of these spacecraft took many years to plan and build. Each mission was ambitious in the breadth and depth of its scientific objectives and typically cost taxpayers between \$1 and \$2 billion. During a 1990s change in administration, NASA introduced a "faster, cheaper, better" paradigm for a new class of spacecraft that cost between \$100 and \$200 million. Unlike previous spacecraft, these could be planned and designed swiftly, enabling missions with more sharply defined objectives. Of course that meant a mission failure would be less costly and less damaging to the overall program of exploration.

In 1999, however, two of these more economical Mars missions failed, with a total hit to taxpayers of about \$250 million. Yet public reaction was just as negative as it had been to the billion-dollar *Mars Observer*. The news media reported the \$250 million as an unthinkable huge waste of money and proclaimed that something was wrong with NASA. The result was an investigation and a congressional hearing.

Not to defend failure, but \$250 million is not much more than the cost to produce Kevin Costner's film flop *Waterworld*. It's also the cost of about two days in orbit for the space shuttle, and it's one-fifth the cost of the previously lost *Mars Observer*. Without these comparisons, and without the reminder that these failures were consistent with the "faster, cheaper, better" paradigm, in which risks are spread among multiple missions, you would think that \$1 million equals \$1 billion equals \$1 trillion.

Nobody announced that the \$250-million loss amounts to less than \$1 per person in the United States. This much money, in the form of pennies, is surely just laying around in our streets, which are filled with people too busy to bend down and pick them up.

ON BEING BAFFLED

Maybe it's the need to attract and keep readers. Maybe the public likes to know those rare occasions when scientists are clueless. But how come science writers can't write an article about the universe unless they describe some of the astrophysicists they interview as being "baffled" by the latest research headlines?

Scientific bafflement so intrigues journalists that, in what may have been a first for media coverage of science, an August 1999 page-one story in *The New York Times* reported on an object in the universe whose spectrum was a mystery (Wilford 1999). Top astrophysicists were stumped. In spite of the data's high quality (observations were made at the Hawaii-based Keck telescope, the most powerful optical observatory in the world), the object wasn't any known variety of planet, star, or galaxy. Imagine if a biologist had sequenced the genome of a newly discovered species of life and still couldn't classify it as plant or animal. Because of this fundamental ignorance, the 2,000-word article contained no analysis, no conclusions, no science.

In this particular case, the object was eventually identified as an odd, though otherwise unremarkable, galaxy—but not before millions of readers had been exposed to a parade of selected astrophysicists saying, "I dunno what it is." Such reporting is rampant, and grossly misrepresents our prevailing states of mind. If the writers told the whole truth, they would instead report that *all* astro-