The amateur mathematicians built upon an existing tradition of hanging wooden tablets with poetry or paintings in Shinto shrines and Buddhist temples, painting or engraving sangaku that typically give the result of a problem but not the proof. "Ostensibly, the tablets were left as gifts to the gods," Fukagawa explains. "In reality, people were showing off and challenging others to work out the proof."

The vast majority of the problems involve plane geometry. But some involve calculating volumes of solids and others deal with algebra-like equations. The sangaku crafters typically included their names and the dates they hung the tablets.

Once Japan ended its isolation in the mid-1800s, the government encouraged the study of the European mathematical tradition as part of its push to catch up to the West technologically and economically. The archaic Chinese characters of Japanese mathematics fell into disuse, and the sangaku tradition disappeared. The rediscovery of sangaku is due in large part to 61-year-old Fukagawa, who holds a degree in mathematics and who has spent nearly 40 years teaching high school math in Aichi Prefecture. Looking for material to enliven his classes, he stumbled upon sangaku. "At the time, no Japanese mathematician had studied sangaku in any depth," he says.

His first step was to teach himself the archaic Chinese characters used on the tablets. The more sangaku Fukagawa deciphered, the more impressed he became with their sophistication. Japanese mathematicians were less enthralled, however, so Fukagawa started contacting geometers in other countries. His search led to a number of collaborations. In 1989 he and Daniel Pedoe of the University of Minnesota, Twin Cities, co-authored *Japanese Temple Geometry Problems*, which remains the most complete monograph on sangaku in any language. In 2002 he and John Rigby of Cardiff University in Wales published *Traditional Japanese Mathematics Problems from the 18th and 19th Centuries*.

The first book describes a number of Western geometrical theorems that were solved independently in Japan. One notable example is Soddy's hexlet, a theorem published in 1936 by Frederick Soddy, a British chemistry Nobel laureate, involving a complex construction of spheres within a sphere. Fukagawa and Pedoe found that the identical solution had been inscribed on a sangaku placed at a shrine in Kanagawa Prefecture in 1822. (The tablet is lost but is described in a written text.)

Even so, the mathematical significance of the sangaku tradition is an open question. Hikosaburo Komatsu, a mathematician at the Science University of Tokyo who studies Japan's indigenous math, agrees that their existence "shows that knowledge of math among ordinary citizens of that time was quite high." But the tablet format limits results so that

Sleuth. Hidetoshi Fukagawa has written the definitive text on sangaku.

"mathematically, sangaku are not very deep," he says. Serious Japanese mathematicians were producing much more significant theoretical work at the time, he notes. Still, Peter Wong, who grew up in Hong Kong and now teaches mathematics at Bates College in Lewiston, Maine, says the sangaku "open up all sorts of questions" about how laypeople developed sufficient mathematical skills to tackle nontrivial problems.

Fukagawa hopes further study will provide some answers. About 900 sangaku are known to remain, and dozens more that have been lost are known from written references. Only last year, during a visit to a shrine in Mie Prefecture, Wong used his knowledge of Chinese characters to point out a sangaku that Fukagawa had overlooked. Fukagawa also hopes the exhibition, which runs from 19 April to 26 June, will stimulate interest in the topic and yield additional sangaku. –DENNIS NORMILE

Public Health

Provocative Study Says Obesity May Reduce U.S. Life Expectancy

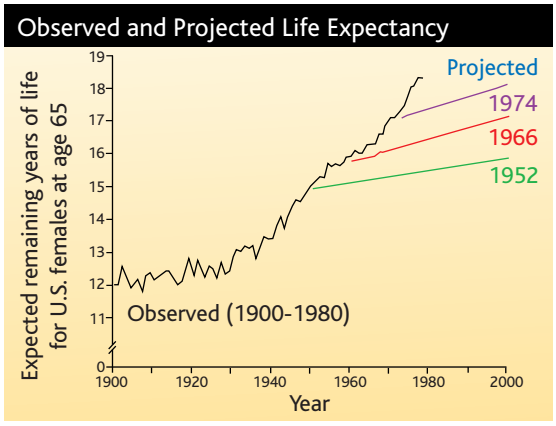
The rising incidence of obesity, especially among children and teenagers, is leading to a variety of diseases that could depress average life span

In the 1980s and 1990s, the late maverick economist Julian Simon infuriated environmentalists by arguing that free markets and scientific progress were constantly improving human life rather than pushing the world toward ecological ruin, social collapse, and famine. A key example was life expectancy at birth, which Simon showed had been steadily rising for centuries. Using that as a metric, he repeatedly claimed that in the 21st century, "humanity's condition will improve in just about every material way."

Not so, says a 10-person research team led by S. Jay Olshansky of the University of Illinois, Chicago, and David S. Ludwig of Children's Hospital in Boston, Massachusetts. In a study published in the 17 March *New England Journal of Medicine*, the team predicts that U.S. life expectancy "could level off or even decline" by 2050.

The culprit, though, is not environmental heedlessness but the very market-driven affluence that Simon celebrated, because it has fostered an explosive rise in obesity, and especially childhood obesity. That rise, the research team argues, has already offset increasing life expectancy "by 0.33 to 0.93 year for white males," with similar offsets for women and other races. Assuming that current trends continue and that no big technical fixes emerge, Olshansky says, "we have strong reason to believe this number will rise rapidly in the coming decades."

That conclusion is likely to be controversial. Critics argue that it is based on a partial reading of the evidence. "Obesity is indeed a problem," says James Vaupel, director of the Max Planck Institute for Demographic Research in Rostock, Germany. "But on the other side there are extraordinary advances being made as a result of biomedical research." Moreover, he says, "the United States has seen a slowdown in life expectancy, but in other countries it's going up fairly rapidly—about 3 months per year in places like France and Japan."



End of an era? Average years remaining for U.S. females at age 65 rose steadily, in spite of projections to the contrary.

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To Olshansky, the continuing increases in those countries may mean only that they have not yet reached U.S. obesity levels. If the projections in the *New England Journal* article come true, he notes, the next generations will be the first in recorded history to die younger and sicker than their parents—a public-health catastrophe.

But there may be more immediate consequences as well. In 2004 the Social Security Administration estimated that by 2078 female and male life expectancy will jump from their current levels of, respectively, 79.9 and 74.5 years to 89.2 and 85.9 years. That rapid increase, which will increase disbursals, is one of the motors driving the current debate over the program's potential insolvency. "Those projections are made from mathematical models," Olshansky says. "If you look at actual people now, I believe you see very quickly that this is not going to happen. The 'benefit,' if you can call it that, is that Social Security will be in less trouble, because fewer people will be alive to collect it."

A growing health burden. One in eight U.S. youths is now overweight.

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What goes up ...

In the 20th century, U.S. life expectancy climbed from 47 to its present height, a rise unprecedented in human history. The fastest part of the increase occurred in the first few decades of the century, as improved sanitation and nutrition dramatically reduced infant and child mortality. Because a child who avoids death from measles may go on to live for decades more, whereas an older person who avoids death from the same cause will only live a little longer, reducing childhood mortality has a disproportionately large impact on overall life expectancy.

Now, if the *New England Journal* authors are correct, the unprecedented rise in life expectancy will be followed by an equally unprecedented fall. In the 1999–2002 period, according to a Centers for Disease Control and Prevention (CDC) analysis last year, some 16% of U.S. children from 6 to 19—more than 1 out of 8—were overweight, a proportion that has more than tripled in the past 30 years. (Overweight is defined as a body mass index, or BMI—weight in kilograms divided by the square of height in meters—for age and gender at or above the 95th percentile of CDC's baseline growth charts.) Another 15% were at risk for becoming overweight (a BMI between the 85th and 95th percentiles of CDC's growth charts). (For adults, a BMI of 30 or above is considered "obese," and between 25 and 30 is "overweight.")

Because the health effects of obesity can take decades to appear and childhood obesity is a relatively new phenomenon, researchers have relatively little firsthand information on the impact that being overweight in childhood has on the incidence of disease in later life. Instead they make projections from the consequences of obesity on life expectancy for adults. "Obesity is not like running through a minefield, which kills you all at once or lets you run through it unscathed," says David Allison, a biostatistician at the University of Alabama, Birmingham, and a co-author of the *New England Journal* paper. "Instead, your risk increases over time. What you die of is the accumulated effects from years of obesity."

In a typical study, the Netherlands Epidemiology and Demography Compression of Morbidity Research Group analyzed data from the Framingham Heart Study to find in January 2003 that obesity led to declines in life expectancy of 7.1 years for 40-year-old female nonsmokers and 5.8 years for 40-year-old male nonsmokers. The next day, Allison's research team released a study arguing that life expectancy for extremely obese white 20-year-olds (BMIs of 45 or more) is 13 years lower than that for people of normal weight. "The younger you become obese, the more years of life you lose," Allison says. "That's not at all surprising. If you become obese as a child, the impact should be even greater."

Conservative assumptions

For the *New England Journal* study, Olshansky says, "we tried to answer a simple question: What would life expectancy be like in the U.S. if obesity did not exist?" Basing their estimates on data from CDC's big National Health and Nutrition Examination Surveys, they assumed, for simplicity's sake, that all overweight or obese people had BMIs of either 30 or 35, respectively. The assumption had the additional beneficial effect of making the calculation "very conservative," Olshansky says, because it implicitly excluded the impact of higher BMIs. "The proportion of extremely obese is rising very rapidly—things are really moving in the wrong direction—and we ultraconservatively eliminated that." The researchers also assumed that obesity had no effect before the age of 20 or after 85, both of which "we know are not true."

Although Olshansky stresses that the estimate is "a first-pass approximation," he believes the effect is large enough to demonstrate "that trends in obesity in younger ages will lead to significantly higher rates of mortality in the future—we will lose 2 to 5 or more years [of life expectancy] in the coming decades" if the obesity epidemic continues unchecked. Another way of expressing this impact is to note that curing all forms of cancer would only add 3.5 years to average U.S. life expectancy. Rising obesity would more than cancel that out.

Perhaps so, says Vaupel of the Max Planck Institute. But on a global level the United States is an outlier—life expectancy is continuing to rise elsewhere. "That suggests to me that this is a localized problem that could be addressed by appropriate public-health policies," Vaupel says. As he has argued (*Science*, 10 May 2002, p. 1029), demographers have repeatedly predicted that increases in life expectancy will level off. "And they've always been wrong. Olshansky himself wrote in 1990 [*Science*, 2 November 1990, p. 634] that life expectancy would never exceed 85 on average without major breakthroughs. Well, in 2003, Japanese female life expectancy reached 85.33."

To team co-leader Ludwig, the *New England Journal* paper is a "call to action when action could still make a difference." The explosion in obesity, he says, will occur in three phases. The first is increased prevalence. "For the first decade or so, very little occurs—you just have a lot of heavy kids." In the second phase, the rising prevalence is "translated into actual diseases. Then, after yet another period of time, the third phase comes, when those diseases come to translate into lower life expectancy. Right now, we're at the beginning of the second phase. … The first wave of children diagnosed with type 2 diabetes in adolescence is now reaching their late 20s, and we're just starting to see [circulatory problems leading to] amputations, kidney failure requiring dialysis, and increased mortality."

–CHARLES C. MANN

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