MATHEMATICS

An Awesome Look at Japan's Math SAT

Study after study has shown that Japanese high school students are head and shoulders above their U.S. counterparts, especially in math and science. In spite of much public handwringing in the United States, the gap doesn't seem to be closing (see page 53). A case in point is the complexity of the math problems on Japanese university entrance exams.

The Mathematical Association of America (MAA) has just published an English translation of the mathematics portion of the 1990 University Entrance Center Examination (UECE)—Japan's equivalent of the American SAT—and a sample of individual university exams. U.S. mathematicians who have read the translation are awed, even dumbfounded, by the mathematical sophistication expected of students taking the tests. "It's an impressive amount of mathematics," says Don Albers, associate director of MAA, who sought the translation in order to "get some facts on the table." Agrees the translator, Eileen Wu of Menlo College in Atherton, California, "They're asking quite a bit more of their students." Richard Askey, a professor of mathematics at the University of Wisconsin is blunter: College-bound U.S. students given the exams "would bomb out completely," he predicts.

Even if Askey is right, there's a caveat: The significance of any comparison between students is muddied by statistical differences in the test-taking groups. According to 1987 data, the SAT was taken by 31% of the U.S. college-age population; the corresponding figure for the Japanese UECE is 14%. Presumably the better students in Japan are disproportionately represented among the test-takers there. But Askey opines that only the very best U.S. students would match the Japanese students' average scores. "The level at which [Japanese] students perform on these [exams] is just incredible," he says.

Faced with problems this challenging, Japanese students have one thing to be thankful for: The UECE has just a handful of problems, compared with dozens of multiple-choice questions on the SAT. Each UECE problem, though, typically has several parts, and students don't have a multiple-choice menu of answers to fall back on. (The Japanese exam uses a unique response format that allows complex answers to be graded by machine.)

How do *Science* readers stack up against fresh high school graduates in Japan? Readers can test their mettle on the sample problem from the UECE in the box. And if you're feeling even more daring, take a crack at the following problem, from an exam given by Tokyo University:

"Given a regular pyramid, there is a ball with its center on the bottom of the pyramid and tangent to all edges. (A regular pyramid has four isosceles triangles adjoined to a square base.) If each edge of the pyramid base is of length a, find the height of the pyramid and the volume of the portion it has in common with the ball." (Answer: Height=$\sqrt{2}/2\ a$; shared volume=$(7\sqrt{6}/54 - 1/4)\pi a^3$.)

Admittedly, Tokyo University is Japan's most elite school. But the pyramid problem isn't given to prospective math and science majors. No, it's for students who want to study humanities. When U.S. math majors might trail even lit students in Japan, there's a lot of catching up to do.

–Barry Cipra

The Exam Starts Easy

Directions: Each problem contains several blanks. Blanks are represented by bracketed, underlined numbers. Each blank must be filled with a single digit or sign.

Section 1, Question 1

Suppose the polynomial $P(x)$ with integer coefficients satisfies the following conditions:

(A) If $P(x)$ is divided by x^2-4x+3, the remainder is $65x-68$.

(B) If $P(x)$ is divided by x^2+6x-7, the remainder is $-5x+a$.

Then we know that a = {1}.

Let us find the remainder $bx+c$ when $P(x)$ is divided by $x^2+4x-21$.

Condition (A) implies that {2} $b+c$ = {3}{4}{5} and a = {1}.

Condition (B) implies that {6}{7}$b+c$ = {8}{9}. It follows that b = {10} and c = {11}{12}{13}.

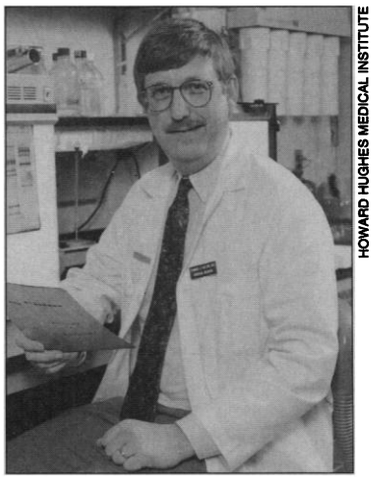
Answer

a = {1}
$a = 2$
{2} $b+c$ = {3}{4}{5}
$3b+c = 127$
{6}{7}$b+c$ = {8}{9}
$-7b+c = 37$
b = {10}
$b = 9$
c = {11}{12}{13}
$c = 100$

HUMAN GENOME PROGRAM

Healy and Collins Strike a Deal

After months of rumor, speculation, and frequent campus sightings, geneticist Francis S. Collins has agreed to take over the directorship of the National Center for Human Genome Research at the National Institutes of Health (NIH). "We have a verbal agreement which is very concrete," NIH Director Bernadine Healy told *Science*. "It's the biggest Christmas present for NIH. This is a scientific coup, and a morale booster for all of the NIH campus." Although final details need to be resolved, the deal Healy has struck with Collins will result in a major expansion of human genome studies on NIH's Bethesda campus.



HOWARD HUGHES MEDICAL INSTITUTE

Gene meister. Francis Collins will head a new institute.

Collins confirmed that he has tentatively accepted the job, which was vacated last April by James Watson. He hopes to start part time this month, full time in March, and relocate his laboratory from the University of Michigan Medical School over the next year. But, he cautioned, "I have not yet received a written offer, nor made a formal acceptance." The stumbling block seems to be in Little Rock. While both Healy and Collins have gotten general support for the appointment from the transition team of President-elect Bill Clinton, Collins says, "I need to get a stronger sense of how deep their enthusiasm is for the genome project. The resources we are asking for will only be truly meaningful if they are backed up by the Administration and Congress."

Healy and Collins want a lot of resources because they expect to turn the genome center into NIH's newest institute: the National Institute for Human Genetics. NIH's share of the genome project—$106.2 million this year—now goes mostly to university scientists. The proposed new genetics institute will add an intramural component, rapidly expanding funds, space, and personnel for genetics research on the NIH campus.

To lure Collins from Michigan, Healy threw in everything, including the laboratory sink. She committed most of the NIH director's discretionary budget to set up a new lab for Collins, agreeing to spend between $5 million and $10 million in the first year to begin relocating his Michigan crew. They will be housed in 45,000

square feet of recently reallocated space in the Warren G. Magnuson Clinical Center, NIH's 500-bed hospital, and the new Silvio O. Conte building, named for the late Republican congressman from Massachusetts.

When the new fiscal year starts in October, Collins hopes to boost the intramural budget to $25 million, and then to $30 million to $40 million in 1995. He will be looking for more money to spend off campus as well. "My sense is that the genome project is underfunded by a factor of two," Collins said. "One of my major tasks is to try to correct that."

If Congress agrees to these sums, Collins will hire some 180 full-time staffers by 1995, including 20 principal investigators, some working on projects that link traditional research to track down disease genes with genetic treatments. "The connection of gene discovery and gene therapy is very appropriate," said Collins, who watched his codiscovery of the cystic fibrosis gene 3 years ago turn into a gene treatment now entering clinical trials. Collins' group also codiscovered the neurofibromatosis gene that causes nerve cells to form tumors on the face and other body areas, and he pioneered gene detecting techniques that became standard lab procedures worldwide.

"This is probably the biggest recruitment that NIH ever made, in stature and resource commitment," Healy said. "He will be a magnet for other recruitment to NIH. This is a reverse of the brain drain."

While the move may be great for government research, it may not be good for Francis Collins. For one thing, he says, "I will be taking a substantial pay cut to take this job." He will also have to juggle research and a heavy administrative load. "I am determined to keep my research lab active. Yet, I am aware that in taking on this job, the stresses are going to be severe," says Collins, adding that at age 42, "it is too early for me to be stuck in some bureaucratic position." And he will have to sever a longstanding relationship with the Howard Hughes Medical Institute (HHMI), the nation's wealthiest foundation. HHMI has employed Collins since 1987, supporting him and seven other Hughes investigators at Michigan to the tune of $6.33 million last year. "We will be sad to see him leave the ranks of HHMI," said Hughes' president Purnell W. Choppin, who calls Collins "a brilliant scientist."

So why did he take the job? Collins says he jumped at the chance "because there is only one human genome program. It will only happen once, and this is that moment in history. The chance to stand at the helm of that project, and to put my own personal stamp on it is more than I could imagine."

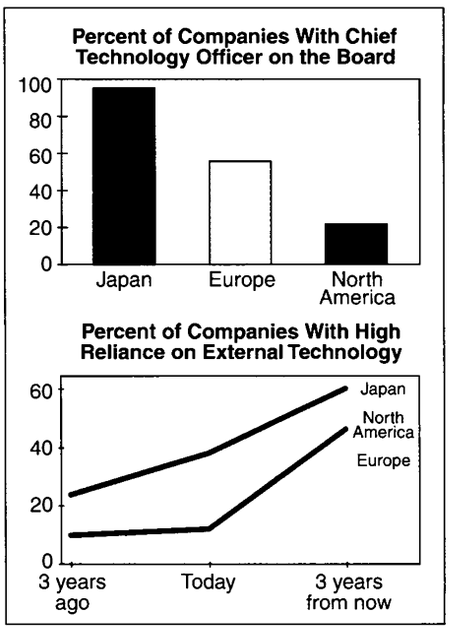
–Larry Thompson

Larry Thompson is a science writer living in Bethesda, Maryland.

INDUSTRIAL RESEARCH

How U.S. Companies Measure Up

When International Business Machines (IBM) announced in mid-December that it will lay off 25,000 workers and slash R&D spending by $1 billion next year, IBM chairman John Akers put part of the blame on the company's slowness in adapting to changing technology. Is it just Big Blue that has lost its way, or do the computer giant's troubles reflect deep-seated problems in the way U.S. companies manage technology? A major study being conducted by the Massachusetts Institute of Technology's (MIT) Industrial Liaison Program and PA Consulting Group, a Princeton-based firm specializing in business and technology analysis, may help answer that question. At a recent symposium at MIT,* study participants presented some provocative preliminary findings from an international survey of senior technology executives, suggesting that U.S. firms in general are more likely to be blind-sided by changing technology than their competitors in Europe and Japan.



Global benchmarking. In Japan and Europe, CTOs wield much more influence. And the United States still lags behind Japan in exploiting "external" sources of R&D.

Perhaps the most striking finding of the survey, to which executives from 95 of the world's leading R&D companies responded, was the differing roles of a company's chief technology officer (CTO). In the Japanese companies that responded, 90% of the CTOs held a position on the board of directors or main managing board, whereas less than 25% of North America CTOs had similar influence. "In many [U.S.] companies, there is no such animal as a chief technology officer," says study director Edward Roberts, who is chairman of both MIT's Management of Technology and Innovation Group and Pugh-Roberts Associates, a division of PA Consulting. Even European companies fared better than their U.S. counterparts—more than half their CTOs were part of the managing elite. As a result, Japanese and European firms believe their technology strategy is much better linked to their overall corporate strategy. Roberts agrees, calling these results the "single biggest damnation" of U.S. industry found in the survey.

The survey also suggests that U.S. firms have not positioned themselves to take advantage of outside sources of technology such as suppliers, joint ventures, or university-sponsored research. Compared to North America, significantly more Japanese and European companies report they have a "high" reliance on these external sources. While Europe's dependence seems to derive, in large part, from recession-driven cutbacks in internal R&D, Japan's reliance is mostly deliberate. "It's a Japanese policy of working with their supplier," comments analyst Jeffrey Lindsay of Pugh-Roberts, explaining that firms in Japan commonly negotiate long-term contracts that allow their suppliers the security to pursue new technology themselves. In contrast, he says, until recently American companies held bidding wars between suppliers that left little margin for them to pursue R&D.

But elements in that picture are already changing, as the study participants acknowledged. American companies, for example, are now looking for ways to foster R&D among their suppliers; they expect to become increasingly reliant in future years on outside technology. And the struggling global economy is eroding European strength in R&D; indeed, Lindsay warns that European firms may have irrevocably damaged their future competitiveness with the cuts made over the past few years. Only companies in Japan appear to be intensifying their R&D efforts.

He cautions, however, that specific industries, such as pharmaceuticals, which are increasing, not slashing, their R&D budgets, do belie some of the general trends found in the survey. Such trends will be grist for the continuation of the study. Over the next few years Lindsay and his colleagues plan to increase the sample size, as well as focus more on individual industries. When finished, the survey should provide a much clearer picture of how companies manage technology—and whether what's happening at IBM may be a lesson for the rest of U.S. high-tech industry.

–John Travis

*Strategic Management of Technology: Global Benchmarking, 10 December 1992, MIT.