GLOBALIZATION of science is a hot topic. Yet, no single set of quantitative data gives a definitive fix on what is going on in science and where science is being done. There are data compilations—such as on R&D spending and investment, patent activity, and scientific manpower—that each give part of the evolving worldwide story.

Another such indicator is detailed year-by-year information on the number of articles published in peer-reviewed scientific and engineering journals. If analyzed with caution, such data can identify, if not always explain, broad trends in scientific activity.

The latest data on article publication from the National Science Foundation, Thomson Scientific (formerly the Institute for Scientific Information, or ISI), Chemical Abstracts Service (CAS), and the American Chemical Society’s journals operation all indicate above-average worldwide growth recently and especially rapid and substantial gains for China and selected other Asian and Western European nations. The NSF/ISI data are through 2003; the CAS and ACS data are through 2005.

The new data also confirm the relatively slower growth for papers from the U.S., which, nevertheless, remains the largest single national source of papers by a substantial margin.

From 2001 to 2003, the NSF count—which is derived from ISI data—of papers worldwide rose by 7.5%, or 3.5% per year. This growth is higher than the average 2.7% average annual growth for the previous 13 years. The 2003-to-2005 increase in the number of papers abstracted by CAS was 12.5%, or 6.1% per year, and well above the average of 3.5% per year for the 15 previous years. The 2003-to-2005 increase in papers published in ACS journals was 21.0%, or 10.0% per year, again, higher than the 1988-to-2003 average of 5.5%.

The U.S. accounted for only 14% of the 1988-to-2003 increase in the NSF/ISI count of papers published worldwide; 18% of the 1988-to-2005 increase in the papers abstracted by CAS, and 24% of the 1988-to-2005 gain in the number of papers published in ACS journals.

The U.S.’s share of all scientific papers published worldwide dropped, according to NSF/ISI, from 38% in 1988 to 30% in 2003. By the CAS count, the decline was from 27% in 1988 to 23% in 2005. The percentage of the papers published in ACS journals that are from U.S. sources fell the most, from 64% in 1988 to 39% in 2005.

For all these data sets, a paper is attributed to a nation by institutional affiliation of its author or authors at the time of publication, not by the nationality of the authors.

These major findings confirm and extend the three major trends in scientific publication described two years ago in C&EN: These trends are of solid growth almost worldwide, a huge surge in papers from rapidly developing nations, and erosion of the U.S.’s share (C&EN, June 14, 2004, page 38).

However, one possible inference from the two years of new data is that the prolonged decline in the U.S.’s share of papers and abstracts may be slowing. The percentage of CAS abstracts from U.S. sources held at just over 23% for 2003, 2004, and 2005. The U.S. share of the NSF count slipped slightly from 30.9% in 2001 to 30.2% in 2003. And the U.S. share of the papers published in ACS journals slipped from 40.2% in 2003 to 38.6% in 2005. This is a 1.6%
decline, but it is less than the 2.6% decline over the previous two years.

The NSF data in this report are from the 2006 edition of the foundation’s biennial Science and Engineering Indicators. They are derived from the papers published in the expanding number of peer-reviewed journals—4,458 in 1988 and 5,315 in 2003—tracked by Thomson Scientific’s Science Citation Index (SCI) and Social Science Citation Index (SSCI).

Journals are assigned to one of 134 fields, which are in turn grouped into chemistry and 11 other major fields. There are eight hard science fields and four social science fields; the latter group accounted for 13% of the 2003 total. Chemistry is defined along traditional lines as analytical, applied, general, inorganic, nuclear, organic, physical, and polymer chemistry.

CAS’s data on the number of abstracted papers are based on its monitoring of a somewhat larger number of journals, about 9,000 in 2005. The data on the papers in ACS journals come from a program that has expanded from 19 journals in 1988 to 33 in 2005 and so have a substantially higher growth rate than for chemistry itself.

According to the NSF/ISI data, the number of scientific papers published worldwide rose from 466,000 in 1988 to 699,000 in 2003. This is a gain of a little over 232,000, or 50%. Growth in non-U.S. papers was 199,000—from 289,000 to 488,000—or 69%.

Growth in the number of U.S. papers was a more modest 33,000, or 19%, from 178,000 in 1988 to 211,000 in 2003. From 1991 to 2002, there was no sustained growth. Annual totals held at between 194,000 and 203,000 and were at 196,000 for 2002. The 2003 total moved up to 211,000 for the biggest annual gain in many years.

NSF points out that there is no clear reason for the flattening of U.S. R&D publications in the 1990s and through 2002. The stagnation contrasts with continuing increases in both real R&D expenditure and the number of researchers.

The foundation is undertaking a special study to find the reasons, such as changes in publication practices, behind this prolonged lack of growth.

The CAS data indicate a similar pattern but with a somewhat muted difference between U.S. and non-U.S. performance. Between 1988 and 2005, the worldwide total of abstracted papers rose from 390,000 to 728,000, or by 87%. Non-U.S. papers increased from 283,000 to 559,000, or by 97%. U.S. papers were up by a smaller 58%, from 107,000 to 169,000.

The large 169% increase in the number of papers published in ACS journals—from 10,900 in 1988 to 29,300 in 2005—is partly due to the aggressive expansion of the ACS journals operation over the period. U.S. papers were up by 63%, from 6,900 to 11,300, and non-U.S. papers by 355%, from 3,900 to 18,000.

Of the 18,400 increase in the papers published between 1988 and 2005, 13,100 came in the 20 journals already established in 1988 and 5,300 were from the 13 journals established since 1988.

The 33,000 increase in the number of papers published by U.S. institutions between 1988 and 2003, according to the NSF/ISI data, falls well shy of the gains of 97,000 for Western Europe and 79,400 for Asian nations.

Western Europe has moved ahead of the U.S. In 2003, it had 241,000 articles, and the U.S. had 211,000. Compared with the 19% increase in U.S. papers, particularly large 1988-to-2003 gains were posted by Spain, 210%; Italy, 120%; the Netherlands, 57%; Germany, 51%; and France, 49%.

For Japan, the 1988-to-2003 increase in scientific articles was 74%, and for Australia, it was 60%.

The truly spectacular gain was posted by

<table>
<thead>
<tr>
<th>TRENDS IN CAS ABSTRACTS</th>
</tr>
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<tbody>
<tr>
<td><strong>Foreign sources have long been dominant</strong></td>
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<tr>
<td><strong>Thousands of Abstracts</strong></td>
</tr>
<tr>
<td>1988</td>
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<td>1989</td>
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<td>1990</td>
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<td>2003</td>
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<tr>
<td>2004</td>
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<tr>
<td>2005</td>
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</tbody>
</table>

**Source:** Chemical Abstracts Service

<table>
<thead>
<tr>
<th>PAPERS PUBLISHED IN ACS JOURNALS</th>
</tr>
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<tbody>
<tr>
<td><strong>U.S. share has dropped from 64% to 39%</strong></td>
</tr>
<tr>
<td><strong>Number of Papers</strong></td>
</tr>
<tr>
<td>1988</td>
</tr>
<tr>
<td>1989</td>
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<tr>
<td>1990</td>
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<td>2003</td>
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<tr>
<td>2004</td>
</tr>
<tr>
<td>2005</td>
</tr>
</tbody>
</table>

**Source:** ACS Journals Publishing Group

No single set of quantitative data gives a definitive fix on what is going on in science and where science is being done.
what NSF defines as the East Asia 4—China, Singapore, South Korea, and Taiwan—with a boost from a combined total of 7,200 papers in 1988 to 55,300 in 2003. This is a 667% gain in 15 years, or an average of 14.5% per year. Much of this gain has been in China (from 4,600 papers in 1988 to 29,200 in 2003) and South Korea (from 800 in 1988 to 13,700 in 2003). China's total in 2003 placed it sixth on the world ranking.

The only region with a decline in papers is Eastern Europe and the nations of the former Soviet Union, with a dip of from 41,500 papers in 1988 to 35,100 in 2003. The CAS data show a similar national

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**ACS JOURNAL ARTICLES**

Most growth has come in the long-established journals

<table>
<thead>
<tr>
<th>NUMBER OF PAPERS</th>
<th>1988</th>
<th>2005</th>
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</thead>
<tbody>
<tr>
<td><strong>OLDER JOURNALS</strong></td>
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<tr>
<td>Accounts of Chemical Research</td>
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<td>Chemical Research in Toxicology</td>
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<td>Chemical Reviews</td>
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<td>134</td>
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<tr>
<td>Energy &amp; Fuels</td>
<td>139</td>
<td>337</td>
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<tr>
<td>Environmental Science &amp; Technology</td>
<td>192</td>
<td>1,288</td>
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<tr>
<td>Industrial &amp; Engineering Chemistry Research</td>
<td>406</td>
<td>1,120</td>
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<tr>
<td>Inorganic Chemistry</td>
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<td>1,178</td>
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<tr>
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<td>1,528</td>
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<td>J of the American Chemical Society</td>
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<td>J of Chemical &amp; Engineering Data</td>
<td>165</td>
<td>388</td>
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<td>J of Chemical Information &amp; Modeling</td>
<td>34</td>
<td>215</td>
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<td>J of Medicinal Chemistry</td>
<td>385</td>
<td>876</td>
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<td>J of Organic Chemistry</td>
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<td>J of Physical Chemistry</td>
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<td>Macromolecules</td>
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<td>1,419</td>
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<td>Organometallics</td>
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<td>849</td>
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**JOURNALS NEW SINCE 1988**

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<th>1988</th>
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<tr>
<td>Biocatalysis</td>
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<td>Biotechnology Progress</td>
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<tr>
<td>Chemistry of Materials</td>
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<td>Crystal Growth &amp; Design</td>
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<tr>
<td>J of Chemical Theory &amp; Computation</td>
<td>133</td>
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<tr>
<td>J of Combinatorial Chemistry</td>
<td>132</td>
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<tr>
<td>J of Natural Products</td>
<td>385</td>
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<tr>
<td>J of Proteome Research</td>
<td>269</td>
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<td>Molecular Pharmaceutics</td>
<td>57</td>
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<tr>
<td>Nano Letters</td>
<td>492</td>
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<td>Organic Letters</td>
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</table>

**GRAND TOTAL**

|                     | 10,875 | 29,302 |

**SCIENTIFIC PAPERS BY SOURCE**

European Union contributed most to growth between 1988 and 2003

<table>
<thead>
<tr>
<th>THOUSANDS OF PAPERS</th>
<th>1988</th>
<th>% OF TOTAL</th>
<th>2003</th>
<th>% OF TOTAL</th>
<th>CHANGE</th>
<th>% CHANGE</th>
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</thead>
<tbody>
<tr>
<td>WORLD TOTAL</td>
<td>466.4</td>
<td>100.0%</td>
<td>698.7</td>
<td>100.0%</td>
<td>232.3</td>
<td>50.0%</td>
</tr>
<tr>
<td>U.S.</td>
<td>177.7</td>
<td>38.1%</td>
<td>211.2</td>
<td>30.2%</td>
<td>33.5</td>
<td>19.0%</td>
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<tr>
<td>Non-U.S.</td>
<td>288.7</td>
<td>61.9%</td>
<td>487.5</td>
<td>69.8%</td>
<td>198.8</td>
<td>69.0%</td>
</tr>
<tr>
<td>EUROPEAN UNION</td>
<td>134.6</td>
<td>28.9%</td>
<td>220.0</td>
<td>31.5%</td>
<td>85.4</td>
<td>64.0%</td>
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<tr>
<td>France</td>
<td>21.4</td>
<td>4.6%</td>
<td>32.0</td>
<td>4.6%</td>
<td>10.6</td>
<td>49.0%</td>
</tr>
<tr>
<td>Germany</td>
<td>29.3</td>
<td>6.3%</td>
<td>44.3</td>
<td>6.3%</td>
<td>15.0</td>
<td>51.0%</td>
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<tr>
<td>Italy</td>
<td>11.2</td>
<td>2.4%</td>
<td>24.7</td>
<td>3.5%</td>
<td>13.5</td>
<td>120.0%</td>
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<td>Netherlands</td>
<td>8.6</td>
<td>1.8%</td>
<td>13.5</td>
<td>1.9%</td>
<td>4.9</td>
<td>57.0%</td>
</tr>
<tr>
<td>Spain</td>
<td>5.4</td>
<td>1.2%</td>
<td>16.8</td>
<td>2.4%</td>
<td>11.4</td>
<td>210.0%</td>
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<td>Sweden</td>
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<td>1.6%</td>
<td>10.2</td>
<td>1.5%</td>
<td>2.6</td>
<td>34.0%</td>
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<tr>
<td>U.K.</td>
<td>36.5</td>
<td>7.8%</td>
<td>48.3</td>
<td>6.9%</td>
<td>11.8</td>
<td>32.0%</td>
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<tr>
<td>OTHER WESTERN EUROPE</td>
<td>9.3</td>
<td>2.0%</td>
<td>20.9</td>
<td>3.0%</td>
<td>11.6</td>
<td>125.0%</td>
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<td>Switzerland</td>
<td>5.3</td>
<td>1.1%</td>
<td>8.5</td>
<td>1.2%</td>
<td>3.2</td>
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<td>Turkey</td>
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<td>0.1%</td>
<td>6.2</td>
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<td>5.7</td>
<td>1,270%</td>
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<tr>
<td>EASTERN EUROPE/ FORMER U.S.S.R. BLOC</td>
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<td></td>
</tr>
<tr>
<td>Poland</td>
<td>4.0</td>
<td>0.9%</td>
<td>6.8</td>
<td>1.0%</td>
<td>2.8</td>
<td>68.0%</td>
</tr>
<tr>
<td>U.S.S.R./Russia</td>
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<td>6.8%</td>
<td>15.8</td>
<td>2.3%</td>
<td>nm</td>
<td>nm</td>
</tr>
<tr>
<td>EAST ASIA 4</td>
<td>7.2</td>
<td>1.5%</td>
<td>55.3</td>
<td>7.9%</td>
<td>48.1</td>
<td>667.0%</td>
</tr>
<tr>
<td>China</td>
<td>4.6</td>
<td>1.0%</td>
<td>29.2</td>
<td>4.2%</td>
<td>24.6</td>
<td>532.0%</td>
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<tr>
<td>Singapore</td>
<td>0.4</td>
<td>0.1%</td>
<td>3.1</td>
<td>0.4%</td>
<td>2.7</td>
<td>661.0%</td>
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<td>South Korea</td>
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<td>0.2%</td>
<td>13.7</td>
<td>2.0%</td>
<td>13.0</td>
<td>1,682.0%</td>
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<td>0.3%</td>
<td>9.3</td>
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<td>7.9</td>
<td>556.0%</td>
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<td>JAPAN</td>
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<td>7.4%</td>
<td>60.1</td>
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<td>74.0%</td>
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<td>OTHER ASIA</td>
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<td>2.2%</td>
<td>15.8</td>
<td>2.3%</td>
<td>5.7</td>
<td>56.0%</td>
</tr>
<tr>
<td>India</td>
<td>8.9</td>
<td>1.9%</td>
<td>12.8</td>
<td>1.8%</td>
<td>3.9</td>
<td>44.0%</td>
</tr>
<tr>
<td>MIDDLE EAST/ NORTH AFRICA</td>
<td>79</td>
<td>1.7%</td>
<td>13.5</td>
<td>1.9%</td>
<td>5.6</td>
<td>71.0%</td>
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<tr>
<td>SUB-SAHARAN AFRICA</td>
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<td>-7.0%</td>
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<td>0.5%</td>
<td>2.4</td>
<td>0.3%</td>
<td>-0.2</td>
<td>-4.0%</td>
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<tr>
<td>CENTRAL/SOUTH AMERICA</td>
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<td>1.2%</td>
<td>18.9</td>
<td>2.7%</td>
<td>13.1</td>
<td>233.0%</td>
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<td>Argentina</td>
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<td>0.3%</td>
<td>3.1</td>
<td>0.4%</td>
<td>1.7</td>
<td>116.0%</td>
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<td>Brazil</td>
<td>1.8</td>
<td>0.4%</td>
<td>8.7</td>
<td>1.2%</td>
<td>6.9</td>
<td>392.0%</td>
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<td>9.9</td>
<td>2.1%</td>
<td>15.8</td>
<td>2.3%</td>
<td>5.9</td>
<td>60.0%</td>
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<tr>
<td>CANADA</td>
<td>21.4</td>
<td>4.6%</td>
<td>24.8</td>
<td>3.1%</td>
<td>3.4</td>
<td>16.0%</td>
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</table>

**Notes:** Data for 2005 for the Journal of Physical Chemistry includes both A and B editions. The Journal of Chemical Information & Modeling was formerly the Journal of Chemical Information & Computer Sciences. Biotechnology Progress is copublished with the American Institute of Chemical Engineers. **Source:** ACS Journals Publishing Group

**nm = not meaningful. Source:** National Science Foundation, Science and Engineering Indicators 2006
profile of growth rates. Increases in the number of abstracted papers between 1988 and 2005 were 668% for South Korea, 647% for China, 179% for Spain, 71% for Germany, 65% for the Netherlands, 58% for the U.S., and 46% for France. China’s 102,000 abstracts in 2005 placed it second on the world list behind the U.S. at 169,000.

The data for ACS’s journals program indicate a 1983-2005 increase in papers published of 228%, from 8,900 to 29,300, with U.S. papers up by 88%, from 6,000 to 11,300, and non-U.S. papers up by 517%, from 2,900 to 18,000.

Data on Asian nations are scanty for 1983, when they produced relatively few papers. But the 1,776 papers from China published in 2005 were enough to place China third, behind Japan at 2,510, and the U.S. at 11,318.

An analysis by NSF gives a guide to the scientific productivity of nations. Based on the most recent data available (from within the 2000-2003 range) for each country, it is expressed as the number of science and engineering articles published per year per million inhabitants.

Of 157 nations ranked, the U.S. ranks 12th at 707 papers per million. The top six are smaller nations, with Sweden at 1,137; Switzerland, 1,120; Israel, 1,018; Finland, 974; Denmark, 933; and the Netherlands at 800. The U.K., at 796, ranks the highest among larger nations at seventh. The worldwide average is 108 papers per million.

The NSF/ISI data indicate that 11.9% of the scientific papers published worldwide in 2003 were in chemistry. This is little changed from 12.1% in 1996. The biggest field in 2003 was clinical medicine, with 27.9% of the papers; followed by physics, with 13.9%; biomedical research, with 13.7%; and then chemistry.

Chemistry’s share of scientific papers varies widely by nation. In 2003, chemistry claimed 26.6% of the papers from India, 25.5% of those from Eastern Europe and the nations of the former Soviet Union, and 20.2% of papers from the East Asia 4. The U.S. was at the other end of this spectrum, with 7.5% of its papers in chemistry. Canada came in at 7.3% and Australia at 8.0%.

PAPERS ABSTRACTED BY CAS, BY SOURCE
Since 1988, China’s share has quadrupled

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NOTES: East Asia 4 consists of China, Singapore, South Korea, and Taiwan. — = data not available. SOURCE: Chemical Abstracts Service

NSF’S TOP 10 PRODUCERS
France replaced the Soviet Union in the top five

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SOURCE: National Science Foundation, Science and Engineering Indicators 2006

TOP 10 SOURCES OF CAS ABSTRACTS
China moves to second, behind U.S.; Japan is third

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SOURCE: Chemical Abstracts Service
## ACS Journal Papers by Source

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## Scientific Papers by Field, 1988 to 2003

By NSF’s count, U.S. share declined in all fields except mathematics.

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<td>% U.S.</td>
<td>23%</td>
<td>19%</td>
<td></td>
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</tr>
<tr>
<td><strong>CLINICAL MEDICINE</strong></td>
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<tr>
<td>World</td>
<td>136.7</td>
<td>194.9</td>
<td>58.2</td>
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<tr>
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<td>65.9</td>
<td>10.9</td>
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</tr>
<tr>
<td>Non-U.S.</td>
<td>81.7</td>
<td>129</td>
<td>47.3</td>
<td>58</td>
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<td>41%</td>
<td>34%</td>
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<tr>
<td><strong>EARTH/SPACE SCIENCES</strong></td>
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<td>19.3</td>
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<td>U.S.</td>
<td>8.1</td>
<td>12.5</td>
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<tr>
<td>Non-U.S.</td>
<td>11.0</td>
<td>25.9</td>
<td>14.9</td>
<td>135</td>
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<tr>
<td>% U.S.</td>
<td>42%</td>
<td>33%</td>
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</tr>
<tr>
<td><strong>ENGINEERING/TECHNOLOGY</strong></td>
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<tr>
<td>World</td>
<td>31.3</td>
<td>62.9</td>
<td>31.6</td>
<td>101</td>
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<tr>
<td>U.S.</td>
<td>11.8</td>
<td>14.8</td>
<td>3.0</td>
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<tr>
<td>Non-U.S.</td>
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<td>48.1</td>
<td>28.6</td>
<td>145</td>
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<tr>
<td>% U.S.</td>
<td>42%</td>
<td>24%</td>
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<tr>
<td><strong>MATHEMATICS</strong></td>
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<td></td>
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<tr>
<td>World</td>
<td>9.8</td>
<td>15.4</td>
<td>5.6</td>
<td>57</td>
</tr>
<tr>
<td>U.S.</td>
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<td>7.8</td>
<td>3.9</td>
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<td>Non-U.S.</td>
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<tr>
<td>% U.S.</td>
<td>40%</td>
<td>51%</td>
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<tr>
<td><strong>PHYSICS</strong></td>
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<tr>
<td>World</td>
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<td>97.2</td>
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<td>57</td>
</tr>
<tr>
<td>U.S.</td>
<td>18.0</td>
<td>18.6</td>
<td>0.6</td>
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<tr>
<td>Non-U.S.</td>
<td>44.0</td>
<td>78.6</td>
<td>34.6</td>
<td>79</td>
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<td>% U.S.</td>
<td>29%</td>
<td>19%</td>
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<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
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<td></td>
</tr>
<tr>
<td>World</td>
<td>422.2</td>
<td>637.2</td>
<td>215.0</td>
<td>51</td>
</tr>
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<td>U.S.</td>
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<td>453.5</td>
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</tr>
<tr>
<td>% U.S.</td>
<td>36%</td>
<td>28%</td>
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<td></td>
</tr>
</tbody>
</table>

% **Change** = (2003-1988)/1988

**How to Read the Table:** In 1988, 35,000 biology articles were published worldwide. Of these, 12,900, or 37%, were from U.S. institutions. **Source:** National Science Foundation, Science and Engineering Indicators 2006

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## Citations in High-Impact Journals

U.S. dominance is still strong but declining.

### How to Read the Table:
- In 1988, 35,000 biology articles were published worldwide. Of these, 12,900, or 37%, were from U.S. institutions. **Source:** National Science Foundation, Science and Engineering Indicators 2006

### Between 1988 and 2003, the number of U.S. chemical papers rose by 2,600, from 13,200 to 15,800, while the number of non-U.S. chemistry papers grew by 23,100, from 44,200 to 67,300. This means that the U.S. contributed only 11% of the overall 15-year gain.

From 1988 to 2003, the U.S.’s share of papers fell in seven of the eight hard sciences. The exception was mathematics.

The bare-bone statistics on the number of articles published or abstracted do not address the issue of the caliber of the...
papers. However, an NSF/ISI analysis indicates that the U.S. holds a strong, if gradually declining, advantage.

The analysis is based on a ranking of the journals covered by the two citation indexes (SCI and SSCI) according to the average number of citations to the articles published in them.

In 2003, 59.3% of the papers in the top 1% of journals ranked this way were from the U.S. Second were the 15 nations that made up the European Union in 1999 (referred to as EU-15) with a total of 25.7%. Japan had 4.6%, and East Asia 4 had 0.8%. In 1992, these shares had been 68.5%, 19.9%, 3.6%, and 0.1%, respectively.

The pattern is similar for the top 10% of journals. The U.S.’s share dropped from 55.9% in 1992 to 43.7% in 2003, while the EU-15’s rose from 25.4% to 32.6%. Japan also advanced, from 6.0% to 7.7%, as did East Asia 4, from 0.7% to 2.8%.

Some journal editors have expressed concern about the uneven quality of the rising tide of articles submitted to their publications from China and other Asian sources (C&EN, Sept. 18, page 35). The fact remains, however, that the rapidly growing number of articles from Asia and other nontraditional sources that are counted, abstracted, or published by ISI, CAS, or the ACS journals meet the criteria established by these entities.