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Opinion

Citation Geography: It's About Location

By Michael Batty

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...tribution of Highly Cited Scientists

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Editor's Note:
A more detailed commentary based on this work is published as "The geography of scientific citation," *Environ Plan A*, 35:761-5, 2003.
Further details of this analysis are given on the author's Web site www.casa.ucl.ac.uk/citations.

PDF:
Top 10 Highly Cited Scientists by Country, (116K)

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Top 10 Highly Cited Scientists by Place, (116K)

PDF:
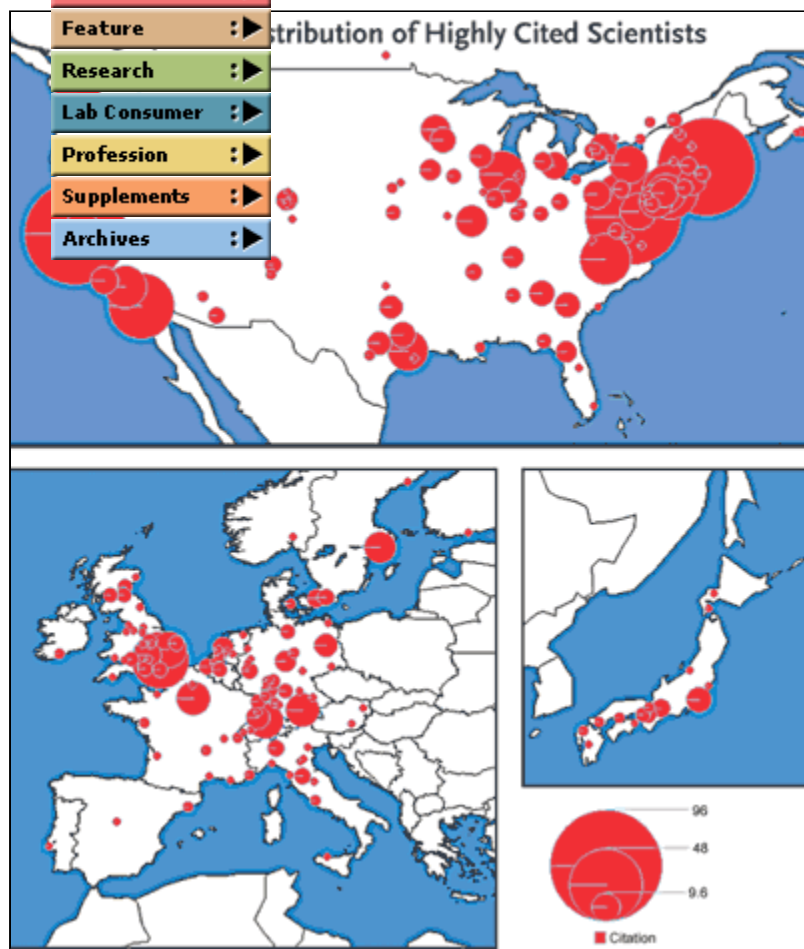Top 10 Highly Cited Scientists by Institution, (62K)

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It is well known that the distribution of citation counts is highly skewed, with a few scientists receiving many citations but with most receiving very few. What is less well known is that when these counts are aggregated by institution, and then by place, these distributions become even more extreme, with most citations being associated with individuals in a small number of institutions in an even smaller number of places and countries.

To demonstrate this geographical concentration, a source is needed for data that can be aggregated. The Institute for

Scientific Information's HighlyCited database (www.isihighlycited.com) is such a source[1]; in December 2002 the database comprised the top 100 or so cited individuals in 21 scientific fields. Here, I use it to illustrate the geography of scientific citation.

I must qualify the analysis: The source has many limitations, as the data used exclude mathematics, the social sciences, and the humanities, and are thus biased towards the medical sciences. Moreover, the database is under rapid development, having almost doubled its size (as of June 2003) since the date of the analysis (December 2002).

The analysis reveals a remarkable concentration pattern: 1,222 scientists work in 429 institutions, which are located in 232 places in 27 countries. Almost half these researchers are in 50 institutions in five countries, with most in the United States. The top 20 institutions are listed in terms of the number and percentage of scientists cited; these 20 institutions employ nearly 30% of them. The concentration increases as the data are aggregated from institution, to place, and then to country. The top 10 locations in terms of the number of scientists and the areas where they work are also shown. In increases, I have computed the relative entropy, $R = 1 - (H / H_{max})$, where H is the Shannon entropy defined in the usual way as $H = -\Sigma j\ pj\ \ln\ pj$, where pj is the proportion of citations in an institution, place, or country. This statistic varies from 0 to 1, where 0 represents a completely dispersed (even) pattern of citations, and 1 represents all citations as being concentrated in one institution, place, or country. For institutions, R is 0.23, increasing to 0.36 for places, and then to a massive 0.79 for countries.

A graphic indication of this basic pattern is illustrated in the figure above, where I have mapped the main locations of places by circles proportional to the number of cited scientists. These locations bear out perceptions of where the world's top institutions are most heavily concentrated: four US cities on the West coast; the Washington-to-Boston area; Chicago; the cluster of towns around Research Triangle Park, NC; and in Europe, central London.

I have not yet examined the local detail of where these institutions are located, but casual knowledge suggests that these are even more highly clustered at ever-finer scales. For example, the institutions in Boston are all within a two-mile radius of the MIT

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Top 10 Highly Cited Scientists by Country (116K)

Top 10 Highly Cited Scientists by Place (116K)

Top 10 Highly Cited Scientists by Institution

(Massachusetts Institute of Technology) (62K)
Museum, and in London, they are within a three-mile radius of the British Museum. On an even more local scale in central London, for example, the majority of the cited scientists can be found within a half-mile of Euston station in Bloomsbury.

Although analysis is limited by the bias in the ISI data to English-language publications, to the medical sciences, and to full-time research rather than education, I consider that these findings have important implications for national educational policies, for the choice of the best graduate schools, and so on. I do not yet know how robust these indicators of geographical concentration actually are, though I suspect they will not change very much on an annual basis. I suspect that from year to year, however, there may be considerable volatility in the actual names of those who form the HighlyCited database, but once the data are aggregated across institutions, places, and countries, such volatility will begin to disappear.

What I am most interested in, however, is how different places and countries are changing over decades rather than years. This will give me some idea of how global research quality is changing, which is of central importance to science policy everywhere.

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1. ISI granted permission for this analysis to be published.

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Top 10 Highly Cited Scientists by Country

Rank	Country	No. of Highly Cited	Percent Highly Cited	No. of Places	Concentration: Scientists/ Places	Highly Cited per Million Population
1	US	815	66.7	90	9.06	3.16
2	UK	100	8.2	24	4.17	1.72
3	Germany	62	5.1	21	2.95	0.78
4	Canada	42	3.4	15	2.80	1.53
5	Japan	34	2.7	14	2.43	0.27
6	France	29	2.3	11	2.64	0.50
7	Switzerland	26	2.1	5	5.20	3.78
8	Sweden	17	1.4	2	8.50	1.96
9	Italy	17	1.4	10	1.70	0.29
10	Australia	17	1.4	9	1.88	0.96

Top 10 Highly Cited Scientists by Place

Rank	Place	No. of Highly Cited Scientists	Percent Highly Cited Scientists
1	San Francisco Bay Area	96	7.8
2	Boston	89	7.2
3	Washington, DC	85	6.9
4	San Diego	44	3.6
5	London	36	2.9
6	New York	33	2.7
7	Research Triangle Park, NC	28	2.3
8	Chicago	25	2.0
9	Seattle	23	1.9
10	Los Angeles	20	1.6

Top 20 Highly Cited Scientists by Institution

Rank	Research Institution	No. of Highly Cited Scientists	Percent Highly Cited Scientists
1	Harvard	52	4.3
2	Stanford	36	2.9
3	UC, San Diego	30	2.5
4	MIT	26	2.1
5	National Cancer Institute	19	1.6
6	UC, San Francisco	17	1.4
	Cornell		
8	UC, Berkeley		
	University College London	16	1.3
10	CalTech	15	1.2
11	National Institute	13	1.1
	of Allergy and		
	Infectious Diseases		
12	Johns Hopkins	12	1.0
	University of Cambridge, UK		
	Univ. of Washington, Seattle		
	Washington Univ., St. Louis		
16	UC, Davis	11	0.9
	MD Anderson Cancer		
	Center, Houston		
18	University of Michigan,	10	0.8
	Ann Arbor		
	Northwestern		
	Yale		