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Current Comments®

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The Role of Undergraduate Colleges in Research. Part 2. Highest Impact Institutions and Most-Cited Papers, 1981-1992

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Abstract

A citation analysis of research publications of 74 primarily liberal arts colleges, based on 14,510 ISI®-indexed papers published and cited from 1981 through 1992, is presented. The highest output, most-cited, and highest impact colleges in all fields of science were identified in part 1. Separate impact rankings in the life sciences, agriculture and biology, and clinical medicine were also included. In this concluding part, the highest impact colleges in the physical and chemical sciences as well as engineering and technology are identified. In addition, the most-cited papers from the liberal arts colleges are presented.

Introduction

Previous studies have documented the important contributions made by liberal arts colleges to the nation's science base. These studies have focused on the critical role of US colleges as a major "pipeline" of the nation's future science graduate and doctoral students. The so-called Oberlin reports of the 1980s[1,2] and, more recently, the 1991 Project Kaleidoscope analysis[3] have demonstrated that select liberal arts colleges produce a disproportionate share of science graduates compared with larger universities with more extensive science curricula and far greater research funds.

In addition to serving as a vital training ground for the nation's future researchers, liberal arts colleges also have significant impact as research institutions. This aspect has not been widely appreciated but we had the opportunity to draw attention to it at a recent meeting cosponsored by the Council on Undergraduate Research (CUR) and the National Institutes of Health.[4]

Based on this analysis, part 1 of this essay presented publication and citation data on 74 primarily liberal arts colleges for the period 1981-1992.[5] They are shown in Table 1. The list includes 50 so-called "science active" colleges examined in the Oberlin analyses, indicated by asterisks. Also included are 24 institutions selected on the basis of their CUR membership—that is, each had at least five individual members, whether faculty or administrators.

The data showed that liberal arts colleges do indeed make a substantial contribution to research. Over a third of these colleges exceeded the world average impact for all fields of science, and several even doubled it. In addition, the average CUR paper was cited more frequently than the world average in agriculture and biological sciences as well as clinical medicine.

However, the CUR average impact in the life sciences (7.2) was less than the world average (8.2). Keep in mind that this field includes molecular biology, genetics, and many other specialties involving sophisticated laboratories and equipment. Thus, many of the smaller liberal arts colleges may be underrepresented in these high impact specialties because they lack the requisite facilities. Nevertheless, seven colleges exceeded the world average in the life sciences—Wellesley (16.0), Pomona (12.3), Amherst (11.2), Barnard (11.1), Mount Holyoke (9.6), Oberlin (9.1), and Williams (8.9).

In this essay, the highest impact colleges in the physical and chemical sciences as

Table 1: Primarily undergraduate liberal arts colleges included in the study. Asterisks indicate those included in the original Oberlin Group reports (see references 1 and 2).

*Albion Coll.	Albion, MI
Allegheny Coll.	Meadville, PA
*Alma Coll.	Alma, MI
*Amherst Coll.	Amherst, MA
*Antioch Coll.	Yellow Springs, OH
Augustana Coll.	Rock Island, IL
*Barnard Coll.	New York, NY
*Bates Coll.	Lewiston, ME
*Beloit Coll.	Beloit, WI
Birmingham Southern Coll.	Birmingham, AL
*Bowdoin Coll.	Brunswick, ME
*Bryn Mawr Coll.	Bryn Mawr, PA
*Bucknell Univ.	Lewisburg, PA
Calvin Coll.	Grand Rapids, MI
*Carleton Coll.	Northfield, MN
Colby Coll.	Waterville, ME
*Colgate Univ.	Hamilton, NY
Coll. Charleston	Charleston, SC
*Coll. Holy Cross	Worcester, MA
Coll. William & Mary	Williamsburg, VA
*Coll. Wooster	Wooster, OH
*Colorado Coll.	Colorado Springs, CO
Connecticut Coll.	New London, CT
*Davidson Coll.	Davidson, NC
*Denison Univ.	Granville, OH
*DePauw Univ.	Greencastle, IN
Dickinson Coll.	Carlisle, PA
*Earlham Coll.	Richmond, IN
Fort Lewis Coll.	Durango, CO
*Franklin & Marshall Coll.	Lancaster, PA
*Grinnell Coll.	Grinnell, IA
*Hamilton Coll.	Clinton, NY
*Hampton Univ.	Hampton, VA
*Harvey Mudd Coll.	Claremont, CA
*Haverford Coll.	Haverford, PA
Hendrix Coll.	Conway, AR
Hobart & Wm. Smith Coll.	Geneva, NY
*Hope Coll.	Holland, MI
Ithaca Coll.	Ithaca, NY
Juniata Coll.	Huntingdon, PA
*Kalamazoo Coll.	Kalamazoo, MI
*Kenyon Coll.	Gambier, OH
Knox Coll.	Galesburg, IL
*Lafayette Coll.	Easton, PA
Lewis & Clark Coll.	Portland, OR
Luther Coll.	Decorah, IA
Lycoming Coll.	Williamsport, PA
*Macalester Coll.	St. Paul, MN
*Manhattan Coll.	Bronx, NY
Mary Washington Coll.	Fredericksburg, VA
*Middlebury Coll.	Middlebury, VT
Montclair State Coll.	Upper Montclair, NJ
*Mt. Holyoke Coll.	South Hadley, MA
*Oberlin Coll.	Oberlin, OH
*Occidental Coll.	Los Angeles, CA
*Ohio Wesleyan Univ.	Delaware, OH
*Pomona Coll.	Claremont, CA
*Reed Coll.	Portland, OR
Rhodes Coll.	Memphis, TN
Skidmore Coll.	Saratoga Springs, NY
*Smith Coll.	Northampton, MA
*St. Olaf Coll.	Northfield, MN
*Swarthmore Coll.	Swarthmore, PA
*Trinity Coll.	Hartford, CT
*Union Coll.	Schenectady, NY
Ursinus Coll.	Collegeville, PA
*Vassar Coll.	Poughkeepsie, NY
*Wabash Coll.	Crawfordsville, IN
*Wellesley Coll.	Wellesley, MA
*Wesleyan Univ.	Middletown, CT
Westmont Coll.	Santa Barbara, CA
*Wheaton Coll.	Wheaton, IL
*Whitman Coll.	Walla Walla, WA
*Williams Coll.	Williamstown, MA

Table 2: Highest impact liberal arts colleges in the chemical and physical sciences, 1981-1992 *SCI*®, which published at least 50 papers.

Rank	Institution	12-Yr. Impact	1981-92 Papers	1981-92 Citations
1.	Ithaca Coll.	14.8	160	2367
2.	Haverford Coll.	13.7	137	1881
3.	Ohio Wesleyan	12.4	69	854
4.	Coll. Wm. & Mary	10.1	816	8263
5.	Hope Coll.	9.9	118	1166
6.	Barnard Coll.	9.2	72	665
7.	Smith Coll.	8.5	182	1550
8.	Colorado Coll.	8.2	103	846
	Wesleyan Univ.	8.2	531	4329
10.	Wellesley Coll.	7.6	171	1299
11.	Coll. Holy Cross	7.5	107	801
	Pomona Coll.	7.5	101	758
13.	Vassar Coll.	7.4	101	744
14.	Bryn Mawr Coll.	7.3	237	1731
	Middlebury Coll.	7.3	110	807
16.	Mt. Holyoke Coll.	7.2	106	766
	CUR AVG.	*6.6*	*6771*	*44,956*
17.	Lafayette Coll.	6.3	176	1111
	Occidental Coll.	6.3	67	424
19.	Franklin & Marshall	6.2	188	1165
20.	Carleton Coll.	5.9	96	564
21.	Trinity Coll.	5.7	123	695
	WORLD AVG.	*5.7*	*2,002,393*	*11,470,263*
22.	Grinnell Coll.	5.5	72	394
23.	Amherst Coll.	5.3	219	1152
	Bowdoin Coll.	5.3	97	510
25.	Colgate Univ.	5.2	196	1009

well as engineering and technology are identified. Their most-cited papers from 1981 through 1992 are also presented. These high impact papers typically are collaborative efforts involving large research universities. A separate list of most-cited papers *solely* from the liberal arts colleges is also presented to highlight their unique contribution to research. As will be seen, many of these are review papers.

Highest Impact Colleges: Physical and Chemical Sciences

Table 2 identifies 25 institutions with a 12-year impact of at least 5.0 in physics and chemistry. The list includes only those colleges that produced at least 50 papers in this field. This arbitrary threshold is intended to exclude the occasional "outlier" institution that may achieve high impact on the basis of just a few highly cited papers. Also shown in italics are the average impact of all CUR colleges combined as well as the "world" average—that is, the average impact for the entire *Science Citation Index*® (*SCI*®) file.

The CUR average impact (6.6) is higher than the world average (5.7). And 21 institutions exceeded the world average in physics and chemistry, more than in any other field included in this analysis. Thus, one might reasonably conclude that the primarily liberal arts colleges are strongest in physics and chemistry research. Indeed, a large proportion of their most-cited papers concerns research in this field, as will be seen. But a more detailed analysis involving a greater number of colleges would be required to determine whether this apparent strength in physics and chemistry is genuine.

Three institutions have impact factors that doubled the world average—Ithaca College (14.8), Haverford (13.7), and Ohio Wesleyan University (12.4).

Table 3: Highest impact liberal arts colleges in engineering and technology, 1981-1992 *SCI*®, which published at least 20 papers.

Rank	Institution	12-Yr. Impact	1981-92 Papers	1981-92 Citations
1.	Smith Coll.	6.2	26	160
2.	Calvin Coll.	5.5	24	133
3.	Bryn Mawr Coll.	4.8	47	227
4.	Manhattan Coll.	4.6	101	460
5.	Coll. Wm. & Mary	4.2	163	683
6.	Trinity Coll.	3.6	34	122
7.	Hamilton Coll.	3.5	20	70
	CUR AVG.	*3.0*	*1208*	*3678*
8.	Colgate Univ.	2.7	26	69
	Swarthmore Coll.	2.7	27	72
10.	Bowdoin Coll.	2.6	20	52
11.	Wesleyan Univ.	2.2	47	105
	WORLD AVG.	*2.1*	*1,161,644*	*2,394,037*
12.	Bucknell Univ.	1.8	74	134
13.	Oberlin Coll.	1.6	29	46
14.	Williams Coll.	1.5	23	34
15.	Harvey Mudd Coll.	1.2	76	90

Impact Rankings in Engineering and Technology

Table 3 shows 15 institutions with an impact of at least 1.2 in engineering and technology. It includes only those institu-

Table 4: Most-cited papers of the 74 CUR liberal arts colleges, 1981-1992 *SCI®*, including other collaborating institutions.

Cites	
762	**Auron P E, Webb A C, Rosenwasser L J, Mucci S F, Rich A, Wolff S M & Dinarello C A.** Nucleotide sequence of human monocyte interleukin-1 precursor cDNA. *Proc. Nat. Acad. Sci. USA* 81:7907-11, 1984. MIT, Cambridge, MA; Harvard Univ., Cambridge, MA; Tufts Univ. Sch. Med., Boston, MA; Wellesley Coll., MA
412	**Yancey P H, Clark M E, Hand S C, Bowlus R D & Somero G N.** Living with water stress—evolution of osmolyte systems. *Science* 217:1214-22, 1982. Whitman Coll., Walla Walla, WA; California State Univ., San Diego; Univ. SW Louisiana, Lafayette, LA; UCSD, La Jolla, CA; Harvard Sch., Los Angeles, CA; and Scripps Institution of Oceanography, La Jolla, CA
278	**Wimmer E, Krakauer H, Weinert M & Freeman A J.** Full potential self-consistent linearized augmented plane wave method for calculating the electronic structure of molecules and surfaces—O_2 molecule. *Phys. Rev. B* 24:864-75, 1981. Northwestern Univ., Evanston, IL; Argonne Natl. Lab., IL; Coll. William & Mary, Williamsburg, VA
268	**Dinarello C A, Cannon J G, Mier J W, Bernheim H A, Lopreste G, Lynn D L, Love R N, Webb A C, Auron P E, Reuben R C, Rich A, Wolff S M & Putney S D.** Multiple biological activities of human recombinant interleukin-1. *J. Clin. Invest.* 77:1734-9, 1986. Tufts Univ. Sch. Med., Boston, MA; New England Med. Ctr., Boston, MA; Repligen Corp., Cambridge, MA; Wellesley Coll., MA; MIT, Cambridge, MA; Cistron Technol. Inc., Pine Brook, NJ
212	**Sancho J M, Miguel M S, Katz S L & Gunton J D.** Analytical and numerical studies of multiplicative noise. *Phys. Rev. A* 26:1589-609, 1982. Univ. Barcelona, Spain; Lafayette Coll., Easton, PA; Temple Univ., Philadelphia, PA
205	**Mangin M, Webb A C, Dreyer B E, Posillico J T, Ikeda K, Weir E C, Stewart A F, Bander N H, Milstone L, Barton D E, Francke U & Broadus A E.** Identification of a cDNA encoding a parathyroid hormone-like peptide from a human tumor associated with humoral hypercalcemia of malignancy. *Proc. Nat. Acad. Sci. USA* 85:597-601, 1988. Yale Univ. Sch. Med., New Haven, CT; Wellesley Coll., MA; Brigham & Women's Hosp., Boston, MA; Vet. Admin. Ctr., New Haven, CT; Mem. Sloan Kettering Cancer Ctr., New York, NY
197	**Tanabe T, Beam K G, Powell J A & Numa S.** Restoration of excitation-contraction coupling and slow calcium current in dysgenic muscle by dihydropyridine receptor complementary DNA. *Nature* 336:134-9, 1988. Kyoto Univ., Fac. Med., Japan; Colorado State Univ., Ft. Collins; Smith Coll., Northampton, MA
186	**Adkins G S & Nappi C R.** Stabilization of chiral solitons via vector mesons. *Phys. Lett. B* 137:251-6, 1984. Franklin & Marshall Coll., Lancaster, PA; Princeton Univ., NJ
169	**Brewer J H, Ansaldo E J, Carolan J F, Chaklader A C D, Hardy W N, Harshman D R,** *et al.* Antiferromagnetism and superconductivity in oxygen-deficient $YBa_2Cu_3O_x$. *Phys. Rev. Lett.* 60:1073-6, 1988. Univ. British Columbia, Vancouver, Canada; TRIUMF, Vancouver, Canada; AT&T Bell Labs., Murray Hill, NJ; Tokyo Inst. Technol., Japan; Univ. Tokyo, Japan; Brookhaven Natl. Lab., Upton, NY; Coll. William & Mary, Williamsburg, VA; Univ. Saskatchewan, Saskatoon, Canada; Hebrew Univ., Jerusalem, Israel; Virginia State Univ., Petersburg, VA
164	**Krakauer H & Pickett W E.** Effect of bismuth on high T_c cuprate superconductors—electronic structure of $Bi_2Sr_2CaCu_2O_8$. *Phys. Rev. Lett.* 60:1665-7, 1988. Coll. William & Mary, Williamsburg, VA; US Navy, Washington, DC
164	**Uemura Y J, Kossler W J, Yu X H, Kempton J R, Schone H E, Opie D, Stronach C E, Johnston D C, Alvarez M S & Goshorn D P.** Antiferromagnetism of La_2CuO_{4-y} studied by muon spin rotation. *Phys. Rev. Lett.* 59:1045-8, 1987. Brookhaven Natl. Lab, Upton, NY; Coll. William & Mary, Williamsburg, VA; Virginia State Coll., Petersburg, VA; Exxon Res. & Engineer. Co., Annandale, NJ
163	**Johnson M K & Raye C L.** Reality monitoring. *Psychol. Rev.* 88:67-85, 1981. SUNY, Stony Brook, NY; Barnard Coll., New York, NY
160	**Uemura Y J, Takagi H, Uchida S, Sternlieb B J, Subramanian M A, Stronach C E,** *et al.* Universal correlations between T_c and NS/M star (carrier density over effective mass) in high T_c cuprate superconductors. *Phys. Rev. Lett.* 62:2317-20, 1989. Columbia Univ., New York, NY; Univ. British Columbia, Vancouver, Canada; Univ. Tokyo, Japan; DuPont Co., Wilmington, DE; Johns Hopkins Univ., Baltimore, MD; IBM Corp., San Jose, CA; Univ. Toronto, Ontario, Canada; Virginia State Univ., Petersburg, VA; Coll. William & Mary, Williamsburg, VA

Table 4 *(continued)*

147	**Bolton P H.** Assignments and structural information via relayed coherence transfer spectroscopy. *J. Magn. Resonance* 48:336-40, 1982. Wesleyan Univ., Middletown, CT
147	**Finan T M, Hirsch A M, Leigh J A, Johansen E, Kuldau G A, Deegan S, Walker G C & Signer E R.** Symbiotic mutants of *Rhizobium meliloti* that uncouple plant from bacterial differentiation. *Cell* 40:869-77, 1985. MIT, Cambridge, MA; Wellesley Coll., MA
143	**Carlson C E & Havens T J.** Quark distributions in nuclei. *Phys. Rev. Lett.* 51:261-3, 1983. SUNY Stony Brook, NY; Coll. William & Mary, Williamsburg, VA
143	**Delos J B.** Theory of electronic transitions in slow atomic collisions. *Rev. Mod. Phys.* 53:287-357, 1981. Coll. William & Mary, Williamsburg, VA
143	**Sawada Y, Dougherty A & Gollub J P.** Dendritic and fractal patterns in electrolytic metal deposits. *Phys. Rev. Lett.* 56:1260-3, 1986. Haverford Coll., PA; Univ. Pennsylvania, Philadelphia, PA
142	**Schlenker B R & Leary M R.** Social anxiety and self-presentation—a conceptualization and model. *Psychol. Bull.* 92:641-69, 1982. Univ. Florida, Gainesville, FL; Denison Univ., Granville, OH
142	**Wang C S, Klein B M & Krakauer H.** Theory of magnetic and structural ordering in iron. *Phys. Rev. Lett.* 54:1852-5, 1985. Univ. Maryland, College Park, MD; US Navy Res. Lab., Washington, DC; Coll. William & Mary, Williamsburg, VA

tions that produced at least 20 papers in this field from 1981 through 1992.

The CUR average impact in this field (3.0) is higher than the world average (2.1). Eleven institutions exceeded the world average. And five had impacts that doubled the world average—Smith (6.2), Calvin College (5.5), Bryn Mawr (4.8), Manhattan (4.6), and William & Mary (4.2).

It should be noted that we are dealing with relatively small numbers of papers in some cases. For example, Hamilton and Bowdoin each produced just 20 engineering papers. At this level, one or a few highly cited papers might significantly influence an institution's overall impact.

Most-Cited Papers—Including Collaborating Universities

Table 4 presents the 20 most-cited papers that included at least one author based at the CUR colleges in this analysis. All but two are collaborative research efforts involving larger research universities. The exceptions are the papers by P.H. Bolton, Wesleyan University, with 147 citations and J.B. Delos, College of William & Mary (143).

The highest impact paper, with 762 citations, was authored by A.C. Webb, Wellesley College, and colleagues at the Massachusetts Institute of Technology, Cambridge; Harvard University, Cambridge; and Tufts University School of Medicine, Boston. Webb also appears on two other papers in Table 4, with 268 and 205 citations. These three papers by Webb are a fraction of the 500 papers Wellesley produced from 1981 through 1992. But they account for 24 percent of its 5,200 citations. Thus, a few papers, labs, teams, or individuals may account for the majority of the institution's total citations and impact. This may be typical of the other CUR colleges examined here, considering the comparatively small numbers of papers involved.

The second most-cited paper, with 412 citations, is a 1982 *Science* review concerning the evolution of osmolyte systems, which was described in a recent *Citation Classic*® commentary by Paul H. Yancey, Whitman College, Walla Walla, Washington.[6] Reviews serve a very useful purpose for the scientific community by providing an overview and synthesis of a body of research literature. But authors at major research universities are not ordinarily encouraged to write review papers. They tend to be valued less than original research papers by tenure, promotion, and grant committees.

These competitive pressures may be less intense at liberal arts colleges where the primary focus is on teaching and mentoring. Thus, colleges can play another important role in research by encouraging their faculty members to publish review papers. This benefits the research community as well as the colleges. Review papers are not only cited more frequently—they also clearly increase an institution's visibility. This can be seen by examining the highest impact papers published by authors based *solely* at liberal arts colleges.

Table 5: Most-cited papers of the 74 CUR liberal arts colleges, 1981-1992 *SCI*®, that do *not* include other collaborating institutions.

Cites	
147	**Bolton P H.** Assignments and structural information via relayed coherence transfer spectroscopy. *J. Magn. Resonance* 48:336-40, 1982. Wesleyan Univ., Middletown, CT
143	**Delos J B.** Theory of electronic transitions in slow atomic collisions. *Rev. Mod. Phys.* 53:287-357, 1981. Coll. William & Mary, Williamsburg, VA
133	**Smith J G.** Synthetically useful reactions of epoxides. *Synthesis-Stuttgart* 8:629-56, 1984. Mt. Holyoke Coll., South Hadley, MA
120	**Wei S H & Krakauer H.** Local density functional calculation of the pressure induced metallization of BaSe and BaTe. *Phys. Rev. Lett.* 55:1200-3, 1985. Coll. William & Mary, Williamsburg, VA
113	**Stearns S C.** The influence of size and phylogeny on patterns of covariation among life history traits in the mammals. *Oikos* 41:173-87, 1983. Reed Coll., Portland, OR
111	**Wilde J A & Bolton P H.** Suppression of homonuclear couplings in heteronuclear two-dimensional spectroscopy. *J. Magn. Resonance* 59:343-6, 1984. Wesleyan Univ., Middletown, CT
95	**Beeman D, Silverman J, Lynds R & Anderson M R.** Modeling studies of amorphous carbon. *Phys. Rev. B* 30:870-5, 1984. Harvey Mudd Coll., Claremont, CA
91	**Glass J D & Lynch G R.** Melatonin—identification of sites of anti-gonadal action in mouse brain. *Science* 214:821-3, 1981. Wesleyan Univ., Middletown, CT
91	**Prioleau L, Murdock M & Brody N.** An analysis of psychotherapy vs placebo studies. *Behav. Brain Sci.* 6:275-85, 1983. Wesleyan Univ., Middletown, CT
90	**Beveridge D L & Dicapua F M.** Free energy via molecular simulation—applications to chemical and biomolecular systems. *Annu. Rev. Biophys.* 18:431-92, 1989. Wesleyan Univ., Middletown, CT
87	**Weiner J & Thomas S C.** Size variability and competition in plant monocultures. *Oikos* 47:211-22, 1986. Swarthmore Coll., PA
85	**Granville M F, Kohler B E & Snow J B.** Franck-Condon analysis of the 11AG-*11BU absorption in linear polyenes with 2 through 6 double bonds. *J. Chem. Phys.* 75:3765-9, 1981. Wesleyan Univ., Middletown, CT
82	**Willeford B R & Veening H.** High performance liquid chromatography—applications to organometallic and metal coordination compounds. *J. Chromatogr.* 251:61-88, 1982. Bucknell Univ., Lewisburg, PA
79	**Jacobs M & Gilbert S F.** Basal localization of the presumptive auxin transport carrier in pea stem cells. *Science* 220:1297-300, 1983. Swarthmore Coll., PA
77	**Stearns S C.** The effects of size and phylogeny on patterns of covariation in the life history traits of lizards and snakes. *Amer. Naturalist* 123:56-72, 1984. Reed Coll., Portland, OR
76	**Ditoro D M & Horzempa L M.** Reversible and resistant components of PCB adsorption-desorption—isotherms. *Environ. Sci. Technol.* 16:594-602, 1982. Manhattan Coll., Bronx, NY
75	**Weiner J.** Size hierarchies in experimental populations of annual plants. *Ecology* 66:743-52, 1985. Swarthmore Coll., PA
74	**Ashmun J W, Thomas R J & Pitelka L F.** Translocation of photo-assimilates between sister ramets in 2 rhizomatous forest herbs. *Ann. Bot.* 49:403-15, 1982. Bates Coll., Lewiston, ME
74	**Pasternack R F, Gibbs E J & Villafranca J J.** Interactions of porphyrins with nucleic acids. *Biochemistry* 22:5409-17, 1983. Swarthmore Coll., PA
74	**Truett M A, Jones R S & Potter S S.** Unusual structure of the FB family of transposable elements in *Drosophila*. *Cell* 24:753-63, 1981. Wesleyan Univ., Middletown, CT
73	**Bodnar T & Cutler A R.** The preparation of organoiron ETA-1-alpha-alkoxyethyl complexes and their reaction with electrophiles—characterization of cationic organoiron ethylidene compounds. *J. Organometal. Chem.* 213:C31-C36, 1981. Wesleyan Univ., Middletown, CT
73	**Tymoczko J L & Phillips M M.** The effects of ribonuclease on rat liver dexamethasone receptor—increased affinity for deoxyribonucleic acid and altered sedimentation profile. *Endocrinology* 112:142-9, 1983. Carleton Coll., Northfield, MN

Most-Cited Papers—Excluding Collaborating Universities

Table 5 identifies the 22 most-cited papers by authors affiliated with the CUR institutions in this study. That is, collaborative papers involving major research universities have been excluded.

The two highest impact papers are those mentioned previously by Bolton and Delos. It is interesting to note that the Delos paper is a 1981 review article published in *Reviews of Modern Physics*. Indeed, 8 of the 22 papers are reviews. In addition to Delos's review, they include the papers by J.G. Smith with 133 citations, S.C. Stearns (two papers with 113 and 77 citations), L. Prioleau et al. (91), D.L. Beveridge and F.M. Dicapua (90), J. Weiner and S.C. Thomas (87), and B.R. Willeford and H. Veening (82). Also, 5 of the 20 papers in Table 4 are reviews. This seems to indicate that authors based at liberal arts colleges are rather active in publishing review papers.

These papers also support the point noted previously that liberal arts colleges seem to be strongest in physics and chemistry. Ten of the 22 most-cited papers in the table concern research in physics and chemistry. And 12 of the 20 papers in Table 4 are in this field. Typically, undifferentiated citation rankings tend to be dominated by life sciences papers. This is due, in part, both to the comparatively larger population of researchers and papers in this field, as well as the higher average number of references per life sciences paper compared with other fields.

Conclusion

In summary, for the group of 74 CUR member institutions, the data show that select liberal arts colleges make a significant contribution to US research. The impact of the average CUR paper was higher than the world average in all fields of science. And with the exception of the life sciences, the average CUR impact exceeded the world average in physics and chemistry, engineering and technology, agriculture and biology, and clinical medicine. The data also suggest that a significant share of a college's overall impact may be accounted for by a few highly cited labs, teams, or individual researchers.

Citation data provide a unique perspective on the role of liberal arts colleges in the nation's scientific enterprise. They enable us to indicate their contributions to the advancement of knowledge through published research. Thus, citation data complement the more traditional statistics on numbers of science graduates and degrees in studies evaluating the impact of undergraduate colleges on US research.

Of course, as a training ground for a substantial proportion of our future scientists, undergraduate colleges make a critical contribution to our research base. However, the contribution they make to published research has not been as widely appreciated. As indicated by this analysis, that contribution is significant—and remarkable, considering the size, facilities, and funding of these colleges compared to the more comprehensive research universities.

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REFERENCES

1. **Carrier S C & Davis-Van Atta D.** *Maintaining America's scientific productivity: the necessity of the liberal arts colleges.* Oberlin, OH: Oberlin College, 1987. 140 p.
2. **Davis-Van Atta D, Carrier S C & Frankfort F.** *Educating America's scientists: the role of the research colleges.* Oberlin, OH: Oberlin College, 1985. 101 p.
3. **Narum J L, ed.** *What works: building natural science communities. A plan for strengthening undergraduate science and mathematics. Volume 2.* Washington, DC: Project Kaleidoscope, 1991. 142 p.
4. **Garfield E.** The impact of undergraduate colleges on US research: a citationist perspective, 1981-1992. Dialogue with NIH and NSF. Council on Undergraduate Research & National Institutes of Health. Bethesda, MD. 16 April 1993.
5. ---------. The role of undergraduate colleges in research. Part 1. Highest output, most-cited, and highest impact institutions, 1981-1992. *Current Contents*® (23):5-11, 7 June 1993.
6. **Yancey P H.** Micromolecules that help macromolecules in dehydration. Citation Classic. Commentary on *Science* 217:1214-22, 1982. *Current Contents/Life Sciences* 36(8):9, 22 February 1993.