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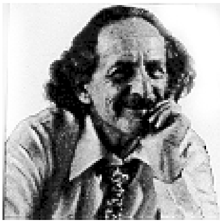

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The 1983 Articles Most Cited in 1983 and 1984. 2. Physical Sciences

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We recently identified and discussed the most-cited life-sciences articles published in 1983.[1] In this essay, we cover the physical sciences.

The most cited of the 103 papers in this study, which are listed in the Bibliography at the end of this essay, is the first of two 1983 papers announcing the discovery of the W^+ and W^- particles (#10). These massive gauge particles communicate the weak force, which is responsible for driving the process of transmutation in the identity of subatomic particles.[2] (p. 78, 96)

The proof of the existence of these particles—achieved through an analysis of the particles resulting from the collision of counter-rotating beams of protons and antiprotons[3]—is the most spectacular and first direct experimental confirmation of the electroweak theory of Sheldon Glashow, Harvard University; Steven Weinberg, University of Texas, Austin; and Abdus Salam, University of London, Imperial College, UK, and the International Centre for Theoretical Physics, Trieste, Italy. The theory, for which the three physicists shared the 1979 Nobel Prize,[4] describes electromagnetism and the weak force as facets of a single underlying phenomenon.

Incidentally, all three 1979 laureates contributed papers in the Bibliography (see papers #52, #58, #86, and #97). So did Burton Richter, Stanford Linear Accelerator Center (SLAC), Stanford University, California, who won the 1976 prize (#69). The Bibliography also contains a contribution by astrophysicist James Maxwell Bardeen, University of Washington, Seattle (#19). James Bardeen works in a completely different field than his father, John Bardeen, University of Illinois, Urbana, who coinvented the transistor and was awarded the Nobel Prize in 1956 *and* 1972.

The influence of the elder Bardeen's work in electrical conductivity of solids and in superconductivity theory is seen in paper #96 on the electronic structure of semiconductors by P. Vogl, Institute for Theoretical Physics, University of Graz, Austria, and Harold P. Hjalmarson and John D. Dow, Department of Physics and Materials Research Laboratory, University of Illinois.[5]

Paper #10, entitled "Experimental observation of isolated large transverse energy electrons with associated missing energy at $\sqrt{s}=540$ GeV," was published in February 1983 in *Physics Letters B*. It has been cited 226 times—41 times in 1983, 129 in 1984, and 56 in the first half of 1985. To put these counts in perspective, it should be noted that the comparable figure for the average 1983 paper is two citations. Even the average highly cited article in the Bibliography received "only" 51 cites—12 in 1983 and 39 in 1984 (the least cited received 32 citations, the threshold for inclusion).

At the same time, however, it should also be kept in mind that this list of 103 papers only scratches the surface of important work reported throughout the world. Of the estimated one million papers published in 1983, over 400,000 were cited in the *Science Citation Index®* (*SCI®*) in 1983 alone. The 103 physical-sciences articles listed in this study were part of a group of 668 articles that were cited 32 times or more during 1983 and 1984. These 668 articles represent just 0.2 percent of the articles cited in the *SCI* during those two years, or approximately 17 percent of the 4,000 or so papers cited 15 or more times in 1983 and 1984.[1]

G. Arnison, Centre d'Études Nucléaires (CEN), Saclay, France, is the first of 135 authors listed alphabetically on paper #10. However, the article is actually the report of the UA1 research team at the multinational European Organization for Nuclear Research (CERN) near Geneva, Switzerland. One of the two CERN teams working toward evidence of the gauge particles of the weak force, the UA1 group was under the direction of Carlo Rubbia, CERN and Harvard. Together with Simon van der Meer, also of CERN, Rubbia was awarded the 1984 Nobel Prize in physics for contributions to the discovery of new subatomic particles.[6] Other affiliations listed by team members include Aachen Technical University, Federal Republic of Germany (FRG); University of Birmingham and Rutherford Appleton Laboratories, Chilton, Oxon, in the UK; University of Helsinki, Finland; University of Rome, Italy; University of California at Riverside; and the College of France in Paris.

The CERN facility not only accounted for this study's most-cited paper, it also placed more papers in this study than any other institution—20, according to Table 1, which lists the 81 institutions in 13 nations included in this study. Six of these CERN papers list either the UA1 or UA2 collaboration, and four of *these* were this study's most-cited papers. The latter group includes not only paper #10 by the UA1 group, but also paper #18 by the UA2 team, which demonstrates the existence of the W particles using a different detector;[7] paper #9 by the UA1 team, which reports the first observation of the Z particle, the neutral partner of the two Ws and the final link in the chain of experimental evidence confirming the electroweak theory;[8] and paper #16 by the UA2 group, which also announces the discovery of the Z particle.[9] These papers comprise a remarkable record for CERN—even more so than its eight papers in our study of 1982 papers.[10] Even the total of three papers we reported in the 1981 study is unusual for a single lab.[11]

As a consequence of these figures, the number of papers emanating from Switzerland is inflated. As shown in Table 2, which lists the national affiliations of the institutions in this study, 22 papers list Swiss institutions, but 20 are from CERN. In fact, all of the Swiss papers for 1982 were from CERN.[10] The appearance of these important papers undoubtedly reflects the completion of the work to transform CERN's Super Proton Synchrotron (SPS) into a Proton-Antiproton (or $\bar{p}p$) Super Collider, capable of much higher energy levels and therefore able to produce particles that the SPS could not.[6]

It is also interesting to note that Japan—which had one paper in the 1981 study and six papers in the 1982 study—dropped out of this year's list, while three 1983 papers listed institutions located in Greece, which had no papers in either of the previous two studies.[10,11] There was also an interesting increase in papers originating from the University of Texas, Austin. Last year's study listed two papers from the university, both by Weinberg;[10] this year, the University of Texas accounts for five papers—of which two, again, were written by Weinberg: paper #97 and paper #58, which was coauthored with Lawrence Hall, University of California, Berkeley, and Joe Lykken, also of the University of Texas.

The 690 unique authors in this year's study are an unusually high number, and the phenomenon is due mainly to the

Table 1: The institutional affiliations of the authors in the Bibliography. Institutions are listed in descending order of the number of times they appear.

CERN, Geneva, Switzerland		20
Univ. California, CA		16
Berkeley	10	
Santa Barbara	2	
Irvine	1	
Livermore	1	
Los Angeles	1	
San Francisco	1	
Harvard Univ., Cambridge, MA		8
Stanford Univ., CA		7
Bell Labs., NJ		6
Murray Hill	5	
Holmdel	1	
Princeton Univ., NJ		6
INFN, Italy		5
Frascati	3	
Milan	1	
Turin	1	
MIT, Cambridge, MA		5
Univ. London, UK		5
Univ. Texas, Austin, TX		5
Caltech, Pasadena, CA		4
Normal Coll., Paris, France		4
Univ. Illinois, Urbana, IL		4
Univ. Pennsylvania, Philadelphia, PA		4
Brookhaven Natl. Lab., Upton, NY		3
Dupont Co., Wilmington, DE		3
Los Alamos Natl. Lab., NM		3
Northeastern Univ., Boston, MA		3
Univ. Chicago, IL		3
Univ. Ioannina, Greece		3
Cornell Univ., Ithaca, NY		2
Fermi Natl. Accel. Lab., Batavia, IL		2
Hamburg Univ., FRG		2
IBM		2
Zurich, Switzerland	1	
San Jose, CA	1	
Inst. Adv. Stud., Princeton, NJ		2
Madrid Autonom. Univ., Spain		2
Max Plank Soc. Adv. Sci., FRG		2
Inst. Phys. Astrophys., Munich	1	
Inst. Solid-State Res., Stuttgart	1	
Ohio State Univ., Columbus, OH		2
Rome Univ., Italy		2
Rutgers Univ., New Brunswick, NJ		2
SUNY, Stony Brook, NY		2
Swiss Fed. Inst. Technol. (ETH), Zurich, Switzerland		2
Tel Aviv Univ., Israel		2
Univ. Arizona, Tucson, AZ		2
Univ. Colorado, Boulder, CO		2
Univ. Michigan, Ann Arbor, MI		2
Univ. Milan, Italy		2
Univ. N. Carolina, Chapel Hill, NC		2
Univ. Rochester, NY		2
Univ. Washington, Seattle, WA		2
Univ. Wisconsin, Madison, WI		2
Boston Univ., MA		1
Brandeis Univ., Waltham, MA		1
CENS, Saclay, France		1
Clark Univ., Worcester, MA		1
Cleveland State Univ., OH		1
CNRS, Grenoble, France		1
Cologne Univ., FRG		1
Emory Univ., Ithaca, NY		1
European Muon Collaboration		1
Exxon Res. Eng. Co., Linden, NJ		1
Free Univ. Brussels, Belgium		1
Hebrew Univ., Jerusalem, Israel		1
Illinois Inst. Technol., Chicago, IL		1
Intl. Ctr. Theor. Phys., Trieste, Italy		1
Ithaca Coll., NY		1
Kitt Peak Natl. Observ., Tucson, AZ		1
McGill Univ., Montreal, Canada		1
NASA, Moffett Field, CA		1
NIKHEF-H, Amsterdam, The Netherlands		1
NYU, New York, NY		1
R & D Assoc., Marina del Rey, CA		1
Rutherford Appleton Labs., Chilton, UK		1
Syracuse Univ., NY		1
Univ. Bielefeld, FRG		1
Univ. Bologna, Italy		1
Univ. Cambridge, UK		1
Univ. Durham, UK		1
Univ. Florida, Gainesville, FL		1
Univ. Graz, Austria		1
Univ. Hawaii, Honolulu, HI		1
Univ. Houston, TX		1
Univ. Maryland, College Park, MD		1
Univ. Notre Dame, IN		1
Univ. Paris XI, Orsay, France		1
Univ. Turin, Italy		1
Univ. Utah, Salt Lake City, UT		1
Univ. Victoria, BC, Canada		1
Vanderbilt Univ., Nashville, TN		1
Villanova Univ., PA		1
Yale Univ., New Haven, CT		1

large number of authors listed on the various CERN collaborations. Indeed, the number of authors on these papers was so large that, due to space considerations, we did not print the full list of authors; interested readers can examine the full list in the recent essay on the 1984 Nobel Prizes in physics and in chemistry.[6] The appropriate references are noted following the abbreviated citations in the Bibliography.

As readily illustrated by the breakdown of the number of authors per paper given in Table 3, the number of papers listing 50 authors or less is similar to those for other years.[10,11] However, the number of papers listing more than 50 authors increased dramatically. In the 1982 study, only one paper listed more than 50 authors;[10] this year, there are eight such papers. Three list over 135 au-

Table 2: National affiliations of the institutions producing the 1983 physical-sciences papers most cited in 1983-1984, in order of the total number of papers in which each nation's authors appeared (column A). B = number of papers coauthored with scientists from other countries. C = national affiliations of coauthors.

Country	A	B	C
US	65	11	Austria, France, Israel, Italy, Switzerland, UK, Greece
Switzerland	22	9	Belgium, France, Greece, Israel, Italy, The Netherlands, US
Italy	8	7	France, Switzerland, UK, US
France	7	4	Italy, Switzerland, US
UK	6	3	Italy, US
FRG	5		
Greece	3	3	Switzerland, US
Canada	2		
Israel	2	1	Switzerland, US
Spain	2		
Austria	1	1	US
Belgium	1	1	The Netherlands, Switzerland
The Netherlands	1	1	Belgium, Switzerland
International Collaboration	1		

thors, one has 123, and another has 79 authors. As I've indicated before,[12,13] the inclusion of dozens of names in the byline for papers makes a mockery of authorship. If huge teams of research scientists are going to publish papers, then they might just as well adopt the convention of the mathematicians who use the pseudonym "Bourbaki."[14]

Since the work of the CERN group is so unusual and its type of facilities are limited to a few labs throughout the world, I was curious to know something about the possible self-citation effect. The paper on "Observation of jets in high transverse energy events at the CERN proton antiproton Collider"[15] demonstrated that, out of the 149 institutional affiliations listed in the 37 papers citing the CERN article in 1983 and 1984, only 20 of these affiliations were accounted for by CERN itself. This is a self-citation rate of approximately 13 percent, which would correspond to the typical self-citation pattern.[16]

Another way to confirm the high and immediate impact of the 103 papers in the Bibliography is to note that 80 percent were identified as core papers in research fronts generated from the *SCI* and the *Social Sciences Citation Index*® (*SSCI*®) in 1983 and 1984. The appropriate front for each paper appears after the paper's bibliographic data. Table 4 lists the research fronts for which at least two of the papers in this study were core articles.

Scanning this list provides a quick overview of many *newly* active research areas in the physical sciences. Keep in mind that these are not necessarily the most active, if "activity" is defined as the sheer *number* of papers published. The prominent emphasis on high-energy, elementary particle physics and cosmology papers is apparent. For example, paper #10 is one of three articles in this study that help form the core of the 1983 research front we named "Experimental evidence for bosons from colliders" (#83-1158); the other two are also by the

Table 3: The number of authors per paper for the 1983 physical-sciences articles most cited, 1983-1984. A = number of authors for each paper. B = number of papers with corresponding number of authors.

A	B
139	1
138	1
135	1
123	1
79	1
67	1
63	1
59	1
45	2
29	1
11	1
10	1
7	2
6	1
5	1
4	10
3	32
2	19
1	25

Total Authorships = 1,164

Table 4: The 1983 and 1984 *SCI®/SSCI®* research fronts that include at least two of the 1983 most-cited physical-sciences papers as core documents. A = number. B = name. C = number of 1983 most-cited physical-sciences papers included in the core of each research front. D = total number of core papers and 1983 or 1984 citing papers for the year designated by the prefix in column A. (The number for each core article in the Bibliography follows the research-front name in parentheses.)

A	B	C	D
83-0506	Renormalization group approach in Pott's models of percolation and critical behavior in fractal lattices (50,85)	2	19/314
83-0966	Monte Carlo methods for lattice gauge theory approaches to quantum chromodynamics (25,59,65)	3	53/575
83-1158	Experimental evidence for bosons from colliders (9,10,18)	3	5/62
83-1184	Yang-Mills and other supersymmetric grand unification theories with supergravity effects (12,32,43,97)	4	52/516
83-1371	Measurement of nucleon structure by deep inelastic lepton scattering from iron, deuterium and other nuclei (14,64)	2	6/66
83-2796	Characterization of supergravity and supersymmetric Kaluza-Klein theories (24,34)	2	22/319
83-8116	Theory of crystal growth, solidification of alloys and diffusion-limited aggregation in 3 dimensions (72,73)	2	9/103
84-0021	11-dimensional Kaluza-Klein supergravity (7,15,24,38,39,51,86)	7	41/386
84-0022	Weak boson production, electroweak interactions and Higgs masses (8,9,10,16,18,20)	6	23/468
84-0099	Theory of the quantized Hall effect in two-dimensional localized potentials (68,91,102)	3	49/503
84-0265	Chiral anomalies, magnetic monopoles and the bag model in QCD (2,63,87,99,100)	5	58/771
84-0400	Studies of magnetic and other properties of Ising and Heisenberg spin glasses (80,103)	2	38/352
84-0548	Application of fractal models to percolation clusters and related problems (50,54,66,71,72,73,74,79,85,101)	10	41/451
84-0623	Experimental and theoretical studies of mixed-valence compounds containing cerium using Anderson and Kondo models (6,57)	2	19/182
84-0712	Unified theories of supergravity and supersymmetry (5,27,32,41,43,53,58,61,70,77,92,97)	12	57/597
84-0979	Structure and evolution of galaxies and the universe based on the observations of radio jets, quasars and other radio sources (35,49,88)	3	31/458
84-1385	Antineutrino interactions, nuclear structure and deep inelastic lepton scattering from nuclei (14,26,64)	3	8/88
84-1752	Lattice gauge theories, Monte Carlo methods, chiral symmetry, renormalization groups and finite temperature QCD (29,59,65,98)	4	52/541
84-1810	Experimental studies of charge density waves, conductivity and related properties of niobium triselenide, tantalum trisulfide and other solids (40,47,55)	3	25/169
84-2058	Analysis of proton decay, CP violation and other problems by grand unification theories (23,30,45,52,69)	5	25/461
84-5383	Cosmological models of Higgs boson and other particle production (37,84)	2	7/87

CERN group (#9 and #18). Sixty-two current papers in 1983 cited the five total core documents of this front. Paper #10 is also among the 23 core papers for the corresponding 1984 front on "Weak boson production, electroweak interactions and Higgs masses" (#84-0022), as is paper #16. There were about 470 papers published that year on the topic of this front.

Twelve more papers in this study are core to the 1984 research front on "Unified theories of supergravity and supersymmetry" (#84-0712), which has a total of 57 core papers cited by almost 600 1984 articles. According to Paul J. Steinhardt, Department of Physics, University of Pennsylvania, Philadelphia, the term "supergravity" refers to "an attempt to develop a supersymmetric quantum theory of gravity consistent with Einstein's theory of general relativity in the classical limit. Supersymmetry is a symmetry between bosonic (integral spin) particles and fermionic (half-integral spin) particles, such that for each bosonic particle there is a fermionic partner of the same mass. For example, the particle that transmits the gravitational force—the graviton—is a spin-2 particle, and it has a fermionic spin-3/2 superpartner called the gravitino. It is hoped that, with supersymmetry, a renormalizable quantum theory of gravity can be developed."[17]

Among the articles that are core to front #84-0712 is paper #32, "Yang-Mills theories with local supersymmetry: Lagrangian, transformation laws and super-Higgs effect," published in *Nuclear Physics B* by E. Cremmer, Laboratory of Theoretical Physics, Normal College, Paris, France, S. Ferrara and A. Van Proeyen, CERN, and L. Girardello, Institute of Physics, University of Milan, Italy. Although supersymmetry may be necessary to obtain a sensible quantum theory of gravity, the theoretical superpartners mentioned earlier have not yet been observed. The basic approach, then, according to Steinhardt, is to assume that supersymmetry is spontaneously broken at high temperatures.[17] And in paper #32, the authors analyze the gravitational effects when supersymmetry is broken.[18] The article was cited in 39 papers in 1983 and 68 in 1984 and is also among the core papers for the 1983 front entitled "Yang-Mills and other supersymmetric grand unification theories with supergravity effects" (#83-1184). About 500 articles published in 1983 cited this front's 52 core papers.

Two more papers that are core to front #84-0712 were authored by John Ellis, SLAC, and colleagues at Stanford, CERN, and the University of Ioannina, Greece; both were published in *Physical Letters B*. One, written with John S. Hagelin, SLAC, D.V. Nanopoulos, CERN, and K. Tamvakis, University of Ioannina, is entitled "Weak symmetry breaking by radiative corrections in broken supergravity" (#41). A discussion of various scenarios in which supersymmetry breaks down,[19] it was cited 20 times in 1983 and 40 times in 1984. Nanopoulos, incidentally, is one of the 223 authors mentioned more than once in the Bibliography. His name appears on five papers (#41-#43, #46, and #75). Affiliated with CERN for 9 of the last 10 years, Nanopoulos also spent a year at Harvard in 1979-1980. Nanopoulos is one of many physicists working on a Grand Unified Theory (GUT), which seeks to unite under one theoretical description the forces of electromagnetism, gravity, the strong force that binds together atomic nuclei, and the weak force. One hundred eighteen authors are listed four times each, while 17 are listed three times, and 87 are each listed twice.

The other paper in this study that is core to research front #84-0712 is entitled "Grand unification in simple supergravity" and was written by Ellis, Nanopoulos, and Tamvakis when all three were at CERN (#43). The authors propose a specific example of a GUT combining a reinterpretation of supergravity and supersymmetry theory.[20] The paper received 86 citations—45 in 1983 and 41 in 1984.

Seven more papers in this study are core to "11-dimensional Kaluza-Klein supergravity" (#84-0021), which has a total of 41 core papers cited by 386 current articles. The front concerns the theories, first promulgated in the 1920s, of the little-known German mathematical physicist Theodor F.E. Kaluza (1885-1954) and those of Swedish physicist Oscar Klein (1895-1977). Inspired by the power of Einstein's relativistic geometry to describe gravity, Kaluza attempted to extend Einstein's work to include electromagnetism—the only other known force of nature at the time—by expanding the four familiar dimensions of length, width, depth, and time to include an extra, unseen dimension. In Kaluza's theory, an electromagnetic wave is merely a ripple in this fifth dimension, which remains imperceptible to us, according to Klein, because it is, in effect, "rolled up" to a very small size indeed—about 10^{-20} of the size of an atomic nucleus. Modified to include the weak and strong forces, the modern versions of the Kaluza-Klein theory propose further extra dimensions (an additional six or seven are the most popular numbers), not just one, in order to incorporate the gauge theory that describes the strong and weak interactions in addition to electromagnetism.[2] (p. 150-68)

This year's study of the physical sciences includes several research fronts in areas similar to those discussed last year.[10] In fact, in that study, 12 papers were core to "Yang-Mills and other supersymmetric grand unification theories with supergravity effects" (#83-1184), mentioned earlier; moreover, 4 of the 1982 core papers in front #83-1184 are also core to the 1984 front "Unified theories of supergravity and supersymmetry" (#84-0712), also mentioned earlier.

From this lengthy discussion of the particle-physics papers, one might have the erroneous impression that the physical sciences in 1983 consisted of nothing but high-energy physics. But consider that 10 papers are core to "Application of fractal models to percolation clusters and related problems" (#84-0548). Among these is "Random walks on fractal structures and percolation clusters," by R. Rammal and G. Toulouse, Physics Laboratory, Normal College (#85). It received 159 citations—28 in 1983, 88 in 1984, and 43 in the first six months of 1985. In their paper, Rammal and Toulouse present equations shedding new light on percolation problems—a class of problems relevant to a wide variety of physical phenomena, including the growth of bubbles of stable phase during the course of a first-order phase transition, which occurs when matter changes its state.[21]

Another paper that is core to front #84-0548 is paper #50, "Anomalous diffusion on percolating clusters," by Yuval Gefen and Amnon Aharony, Department of Physics and Astronomy, Tel Aviv University, Ramat Aviv, Israel, and Shlomo Alexander, Racah Institute of Physics, Hebrew University, Jerusalem. Published in *Physical Review Letters*, the article presents equations for determining electrical conductivity and the dielectric constant of a dilute solution near phase transition.[22] It was cited 102 times. Both this paper and the one by Rammal and Toulouse (#85) are among the core articles for the 1983 research front "Renormalization group approach in Pott's models of percolation and critical behavior in fractal lattices" (#83-0506). This front has a total of 19 core papers, cited by 314 1983 articles.

Articles from other disciplines also deserve mention. In astronomy, for instance, paper #49, published in the *Astrophysical Journal* by Carlos S. Frenk, Simon D.M. White, and Marc Davis, University of California, Berkeley, discusses the evolution of galaxies in the early universe.[23] Paper #35, another article in the *Astrophysical Journal*, was written by Davis and P.J.E. Peebles, Joseph Henry Laboratories, Princeton University, New Jersey. They report a survey of galactic redshifts, which refer to the Doppler effect on light traveling to earth across enormous distances.[24] The paper was core to "Structure and evolution of galaxies and the universe based on the observations of radio jets, quasars and other radio sources" (#84-0979), a 1984 research front with 31 core articles and 458 citing papers published in 1984.

In paper #6, N. Andrei, Department of Physics and Astronomy, Rutgers University, Piscataway, New Jersey, and K. Furuya and J.H. Lowenstein, Department of Physics, New York University, review a solution to various versions of the Kondo problem,[25] which concerns an anomalous increase in the electrical resistance of certain magnetic alloys dissolved at a very low concentration in a nonmagnetic solution as the temperature of the solution is lowered.[26] The Kondo problem is named for Jun Kondo, Electro-technical Laboratory, Nagatacho, Chiyodaku, Tokyo, Japan, who gave the first satisfactory theoretical explanation of the effect in 1964.[27] Study of the effect is expected to provide insight into the electronic structure of the magnetic alloys themselves.[26] The significance of the paper by Andrei and colleagues lies in their mathematically exact model of impurities in metal.[28] Ordinarily, according to Andrei, such models cannot be solved exactly, but this paper's model can be completely analyzed. The review has been cited 12 times in 1983, 25 times in 1984, and 26 times in the first six months of 1985. It is core to the 1984 front on "Experimental and theoretical studies of mixed-valence compounds containing cerium using Anderson and Kondo models" (#84-0623), which has 19 core papers and 182 citing papers published in 1984.

Papers #68 and #102 discuss the quantized Hall effect, discovered in 1980[29] by Klaus von Klitzing, Max Planck Institute for Solid-State Research, Stuttgart, FRG, who was awarded the 1985 Nobel Prize in physics for his work.[30] The Hall effect, discovered in 1879[31] by Edwin Hubert Hall (1855-1938), is one of a number of so-called "galvanomagnetic effects," the electrical and magnetic phenomena that occur when a conductor or semiconductor carrying an electrical charge is placed within a magnetic field.[32] In the Hall effect, specifically, an electrical conductor builds up a transverse potential gradient when it is so positioned that the direction of magnetic flow is perpendicular to the direction of current flow.[33] The analysis of the Hall effect provides important information concerning the band structure of metals and semiconductors and the nature of electrical conductivity itself. In paper #68, "Anomalous quantum Hall effect: an incompressible quantum fluid with fractionally charged excitations," R.B. Laughlin, Lawrence Livermore National Laboratory, University of California, Livermore, presents mathematical wave functions describing the condensation of a two-dimensional electron gas into a new state of matter.[34] And in paper #102, "Ground state of two-dimensional electrons in strong magnetic fields and ⅓ quantized Hall effect," D. Yoshioka, Bell Laboratories, Murray Hill, New Jersey, B.I. Halperin, Harvard and Normal College, and Patrick A. Lee, Department of Physics, MIT, give a quantum explanation of the Hall effect.[35]

Two other papers in this study are of special interest, due to their subject matter. One, #33, is by Lawrence E. Crooks and colleagues, Radiologic Imaging Laboratory, University of California at San Francisco, and is entitled "Clinical efficiency of nuclear magnetic resonance imaging." Published in *Radiology*, it received a total of 49 citations—9 in 1983 and 40 in 1984—and was core to "Use of contrast agents in nuclear magnetic resonance imaging for the evaluation of multiple sclerosis and other disorders" (#84-0555). Although the paper deals with the subject of nuclear magnetic resonance (NMR) with an eye toward its clinical applications, the discussion of the technique concerns improving image resolution and shortening the time needed to produce an image.[36]

The second paper is #94, the now-famous article on nuclear winter by R.P. Turco, R & D Associates, Marina del Rey, California, O.B. Toon, T.P. Ackerman, and J.B. Pollack, all of the NASA Ames Research Center, Moffett Field, California, and Carl Sagan, Cornell University, Ithaca, New York. Entitled "Nuclear winter: global consequences of multiple nuclear explosions" and published in the December 23, 1983, edition of *Science*, the paper was cited once in 1983, 44 times in 1984, and 30 times in the first six months of 1985. Using models previously developed to study the global atmospheric and climatic effects of volcanic eruptions, the authors develop a range of scenarios describing the meteorological consequences of a nuclear war.[37] They estimate that dust and smoke generated by nuclear explosions and fires started by the bombs could block so much of the sun's heat that subfreezing temperatures would result all over the world, even in summer. This paper and others inspired a similar study conducted and recently published by Yevgeni Velikhov, chairman, Soviet Scientists' Committee for the Defence of Peace Against Nuclear Threat, and vice-president, USSR Academy of Sciences, and other Soviet scientists.[38]

Table 5 lists the 20 journals that published the papers in the Bibliography. Just two account for over 58 percent of the articles: *Physical Review Letters* (35 papers) and *Physics Letters B*, which published 25. Both of these journals have dominated our physical-sciences studies for the past two years.[10,11] All the articles in this study were published in English.

A few of the reviewers for this paper were concerned about false conclusions that might be drawn from the data reported here. It is well known that there are more people working in the particle-physics community than there are in the theoretical-physics community. However, an examination of the research fronts we have identified demonstrates how difficult it is to make distinctions between experimental and theoretical work. But these problems abound in chemistry, biology, and mathematics as well. It may take many more years for potential Citation Classics in theoretical physics to emerge as such. But that may have less to do with the number of theorists than it has to do with the inherent delay in the adoption of their theories. Only a very carefully evaluated study—along the lines of the citation study of high-energy theoretical-physics papers by M.J. Moravcsik and P. Murugesan, Institute of Theoretical Science, University of Oregon, Eugene[39]—could establish whether or not theoretical papers are cited less frequently than experimental ones. Incidentally, Moravcsik recently contributed a *Citation Classic*® commentary to *Current Contents*® on his scientific work.[40]

This concludes our look at the most-cited 1983 physical-sciences papers.

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Table 5: The 20 journals represented on the list of 103 1983 physical-sciences papers most cited in 1983-1984. The numbers in parentheses are the 1983 impact factors for the journals. (The 1983 impact factor equals the number of citations received by 1981-1982 articles in a journal divided by the number of articles published by the journal during the same period.) Data were taken from the *JCR*®. The figures at the right indicate the number of papers from each journal that appears on the list.

Journal	Number of Papers
Phys. Rev. Lett. (6.46)	35
Phys. Lett. B (3.93)	25
Nucl. Phys. B (4.58)	14
Phys. Rev. D—Part. Fields (2.65)	5
Astrophys. J. (3.94)	4
Phys. Rev. B—Condensed Matter (3.27)	4
Astrophys. J. Suppl. Ser. (---)	2
Phys. Rev. A—Gen. Phys. (2.64)	2
Annu. Rev. Astron. Astrophys. (8.67)	1
Appl. Phys. Lett. (3.31)	1
Comments Solid State Phys. (---)	1
J. Magn. Resonance (2.78)	1
J. Phys. Chem. Solids (1.01)	1
J. Phys. Lett.—Paris (3.31)	1
Nucl. Phys. A (2.46)	1
Phys. Rep.—Rev. Sect. Phys. Lett. (8.15)	1
Radiology (2.73)	1
Rep. Progr. Phys. (7.18)	1
Rev. Mod. Phys. (19.85)	1
Science (7.41)	1

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