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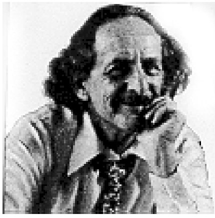

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The Articles Most Cited in the *SCI* from 1961 to 1982. 7. Another 100 *Citation Classics*: The Watson-Crick Double Helix Has Its Turn

Number 20 May 20, 1985

This is the seventh in a series of essays reporting the papers most cited in the *Science Citation Index®* (*SCI®*) from 1961 to 1982. To date, we have listed 600 papers in groups of 100.[1] The seventh group is listed here in alphabetic order by first author. (See Table 1.)

As expected, life sciences papers predominate and account for about 70 percent of the articles. This compares to 85 percent in the first part of the series, and 66 percent in the sixth part. Physical sciences papers account for 25 percent of the articles in Table 1, and papers from other disciplines, such as statistics and psychology, account for 5 percent. Several papers are difficult to classify because they discuss overlapping problems and methods involving different disciplines. For example, R. Peto, Oxford University, England, and colleagues published a two-part paper in the *British Journal of Cancer* that describes a statistical design and methodology for comparing survival rates of different groups of patients, including those with leukemia.[2] Part I of this paper has been cited "only" 417 times since it was published. But Part II appears in Table 1, and, as discussed later, is the most-recent paper in the list.

Table 2 includes the journals that published at least 2 of the 100 articles. The *Journal of Biological Chemistry* published 6 papers, and now accounts for 11 percent of the 700 articles discussed so far. Multidisciplinary journals such as *Nature* (which includes *Nature: New Biology*) (4 percent) and *Science* (3 percent) also continue to appear, but a few high-impact journals, such as the *Journal of the American Chemical Society* (*JACS*) (3 percent), and the *Journal of Molecular Biology* (3 percent) are conspicuous by their absence in this particular segment of the study. Recently, I analyzed the 1981 output of *JACS*.[3]

The authors of 38 papers in Table 1 have published commentaries on their *Citation Classics*™. B.F. Trump's 1961 paper in the *Journal of Ultrastructure Research* was the first paper he ever published.[4] Coauthored with E.A. Smuckler and E.P. Benditt, University of Washington, Seattle, the paper describes a technique used to stain sections of osmium-fixed, epoxy-embedded tissues for light microscopic studies. When sections are stained by this method, "...their images under the light microscope are striking due to their great definition and resemblance to electron micrographs."[4]

Lists of highly cited papers often include methodological works. In the first part of this series, about 70 percent of the articles were so classified. In this seventh group of papers, approximately 41 percent describe new or modified scientific methods. Several of these discuss new procedures in the physical sciences. The 1960 paper by R.J. Britten and R.B. Roberts, Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC, discusses a method of sedimentation analysis that separates ribonucleoprotein particles (ribosomes) using a density-gradient stabilized liquid column.[5] And H. Schlenk and J.L. Gellerman, Hormel Institute, University of Minnesota, Austin, describe a routine procedure for esterifying milligram amounts of fatty acids by diazomethane (CH_2N_2).[6]

One item in Table 1, by N.-E. Andén and colleagues, University of Göteborg, and Karolinska Institute, Sweden, is actually a three-page letter to the editor. It discusses the evidence for dopamine-receptor stimulation by apomorphine and was published in the *Journal of Pharmacy and Pharmacology* in 1967.

The paper by W.W. Douglas, Albert Einstein College of Medicine, New York, is, in fact, the first Gaddum Memorial Lecture. This recurring lecture commemorates the work of John Henry Gaddum (1900-1965), who was associated with the Institute of Animal Physiology, Cambridge, England, when he died. Gaddum was a physiologist first but became interested in pharmacology in the 1930s. Eventually, he became a specialist in autopharmacology, a discipline that combines both of these areas.[7] Gaddum experimented with pharmacologically active substances, such as acetylcholine, that are extractable from body tissue. He also performed experiments with LSD and 5-hydroxytryptamine. This research encouraged the study of neurotransmitters within the brain and the growth of the field of psychopharmacology.[8] Douglas's paper considered the mode of action of acetylcholine in eliciting secretion from adrenal chromaffin cells and presented a general concept of stimulus-secretion coupling in which the immediate stimulus to secretion in diverse secretory cells—endocrine, exocrine, neurosecretory, and other—is mediated by calcium ions, these serving probably to activate some common mechanism, most likely exocytosis.

Probably few papers in the history of science have attracted as much attention as that of the 1953 classic paper by J.D. Watson and F.H.C. Crick on "Molecular structure of nucleic acids." (See Table 1.) They described the double-helix structure for the salt of DNA. It was considered radically different than any other model at that time. A decade later, in 1962, Watson (US) and Crick (UK) shared the Nobel Prize in medicine with Maurice H.F. Wilkins (UK) for their work with DNA. In the same issue of *Nature* (published April 25, 1953) that included the Watson-Crick paper, Wilkins published "Molecular structure of deoxypentose nucleic acids." The paper was coauthored with A.R. Stokes and H.R. Wilson, King's College, London. They presented X-ray diffraction studies that showed the basic molecular configuration of deoxypentose nucleic acid. The paper included some of the experimental evidence eventually used to prove the helical structure of the polynucleotide chain in its natural state.[9] Incidentally, this paper has been cited over 114 times since 1955.

Figure 1 provides a year-by-year analysis of citations to the Watson-Crick paper. We won't be able to give the precise data for the period immediately after its publication until we create the *SCI* for 1945-1954. But this work is now in progress. One can only speculate that the sharp rise of citations in 1963 was due in part to the Nobel Prize that they won in the previous year. However, it is generally believed that the Nobel Prize is conferred too late to have such an impact on current research.

I will comment further on the significance of the citations to Watson and Crick's paper in the conclusion of this series. One may well ask what can we expect of *any* paper if this superstar article was explicitly cited "only" 1,000 times in over 30 years? Indeed, is there a finite limit to the life of any paper unless some controversy causes it to be discussed and cited much longer? Consider the contrasting citation histories of the Watson and Crick paper and Charles Darwin's *On the Origin of Species by Means of Natural Selection*.[10] In turn, compare these to a classic example of the citation

Table 1: The seventh group of 100 articles most-cited in the *SCI*®, 1961-1982, in alphabetic order by first author. A = 1961-1982 citations. 1983 citations appear in parentheses. B = bibliographic data. An asterisk (*) indicates that the paper was the subject of a *Citation Classic*™ commentary. The issue and year of the commentary follow the bibliographic reference.

A		B
812	(34)	**Anden N-E, Rubenson A, Fuxe K & Hokfelt T.** Letter to editor. (Evidence for dopamine receptor stimulation by apomorphine.) *J. Pharm. Pharmacol.* 19:627-9, 1967.
814	(43)	***Arrighi F E & Hsu T C.** Localization of heterochromatin in human chromosomes. *Cytogenetics* 10:81-6, 1971. (7/83/LS)
818	(18)	**Aubert J J, Becker U, Biggs P J, Burger J, Chen M, Everhart G, Goldhagen P, Leong J, McCorriston T, Rhoades T G, Rohde M, Ting S C C, Wu S L & Lee Y Y.** Experimental observation of a heavy particle. *J. Phys. Rev. Lett.* 33:1404-6, 1974.
827	(23)	**Beaven G H & Holiday E R.** Ultraviolet absorption spectra of proteins and amino acids. *Advan. Prot. Chem.* 7:319-86, 1952.
824	(23)	***Benesch R & Benesch R E.** The effect of organic phosphates from the human erythrocyte on the allosteric properties of hemoglobin. *Biochem. Biophys. Res. Commun.* 26:162-7, 1967. (32/79/LS)
860	(0)	**Berghuis J, Bertha I J, Haanappel M, Potters M, Loopstra B O, MacGillavry C H & Veenendaal A L.** New calculations of atomic scattering factors. *Acta Crystallogr.* 8:478-83, 1955.
841	(75)	**Bernfeld P.** Amylases, *α* and *β*. *Meth. Enzymology* 1:149-58, 1955.
828	(54)	**Boyden S.** The chemotactic effect of mixtures of antibody and antigen on polymorphonuclear leucocytes. *J. Exp. Med.* 115:453-66, 1962.
836	(3)	**Britten R J & Roberts R B.** High-resolution density gradient sedimentation analysis. *Science* 131:32-3, 1960.
810	(0)	**Burton K.** Determination of DNA concentration with diphenylamine. *Meth. Enzymology* 12:163-6, 1968.
839	(17)	**Cahn R D, Kaplan N O, Levine L & Zwilling E.** Nature and development of lactic dehydrogenases. *Science* 136:962-9, 1962.
848	(34)	***Cleland W W.** Dithiothreitol, a new protective reagent for SH groups. *Biochemistry* 3:480-2, 1964. (15/82/LS)
813	(187)	**Cohen S N, Chang A C Y & Hsu L.** Nonchromosomal antibiotic resistance in bacteria: genetic transformation of *Escherichia coli* by R-factor DNA. *Proc. Nat. Acad. Sci. US* 69:2110-4, 1972.
823	(62)	**Coons A H, Leduc E H & Connolly J M.** Studies on antibody production. I. A method for the histochemical demonstration of specific antibody and its application to a study of the hyperimmune rabbit. *J. Exp. Med.* 102:49-59, 1955.
808	(80)	***Cowan W M, Gottlieb D I, Hendrickson A E, Price J L & Woolsey T A.** The autoradiographic demonstration of axonal connections in the central nervous system. *Brain Res.* 37:21-51, 1972. (28/82/LS)
840	(297)	**Cox D R.** Regression models and life-tables. *J. Roy. Statist. Soc. Ser. B Metho.* 34:187-202, 1972.
808	(59)	**Douglas W W.** Stimulus-secretion coupling: the concept and clues from chromaffin and other cells. *Brit. J. Pharmacol.* 34:451-74, 1968.
805	(28)	***Duncombe W G.** The colorimetric micro-determination of long-chain fatty acids. *Biochem. J.* 88:7-10, 1963. (36/80/LS)
832	(59)	**Eggstein M & Kreutz F H.** Eine neue Bestimmung der Neutralfette im Blutserum und Gewebe (A new method for the determination of neutral fats in blood serum and tissue). *Klin. Wochenschr.* 44:262-7, 1966.
795	(189)	**Engvall E & Perlmann P.** Enzyme-linked immunosorbent assay, ELISA. III. Quantitation of specific antibodies by enzyme-labeled anti-immunoglobulin in antigen-coated tubes. *J. Immunol.* 109:129-35, 1972.
828	(18)	**Epstein R H, Bolle A, Steinberg C M, Kellenberger E, Boy de la Tour E, Chevalley R, Edgar R S, Susman M, Denhardt G H & Lielausis A.** Physiological studies of conditional lethal mutants of bacteriophage T4D. *Cold Spring Harbor Symp.* 28:375-92, 1963.
810	(19)	**Farquhar M G & Palade G E.** Cell junctions in amphibian skin. *J. Cell Biol.* 26:263-91, 1965.
826	(25)	**Folch J, Ascoli I, Lees M, Meath J A & LeBaron F N.** Preparation of lipide extracts from brain tissue. *J. Biol. Chem.* 191:833-41, 1951.
811	(42)	**Forster T.** Zwischenmolekulare Energiewanderung und Fluoreszenz (Intermolecular energy transfer and fluorescence). *Ann. Phys.—Leipzig* 2:55-75, 1948.
831	(48)	**Frankenhaeuser B & Hodgkin A L.** The action of calcium on the electrical properties of squid axons. *J. Physiol.—London* 137:218-44, 1957.
792	(32)	***Fraser D R & Kodicek E.** Unique biosynthesis by kidney of a biologically active vitamin D metabolite. *Nature* 228:764-6, 1970. (5/83/LS)

A		B
791	(75)	Friend C, Scher W, Holland J G & Sato T. Hemoglobin synthesis in murine virus-induced leukemic cells in vitro: stimulation of erythroid differentiation by dimethyl sulfoxide. Proc. Nat. Acad. Sci. US 68:378-82, 1971.
860	(144)	*Gehan E A. A generalized Wilcoxon test for comparing arbitrarily singly-censored samples. Biometrika 52:203-23, 1965. (39/79/LS)
855	(25)	Gell-Mann M & Levy M. The axial vector current in beta decay. Nuovo Cimento 16:705-26, 1960.
796	(25)	Gell-Mann M, Oakes R J & Renner B. Behavior of current divergences under $SU_3 \times SU_3$. Phys. Rev. 175:2195-9, 1968.
807	(34)	*Glasoe P K & Long F A. Use of glass electrodes to measure acidities in deuterium oxide. J. Phys. Chem. 64:188-9, 1960. (16/79/PC&ES)
810	(50)	Gowans J L & Knight E J. The route of re-circulation of lymphocytes in the rat. Proc. Roy. Soc. London Ser. B 159:257-82, 1964.
848	(46)	Gray W R. Dansyl chloride procedure. Meth. Enzymology 11:139-51, 1967.
848	(58)	*Hahn E L. Spin echoes. Phys. Rev. 80:580-94, 1950. (39/79/PC&ES)
832	(99)	*Hamberg M & Samuelsson B. Prostaglandin endoperoxides. Novel transformations of arachidonic acid in human platelets. Proc. Nat. Acad. Sci. US 71:3400-4, 1974. (48/84/LS)
834	(38)	Hill A V. The heat of shortening and the dynamic constants of muscle. Proc. Roy. Soc. London Ser. B 126:136-95, 1938.
792	(17)	Horecker B L & Kornberg A. The extinction coefficients of the reduced band of pyridine nucleotides. J. Biol. Chem. 175:385-90, 1948.
791	(4)	*Huang R C & Bonner J. Histone, a suppressor of chromosomal RNA synthesis. Proc. Nat. Acad. Sci. US 48:1216-22, 1962. (12/78)
851	(52)	*Itzhaki R F & Gill D M. A micro-biuret method for estimating proteins. Anal. Biochem. 9:401-10, 1964. (48/82/LS)
849	(21)	Kadanoff L P, Gotze W, Hamblen D, Hecht R, Lewis E A S, Palciauskas V V, Rayl M, Swift J, Aspnes D & Kane J. Static phenomena near critical points: theory and experiment. Rev. Mod. Phys. 39:395-431, 1967.
824	(40)	Karmen A. A note on the spectrophotometric assay of glutamic oxalacetic transaminase in human blood serum. J. Clin. Invest. 34:131-3, 1955.
795	(4)	Kirby K S. A new method for the isolation of ribonucleic acids from mammalian tissues. Biochem. J. 64:405-8, 1956.
832	(34)	Kopriwa B M & Leblond C P. Improvements in the coating technique of radioautography. J. Histochem. Cytochem. 10:269-84, 1962.
837	(21)	Kornberg R D. Chromatin structure: a repeating unit of histones and DNA. Science 184:868-71, 1974.
813	(85)	*Krnjevic K. Chemical nature of synaptic transmission in vertebrates. Physiol. Rev. 54:418-540, 1974. (22/84/LS)
810	(171)	Laemmli U K & Favre M. Maturation of the head of bacteriophage T4. I. DNA packaging events. J. Mol. Biol. 80:575-99, 1973.
822	(37)	*Levy H B & Sober H A. A simple chromatographic method for preparation of gamma globulin. Proc. Soc. Exp. Biol. Med. 103:250-2, 1960. (26/81/LS)
846	(38)	Liu T-Y & Chang Y H. Hydrolysis of proteins with p-toluenesulfonic acid. J. Biol. Chem. 246:2842-8, 1971.
823	(43)	Magee P N & Barnes J M. Carcinogenic nitroso compounds. Advan. Cancer Res. 10:163-246, 1967.
832	(38)	Mataga N & Nishimoto K. Electronic structure and spectra of nitrogen heterocycles. Z. Phys. Chem. Neue Folge 13:140-57, 1957.
855	(72)	Miller G A. The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychol. Rev. 63:81-97, 1956.
791	(44)	*Nagatsu T, Levitt M & Udenfriend S. Tyrosine hydroxylase: the initial step in norepinephrine biosynthesis. J. Biol. Chem. 239:2910-7, 1964. (5/80/LS)
819	(82)	*Nebert D W & Gelboin H V. Substrate-inducible microsomal aryl hydroxylase in mammalian cell culture. I. Assay and properties of induced enzyme. J. Biol. Chem. 243:6242-9, 1968. (5/84/LS)
847	(139)	*Nelder J A & Mead R. A simplex method for function minimization. Comput. J. 7:308-13, 1965. (15/79/ET&AS)
797	(26)	*Nemethy G & Scheraga H A. Structure of water and hydrophobic bonding in proteins. 1. A model for the thermodynamic properties of liquid water. J. Chem. Phys. 36:3382-400, 1962. (22/78)
806	(13)	Ogur M & Rosen G. The nucleic acids of plant tissues. I. The extraction and estimation of desoxypentose nucleic acid and pentose nucleic acid. Arch. Biochem. Biophys. 25:262-76, 1956.

A B

796 (37) *Olins A L & Olins D E. Spheroid chromatin units (ν bodies). *Science* 183:330-2, 1974. (10/83/LS)

859 (47) Ouchterlony O. Diffusion-in-gel methods for immunological analysis II. *Prog. Allergy* 6:30-154, 1962.

813 (17) *Parker A J. The effects of solvation on the properties of anions in dipolar aprotic solvents. *Quart. Rev. Chem. Soc.* 16:163-87, 1962. (27/81/PC&ES)

858 (44) *Paul M A & Long F A. H_0 and related indicator acidity functions. *Chem. Rev.* 57:1-45, 1957. (4/78)

842 (300) Peto R, Pike M C, Armitage P, Breslow N E, Cox D R, Howard S V, Mantel N, McPherson K, Peto J & Smith P G. Design and analysis of randomized clinical trials requiring prolonged observation of each patient. Part II. Analysis and examples. *Brit. J. Cancer* 35:1-39,1977.

834 (13) *Piez K A & Morris L. A modified procedure for the automatic analysis of amino acids. *Anal. Biochem.* 1:187-201, 1960. (23/77)

805 (107) *Pike B L & Robinson W A. Human bone marrow colony growth in agar-gel. *J. Cell. Physiol.* 76:77-84, 1970. (23/83/LS)

833 (56) Politzer H D. Reliable perturbative results for strong interactions? *Phys. Rev. Lett.* 30:1346-9, 1973.

840 (15) Pople J A & Segal G A. Approximate self-consistent molecular orbital theory. II. Calculations with complete neglect of differential overlap. *J. Chem. Phys.* 43:S136-S149, 1965.

812 (37) *Porath J, Axen R & Ernback S. Chemical coupling of proteins to agarose. *Nature* 215:1491-2, 1967. (22/84/LS)

810 (29) *Randle P J, Garland P B, Hales C N & Newsholme E A. The glucose fatty-acid cycle: its role in insulin sensitivity and the metabolic disturbances of diabetes mellitus. *Lancet* 1:785-9, 1963. (31/81/LS)

844 (19) *Revel J P & Karnovsky M J. Hexagonal array of subunits in intercellular junctions of the mouse heart and liver. *J. Cell Biol.* 33:C7-C12, 1967. (42/82/LS)

820 (130) Ropes M W, Bennett G A, Cobb S, Jacox R & Jessar R A. 1958 revision of diagnostic criteria for rheumatoid arthritis. *Bull. Rheumat. Dis.* 9:175-6, 1958.

819 (78) *Rosalki S B. An improved procedure for serum creatine phosphokinase determination. *J. Lab. Clin. Med.* 69:696-705, 1967. (16/83/LS)

825 (51) Rowe W P, Wendell E P & Hartley J W. Plaque assay techniques for murine leukemia viruses. *Virology* 42:1136-9, 1970.

834 (70) Rudolph A M & Heymann M A. The circulation of the fetus in utero. *Circ. Res.* 21:163-84, 1967.

838 (24) Schales O & Schales S S. A simple and accurate method for the determination of chloride in biological fluids. *J. Biol. Chem.* 140:879-84, 1941.

812 (39) Schlenk H & Gellerman J L. Esterification of fatty acids with diazomethane on a small scale. *Anal. Chem.* 32:1412-4, 1960.

837 (49) Schnaitman C & Greenawalt J W. Enzymatic properties of the inner and outer membranes of rat liver mitochondria. *J. Cell Biol.* 38:158-75, 1968.

812 (13) Setlow R B & Carrier W L. The disappearance of thymine dimers from DNA: an error-correcting mechanism. *Proc. Nat. Acad. Sci. US* 51:226-31, 1964.

854 (40) *Severinghaus J W. Blood gas calculator. *J. Appl. Physiol.* 21:1108-16, 1966. (9/80/CP)

825 (56) Shockley W & Read W T. Statistics of the recombinations of holes and electrons. *Phys. Rev.* 87:835-42, 1952.

837 (21) *Simon E J & Shemin D. The preparation of S-succinyl coenzyme A. *J. Amer. Chem. Soc.* 75:2520, 1953. (19/78)

791 (39) Sims P, Grover P L, Swaisland A, Pal K & Hewer A. Metabolic activation of benzo(a)pyrene proceeds by a diol-epoxide. *Nature* 252:326-8, 1974.

822 (27) *Singer J M & Plotz C M. The latex fixation test. I. Application to the serologic diagnosis of rheumatoid arthritis. *Amer. J. Med.* 21:888-92, 1956. (51/77)

823 (56) Smith J B & Willis A L. Aspirin selectively inhibits prostaglandin production in human platelets. *Nature: New Biol.* 231:235-9, 1971.

797 (32) *Smith R E & Farquhar M G. Lysosome function in the regulation of the secretory process in cells of the anterior pituitary gland. *J. Cell Biol.* 31:319-47, 1966. (14/83/LS)

835 (19) Spector S, Sjoerdsma A & Udenfriend S. Blockade of endogenous norepinephrine synthesis by α-methyl-tyrosine, an inhibitor of tyrosine hydroxylase. *J. Pharmacol. Exp. Ther.* 147:86-95, 1965.

858 (45) Sumner A T, Evans H J & Buckland R A. New technique for distinguishing between human chromosomes. *Nature: New Biol.* 232:31-2, 1971.

832 (36) Tanabe Y & Sugano S. On the absorption spectra of complex ions. I. *J. Phys. Soc. Jpn.* 9:753-66, 1954.

808 (43) *Tanford C. Protein denaturation. *Advan. Prot. Chem.* 23:121-282, 1968. (6/80/LS)

A		B
794	(31)	Taylor J A. A personality scale of manifest anxiety. *J. Abnormal Soc. Psychol.* 48:285-90, 1953.
795	(19)	*Tomasi T B, Tan E M, Solomon A & Prendergast R A. Characteristics of an immune system common to certain external secretions. *J. Exp. Med.* 121:101-24, 1965. (47/80/LS)
804	(14)	*Trump B F, Smuckler E A & Benditt E P. A method for staining epoxy sections for light microscopy. *J. Ultrastruct. Res.* 5:343-8, 1961. (15/84/LS)
803	(73)	*Vaitukaitis J, Robbins J B, Nieschlag E & Ross G T. A method for producing specific antisera with small doses of immunogen. *J. Clin. Endocrinol. Metab.* 33:988-91, 1971. (33/80/LS)
804	(33)	Vane J R. A sensitive method for the assay of 5-hydroxytryptamine. *Brit. J. Pharmacol.* 12:344-9, 1957.
818	(16)	*Vogt M. The concentration of sympathin in different parts of the central nervous system under normal conditions and after the administration of drugs. *J. Physiol.—London* 123:451-81, 1954. (16/84/LS)
800	(34)	*Waddell W J. A simple ultraviolet spectrophotometric method for the determination of protein. *J. Lab. Clin. Med.* 48:311-4, 1956. (42/81/LS)
797	(42)	Watson J D & Crick F H C. Molecular structure of nucleic acids. *Nature* 171:737-8, 1953.
809	(6)	Wettstein F O, Staehelin T & Noll H. Ribosomal aggregate engaged in protein synthesis: characterization of the ergosome. *Nature* 197:430-5, 1963.
832	(65)	Wilson K G & Kogut J. The renormalization group and the ε expansion. *Phys. Rep.—Rev. Sect. Phys. Lett.* 12:75-199, 1974.
804	(150)	Witkin E M. Ultraviolet mutagenesis and inducible DNA repair in *Escherichia coli*. *Bacteriol. Rev.* 40:869-907, 1976.
837	(53)	*Woessner J F. The determination of hydroxyproline in tissue and protein samples containing small proportions of this imino acid. *Arch. Biochem. Biophys.* 93:440-7, 1961. (2/80/LS)
841	(52)	Yang C N & Mills R L. Conservation of isotopic spin and isotopic gauge invariance. *Phys. Rev.* 96:191-5, 1954.

obliteration phenomenon—the 1952 Zinder-Lederberg paper on transduction.[11] The 1955-1984 citations for these publications are plotted in Figure 1. Undoubtedly, the increase in citations to Darwin in the last decade is due, in part, to the increased study of human evolution. Another factor may be the revival of creationism. Eugenie C. Scott, University of California, San Francisco, and Henry P. Cole, University of Kentucky, Lexington, have recently reviewed important aspects of this phenomenon.[12] Incidentally, the counts for Darwin do not include citations in the *Arts & Humanities Citation Index*™, where his book is mainly cited as a work of literature.

Eleven other authors from Table 1 have been Nobel Prize recipients. Five (M. Gell-Mann, W. Shockley, S.C.C. Ting, K.G. Wilson, and C.N. Yang) won the prize in physics, while another six (A.V. Hill, A.L. Hodgkin, A. Kornberg, G.E. Palade, B. Samuelsson, and J.R. Vane) were Nobelists in medicine. Samuelsson (Sweden) and Vane (UK) shared the prize for medicine with S.K. Bergström (Sweden) in 1982 for their work with prostaglandins.

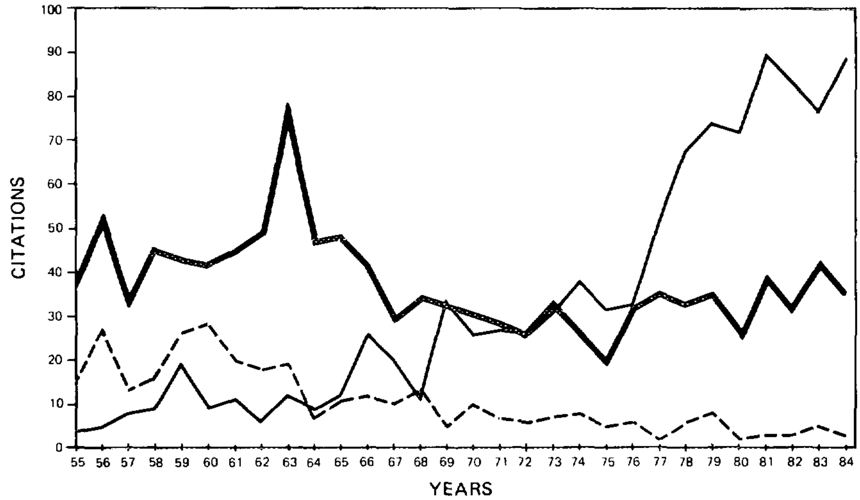
Table 2: Journals that published at least two papers in the seventh group of 100 papers most cited from 1961 to 1982, *SCI*®. A=journal title. B=number of papers. C=1983 impact factor.

A	B	C
Nature*	7	9.3
J. Biol. Chem.	6	5.8
Proc. Nat. Acad. Sci. US	5	8.7
J. Cell Biol.	4	9.2
Phys. Rev.	4	—
Science	4	7.4
J. Exp. Med.	3	11.1
Meth. Enzymology	3	1.3
Advan. Prot. Chem.	2	15.1
Anal. Biochem.	2	2.9
Arch. Biochem. Biophys.	2	2.4
Biochem. J.	2	3.3
Brit. J. Pharmacol.	2	5.0
J. Chem. Phys.	2	3.0
J. Lab. Clin. Med.	2	2.7
J. Physiol.—London	2	3.4
Proc. Roy. Soc. London Ser. B	2	3.0

* Nature includes Nature: New Biol.

Hill (UK) was awarded the 1922 Nobel Prize. He was cited for research relating to heat production in muscles. His 1938

Figure 1: Chronologic distribution of citations to the Watson-Crick double-helix paper (bold solid line), Darwin's *On the Origin of Species by Means of Natural Selection* (solid line), and the Zinder-Lederberg paper on transduction (dotted line). (From the *SCI*®, 1955-1984.)



paper on "The heat of shortening and the dynamic constants of muscle" is the oldest paper in the list. Published in the *Proceedings of the Royal Society of London*, it continues to be cited today—38 times in 1983 and another 60 times in 1984. Biochemist Otto Meyerhof of Germany shared the 1922 award for his work on chemical reactions in muscle metabolism, that is, correlating oxygen consumption and the production of lactic acid in muscles. He wrote many highly cited papers. "On the enzymatic equilibrium reaction between hexosediphosphate and dioxyacetophosphate,"[13] published in 1934, is but one example. This work has been cited 105 times since 1955. Meyerhof died in Philadelphia in 1951, where he served as Research Professor at the University of Pennsylvania.

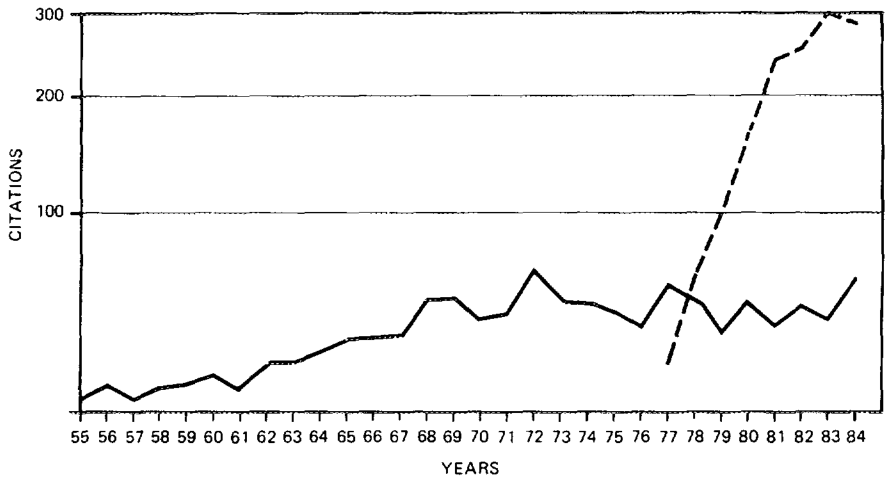
The most-recent paper in Table 1 is the one by Peto and nine coauthors. It was mentioned earlier in this essay. This 1977 article was cited in 842 papers from 1977 to 1982, 300 in 1983, and 285 in 1984. As such, it is quickly joining a small group of statistically oriented papers and books that have had unusually wide citation impact. We have contrasted the citation histories of the Hill and Peto papers in Figure 2.

Table 3: Chronologic distribution of publication dates for the seventh group of 100 most-cited papers, 1961-1982 *SCI*®. A=publication year. B=number of papers.

A	B
1935-1939	1
1940-1949	3
1950-1954	10
1955-1959	14
1960-1964	24
1965-1969	24
1970-1974	22
1975-1977	2

Table 3 provides a chronologic breakdown of the papers in this study. Only four papers were published between 1935 and 1949. Almost half of the articles appeared in the 1960s, and one-fourth were published from 1970 to 1977. In subsequent reports we will attempt to relate these distributions to the actual volume of publication for each year. In short, this may not be simply an age-related phenomenon. The size of each year's literature also helps deter-

Figure 2: Chronologic distribution of citations to Hill's 1938 paper (solid line) and Peto and colleagues' 1977 paper (dotted line).



mine the number of papers we can expect for each frequency range. Such factors may also account for the language of the papers listed. Only two articles in Table 1 were originally published in German. The other 98 papers were written in English. We would expect very different results were we to examine the most-cited papers for earlier decades—an analysis we intend to do one day.

In previous discussions in this series, I mentioned that several authors contributed more than one paper to the lists of papers presented so far. For example, J.A. Pople, Carnegie Institute of Technology and Mellon Institute, Pittsburgh, Pennsylvania, has papers in five parts of this series. Four of these papers are themselves parts of a multipart study on the approximation of the self-consistent molecular orbital theory. Part II is included in Table 1. It received 5 citations in 1984, while the three other parts that Pople authored received 83. Co-counts of these citations reveal that 77 unique articles cited the papers in 1984. That is, only 11 papers cited more than one of Pople's papers at the same time. This indicates that, for the most part, each paper is cited independently of the others, even though they are all part of the same study.

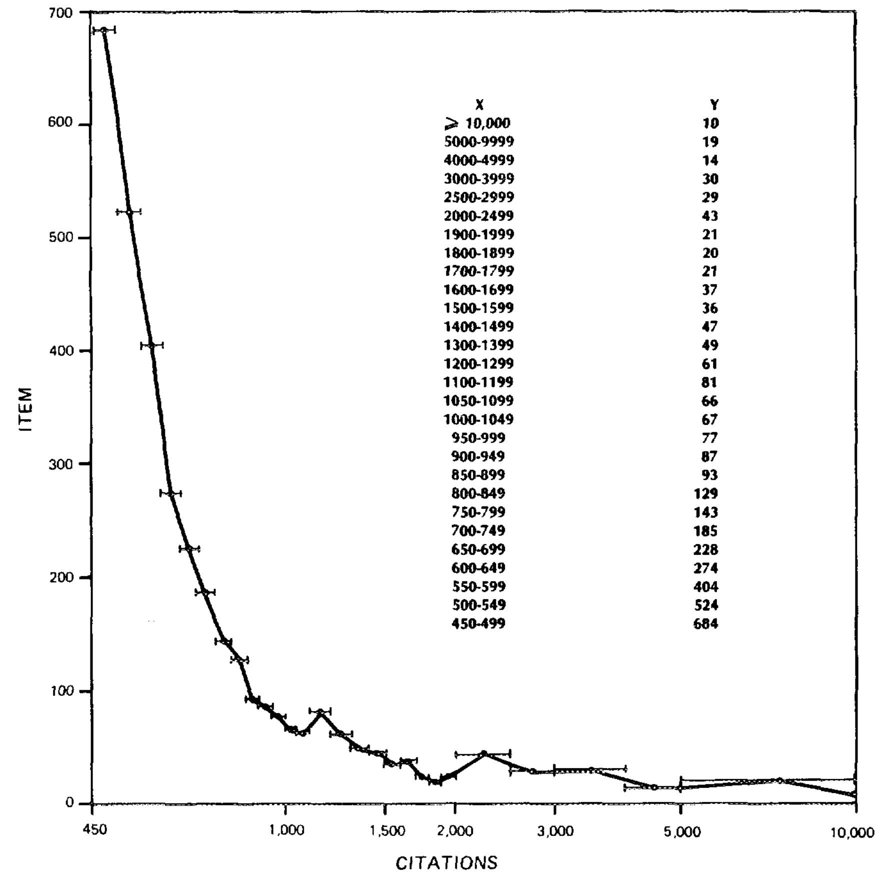
Another frequent contributor to these lists is Ö. Ouchterlony, who appears for the fourth time in this series. His paper in this group reviews the development of immunodiffusion methods, such as diffusion-in-gel, from 1956 to 1960. Diffusion-in-gel methods are used in immunologic analyses to separate and identify various components of mixed immune systems.[14] Ouchterlony's paper was published in *Progress in Allergy* in 1962 and was cited over 850 times from 1962 to 1982, and in 1983 and 1984, another 80 times. Allergies were discussed recently in *Current Contents®* (*CC®*). The discussion included information about the immune mechanisms involved in allergic reactions.[15]

Thus far, we have discussed 700 papers that have been cited at least 791 times in the 1961-1982 *SCI*. Figure 3 shows the number of papers identified for each citation frequency of at least 450 citations. While the selection of references used by each publishing author is anything but random, the overall population of citations produces a hyperbolic distribution that seems to be remarkably consistent.

It is important to mention that in the course of preparing this segment of our study, we discovered that an error—"yours, not ours"—caused a superstar paper by Tjalling C. Koopmans[16] to be omitted from Part 2 of this study. Koopmans, the 1975 Nobel Prize winning economist, began his career in theoretical physics. The *Physica* paper was the only one he published in quantum mechanics. As was calculated from the data plotted in Figure 3, only 280 papers have been cited more than 1,500 times from 1961 to 1982. Koopmans's paper received 1,632 citations. The title of this classic work, "On the assignment of wave functions and eigenvalues to the individual electron of an atom," gives you some idea of its importance to physics. But it would be folly to suggest it was more seminal to the subsequent growth of physics than many other less-cited papers. It continues to be cited because of its continued relevance to modern chemistry and physics.

The reason for the above-mentioned error is relevant to our recent discussion

Figure 3: Citation distribution for all items cited at least 450 times in the *SCI*®, 1961-1982. Items were tabulated for ranges of citations. The midpoint of each citation range is plotted. The horizontal bars through the points indicate the actual ranges. The table of values shows the actual ranges of citation values (x) and of number of items (y).



of pageless documentation,[17] and even more to the cavalier attitude of some journals to absurd editorial practices. Koopmans's paper (*Physica* 1:104-13, 1933/34) was published when the journal first began. Volume 1 of *Physica* was started in 1933, but the first volume was not completed until 1934. So half of the authors who cited the article assumed that it was published in 1933. The actual publication date of Koopmans's paper, however, was 1934, which is the proper date to use. Incidentally, it is not unusual for a classic paper to be associated with a new journal. Evidently it proved to be quite successful. *Physica* is published by Elsevier Science Publishers. Unfortunately, this practice of "volume splitting" is still continued by the journal.

We are now well over halfway to our goal of examining the top 1,000 papers. Later this year, we will report on the next three parts of this series and summarize the data for the first 1,000 papers.

* * * * *

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REFERENCES

1. **Garfield E.** The articles most cited in 1961-1982. Pts. 1-6. *Current Contents* (23):3-9, 4 June 1984; (29):3-12, 16 July 1984; (35):3-9, 27 August 1984; (40):3-9, 1 October 1984; (42):3-12, 15 October 1984; (14):3-10, 8 April 1985.
2. **Peto R, Pike M C, Armitage P, Breslow N E, Cox D R, Howard S V, Mantel N, McPherson K, Peto J & Smith P G.** Design and analysis of randomized clinical trials requiring prolonged observation of each patient. Part I. Introduction and design. Part II. Analysis and examples. *Brit. J. Cancer* 34:585-612, 1976; 35:1-39, 1977.
3. **Garfield E.** The 1981 most-cited chemistry papers. Part 1. Pure and synthetic chemistry. Or, should I say, most-cited papers published in 1981 in the *Journal of the American Chemical Society*? *Current Contents* (12):3-16, 25 March 1985.
4. **Trump B F.** Citation Classic. Commentary on *J. Ultrastruct. Res.* 5:343-8, 1961. *Current Contents/Life Sciences* 27(15):15, 9 April 1984.
5. **Britten R J & Roberts R B.** High-resolution density gradient sedimentation analysis. *Science* 131:32-3, 1960.
6. **Schlenk H & Gellerman J L.** Esterification of fatty acids with diazomethane on a small scale. *Anal. Chem.* 32:1412-4, 1960.
7. **Feldberg W.** John Henry Gaddum. *Biographical memoirs of Fellows of the Royal Society.* London: Royal Society, 1967. Vol. 13. p. 57-77.
8. **Douglas W W.** Stimulus-secretion coupling: the concept and clues from chromaffin and other cells. *Brit. J. Pharmacol.* 34:451-74, 1968.
9. **Wilkins M H F, Stokes A R & Wilson H R.** Molecular structure of deoxypentose nucleic acids. *Nature* 171:738-40, 1953.
10. **Darwin C R.** *On the origin of species by means of natural selection.* London: J. Murray, 1859. 502 p.
11. **Zinder N D & Lederberg J.** Genetic exchange in *Salmonella. J. Bacteriol.* 64:679-99, 1952.
12. **Scott E C & Cole H P.** The elusive scientific basis of creation "science." *Quart. Rev. Biol.* 60(1):21-30, 1985.
13. **Meyerhof O & Lohmann K.** Über die enzymatische Gleichgewichtsreaktion zwischen Hexosediphosphorsaure und Dioxyacetonphosphorsaure (On the enzymatic equilibrium reaction between hexosediphosphate and dioxyacetophosphate). *Biochem. Z.* 271:89-110, 1934.
14. **Ouchterlony Ö.** Diffusion-in-gel methods for immunological analysis II. *Prog. Allergy* 6:30-154, 1962.
15. **Garfield E.** Allergies are nothing to sneeze at. Pts. 1 & 2. *Current Contents* (13):3-15, 1 April 1985; (15):3-13, 15 April 1985.
16. **Koopmans T.** Über die Zuordnung von Wellenfunktionen und Eigenwerten zu den einzelnen Elektronen eines Atoms (On the assignment of wave functions and eigenvalues to the individual electrons of an atom). *Physica* 1:104-13, 1934.
17. **Garfield E.** Pageless documentation; or, what a difference a page makes. *Current Contents* (17):3-6, 29 April 1985.