CURRENT COMMENTS

Highly Cited Articles. 40. Biomedical and Behavioral Papers Published in the 1950s.

Number 29, July 18, 1977

We recently published lists of highly cited 1950s papers in biochemistry[1] and in physics and chemistry.[2] To conclude the discussion of that decade's scientific literature, here are the highly-cited biomedical and behavioral papers.

In Figure 1 we list the 78 articles in alphabetical order according to first author. Each article was cited at least 500 times in the 15-year period 1961-1975. Some of the authors of these articles appeared on our 1940s list:[3] Schneider (56 and 57), Hogeboom (56), Coons (13 & 14), Hodgkin (29 & 30), Ouchterlory (41 & 42), Ussing (72), Zilversmit (73), and Katz (23).

It is interesting to confirm the common wisdom that collaborative research has increased over the years. We found that 25 out of 58 classics of the 19th- and early 20th-century (43%) were collaborations.[4] On the 1940s list, 47 of 85 articles (55%) were co-authored. And in the 1950s, 55 out of 78 (70%) were collaborations.

It is well known that collaborating scientists often alternate as primary and secondary authors. And this is often true even for Nobel Prize winners. For instance, Bernard Katz of England, who won the 1970 Prize for studies of nerve impulse transmissions, is the second author of article 23. James Watson of the U.S., who won the Prize in 1962, is the second of four authors of article 71. This paper was published in the inaugural year of the *Journal of Molecular Biology*.

Other Nobelists also appear on this list. Joshua Lederberg of the U.S. (36) received the Nobel Prize in 1958 for his work in genetics. Renato Dulbecco (19), an Italian-born U.S. citizen, won the Prize in 1975 for his studies concerning the interaction between tumor viruses and genetic material in the cell. George Palade (44) and Christian deDuve (17) of the U.S. were both awarded the 1974 Prize for their studies concerning the inner workings of living cells.

The authors of article 69, William Stein and Stanford Moore of the U.S., shared the 1972 chemistry Prize for their pioneering studies in enzymes. The authors of article 29, Alan Hodgkin and Andrew Huxley of

Figure 1. Highly cited articles in biological sciences, medicine, and psychology published in the 1950s. **A** = item number. **B** = total citations 1961-1975. **C** = average yearly citations 1961-1975. **D** = citations in 1974. **E** = citations in 1975. Articles are listed alphabetically by first author.

A	B	C	D	E	Bibliographic Data
1.	1206	80	77	77	**Abell L L, Levy B B, Brodie B B & Kendall F E.** A simplified method for the estimation of total cholesterol in serum and demonstration of its specificity. *J. Biol. Chem.* **195**:357-66, 1952.
2.	674	45	27	33	**Astrup T & Mullertz S.** The fibrin plant method for estimating fibrinolytic activity. *Arch. Biochem Biophys* **40**:346-51, 1952.
3.	518	35	29	22	**Berson S A, Yalow R S, Bauman M, Rothschild A & Newerly K.** Insulin-I^{131} metabolism in human subjects; demonstration of insulin binding globulin in the circulation of insulin treated subjects. *J. Clin. Invest.* **35**:170-90, 1956.
4.	616	41	60	48	**Blomback B & Blomback M.** Purification of human and bovine fibrinogen. *Arkiv Kemi* **10**:415-43, 1956.
5.	785	52	43	44	**Bogdanski D F, Pletscher A, Brodie B & Udenfried S.** Identification and assay of serotonin in brain. *J. Pharmacol. Exp. Ther.* 117:82-8, 1956.
6.	1246	83	69	43	**Boyden S V.** The adsorption of proteins on erythrocytes treated with tannic acid and subsequent hemagglutination by anti-protein sera. *J. Exp. Med.* **93**:107-20, 1951.
7.	857	57	84	61	**Brecher G & Cronkite E P.** Morphology and enumeration of human blood platelets. *J. Appl. Physiol.* **3**:365-77, 1950.
8.	841	56	26	21	**Brenner S & Horne R W.** A negative staining method for high resolution electron microscopy of viruses. *Biochim. Biophys. Acta* **34**:103-10, 1959.
9.	811	54	21	21	**Burn J H & Rand M J.** The action of sympathomimetic amines in animals treated with reserpine. *J. Physiol.* **144**:314-36, 1958.
10.	870	58	72	67	**Chance B & Williams G R.** The respiratory chain and oxidative phosphorylation. *Adv. Enzymol.* 17:65-134, 1956.
11.	606	40	51	48	**Chauveau J, Moule Y & Rouiller C H.** Isolation of pure and unaltered liver nuclei morphology and biochemical composition. *Exp. Cell Res.* 11:317-21, 1956.
12.	1168	78	94	68	**Clarke D H & Casals J.** Techniques for hemagglutination and hemagglutination-inhibition with arthropod-borne viruses. *Amer. J. Trop. Med. Hyg.* 7:561-73, 1958.
13.	1206	80	56	52	**Coons A H & Kaplan M H.** Localization of antigen in tissue cells. II. Improvements in a method for the detection of antigen by means of fluorescent antibody. *J. Exp. Med.* **91**:1-13, 1950.
14.	529	35	26	34	**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 hyper-immune rabbit. *J. Exper. Med.* **102**:49-71, 1955.
15.	679	45	39	44	**Dalton A J.** A chrome-osmium fixative for electron microscopy. *Anatomical Rec.* 121:281, 1955.

Figure 1 continued

16.	1229	82	99	99	**Davis B D & Mingioli E S.** Mutants of *Escherichia coli* requiring methionine or vitamin B_{12}. *J. Bacteriol.* **60**:17-28, 1950.
17.	1683	112	146	130	**deDuve C D, Pressman B C, Gianetto R, Wattiaux R & Appelmans F.** Tissue fractionation studies. 6. Intracellular distribution patterns of enzyme in rat-liver tissue. *Biochem. J.* **60**:604-12, 1955.
18.	628	42	20	27	**Dement W & Kleitman N.** Cyclic variations in EEG during sleep and their relation to eye movements, body motility, and dreaming. *EEG Clin. Neurol.* **9**:673-90, 1957.
19.	1612	107	136	127	**Dulbecco R & Vogt M.** Plaque formation and isolation of pure lines with poliomyelitis viruses. *J. Exp. Med.* **99**:167-82, 1954.
20.	3610	241	269	240	**Duncan D B.** Multiple range and multiple F tests. *Biometrics* **11**:1-42, 1955.
21.	703	47	27	25	**Eagle H.** Nutrition needs of mammalian cells in tissue culture. *Science* **122**:501-4, 1955.
22.	654	44	79	68	**Farr R S.** A quantitative immunochemical measure of the primary interaction between I*BSA and the antibody. *J. Infect. Dis.* **103**:239-62, 1958.
23.	507	34	19	36	**Fatt P & Katz B.** An analysis of the end-plate potential recorded with an intra-cellular electrode. *J. Physiol.* **115**:320-70, 1951.
24.	524	35	13	10	**Gordon R S & Cherkes A.** Unesterized fatty acid in human blood plasma. *J. Clin. Invest.* **35**:206-12, 1956.
25.	959	64	50	53	**Grabar P & Williams C A.** Methode permettant l'etude conjuguee des proprietes electrophoretiques et immunochimiques d'un melange de proteines. Application au serum sanguin. (Method permitting dual study of electrophoretic and immunochemical properties of a protein mixture. Application to blood serum.) *Biochim. Biophys. Acta* **10**:193-4, 1953.
26.	634	42	24	21	**Grabar P, Williams C A Jr. & Courcon J.** Methode immunoelectrophoretique d'analyse de melange de substances antigeniques. (Immunoelectrophoretic method for analysis of mixed antigenic substances.) *Biochim. Biophys. Acta* **17**:67-74, 1955.
27.	1015	68	118	110	**Hamburger V & Hamilton H L.** A series of normal stages in the development of the chick embryo. *J. Morphology* **88**:49-92, 1951.
28.	643	43	70	92	**Havel R J, Eder H A & Bragdon J H.** The distribution and chemical composition of ultracentrifugally separated lipoproteins in human serum. *J. Clin. Invest.* **34**:1345-53, 1955.
29.	1089	73	84	122	**Hodgkin A L & Huxley A F.** A quantitative description of membrane current and its application to conduction and excitation in nerve. *J. Physiol.* **117**:500-44, 1952.
30.	519	35	31	33	**Hodgkin A L & Horowicz P.** The influence of potassium and chloride ions on the membrane potential of single muscle fibers. *J. Physiol.* **148**:127-60, 1959.

Figure 1 continued

31.	504	34	46	29	**Hugh R & Leifson E.** The taxonomic significance of fermentative versus oxyidative metabolism of carbohydrates by various gram negative bacteria. *J. Bacteriol.* **66**:24-6, 1953.
32.	548	37	39	40	**Karmen A.** A note on the spectrophotometric assay of glutamic-oxyalecetic transaminase in human serum. *J. Clin. Invest.* **34**:131-3, 1955.
33.	636	42	12	15	**Kay A W.** Effect of large doses of histamine on gastric secretion of HCl; an augmented histamine test. *Brit. Med. J.* 2:77-80, 1953.
34.	523	35	59	54	**Kluver H & Barrera E.** A method for the combined staining of cells and fibers in the nervous system. *J. Neuropath. Exper. Neurol.* 12:400-3, 1953.
35.	539	36	45	42	**Kramer C Y.** Extension of multiple range tests to group means with unequal numbers of replications. *Biometrics* 12:307-10, 1956.
36.	527	35	29	19	**Lederberg J & Lederberg E M.** Replica plating and indirect selection of bacterial mutants. *J. Bacteriol.* **63**:399-406, 1952.
37.	729	49	91	68	**Lennox E S.** Transduction of linked genetic character of the host by bacteriophage P1. *Virology* 1:190-206, 1955.
38.	538	36	37	42	**Mauzerall D & Granick S.** The occurrence and determination of δ-aminolevulinic acid and prophobilinogen in urine. *J. Biol. Chem.* **219**:435-6, 1956.
39.	704	47	78	66	**Miller G A.** The magical number seven, plus or minus two; some limits in our capacity for processing information. *Psychol. Rev.* **63**:81-97, 1956.
40.	811	54	26	27	**Morgan J F, Morton H J & Parker R C.** Nutrition of animal cells in tissue culture. I. Initial studies on a synthetic medium. *P. Soc. Exp. Biol. Med.* **73**:1-8, 1950.
41.	822	55	68	53	**Ouchterlony O.** Antigen-antibody reactions in gels. IV. Types of reactions in coordinated systems of diffusion. *Acta. Pathol. Microb. Scand.* **32**:231-40, 1953.
42.	875	58	109	121	**Ouchterlony O.** Diffusion-in-gel methods for immunological analysis. *Prog. Allergy* 5:1-78, 1958.
43.	759	51	62	63	**Oyama B I & Eagle H.** Measurement of cell growth in tissue culture with a phenol reagent (Folin-ciocalteau). *P. Soc. Exp. Biol. Med.* **91**:305-7, 1956.
44.	2072	138	81	48	**Palade G E.** A study of fixation for electron microscopy. *J. Exp. Med.* **95**:285-97, 1952.
45.	549	37	18	18	**Porath J & Flodin P.** Gel filtration; a method for desalting and group separation. *Nature* **183**:1657-9, 1959.
46.	1203	80	49	41	**Poulik M D.** Starch gel electrophoresis in a discontinuous system of buffers. *Nature* **180**: 1477-9, 1957.
47.	516	34	24	24	**Puck T T, Marcus P I & Ciecíura S J.** Clonal growth of mammalian cells in vitro. Growth characteristics of colonies from single hela cells with and without a "feeder" layer. *J. Exper. Med.* **103**:273-84, 1956.

Figure 1 continued

48.	762	51	56	54	**Quastler H & Sherman F G.** Cell population kinetics in the intestinal epithelium of the mouse. *Exp. Cell Res.* 17:420-38, 1959.
49.	668	45	67	57	**Ratnoff O D & Menzie C.** A new method for the determination of fibrinogen in small samples of plasma. *J. Lab. Clin. Med.* 37:306-20, 1951.
50.	1170	78	81	78	**Reitman S & Frankel S.** A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic transaminases. *Amer. J. Clin. Pathol.* 28:56-63, 1957.
51.	533	36	12	11	**Riggs J L, Seiwald R J, Burckhalter J H, Downs C M & Metcalf T G.** Isothiocyanate compounds as a fluorescent labeling agent for immune serum. *Amer. J. Pathol.* 34:1081-98, 1958.
52.	513	34	27	25	**Saifer A & Gerstenfeld X.** The photometric microdetermination of blood glucose with glucose oxidase. *J. Lab. Clin. Med.* 51:448-60, 1958.
53.	732	49	49	40	**Sarnoff S J, Braunwald E, Welch G H, Jr., Case R B, Stainsby W N & Macruz R.** Hemodynamic determinants of oxygen consumption of the heart with special reference to the tension-time index. *Amer. J. Physiol.* 192:148-56, 1958.
54.	509	34	59	62	**Schachman H K.** Ultracentrifugation, diffusion, and viscometry. *Methods Enzym.* 4:32-103, 1957.
55.	3660	244	258	202	**Scheidegger J J.** Une micro-methode de l'immuno-electrophorese. (Method for immunoelectrophoretic microanalysis.) *Internat. Arch. Allergy* 7:103-10, 1955.
56.	947	63	59	55	**Schneider W C & Hogeboom G H.** Intracellular distribution of enzymes. V. Further studies on the distribution of cytochrome-c in rat liver homogenates. *J. Biol. Chem.* 183:123-8, 1950.
57.	620	41	72	103	**Schneider W C.** Determination of nucleic acids in tissues by pentose analysis. *Methods Enzym.* 3:680-4, 1957.
58.	1138	76	50	47	**Seldinger S I.** Catheter replacement of the needle in percutaneous arteriography; a new technique. *Acta Radiologica* 39:368-76, 1953.
59.	539	36	19	20	**Shanes A M.** Electrochemical aspects of physiological and pharmacological action in excitable cells. I. The resting cell and its extrinsic factors. *Pharmacological Revs.* 10:59-164, 1958.
60.	839	56	70	62	**Shore P A, Burkhalter A & Cohn V H Jr.** A method for the fluorometric assay of histamine in tissues. *J. Pharmacol. Exp. Ther.* 127:182-6, 1959.
61.	1297	86	31	23	**Smithies O.** An improved procedure for starch-gel electrophoresis; further variations in the serum proteins of normal individuals. *Biochem. J.* 71:585-7, 1959.
62.	570	38	35	25	**Silber R H, Busch R D & Oslapas R.** Practical procedure for estimation of corticosterone or hydrocortisone. *Clinical Chemistry* 4:278-85, 1958.
63.	652	43	15	23	**Silber R H & Porter C C.** The determination of 17, 21-dihydroxy-20-ketosteroids in urine and plasma. *J. Biol. Chem.* 210:923-32, 1954.

Figure 1 continued

64.	533	36	32	30	**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.
65.	617	41	35	32	**Singer K, Chernoff A J & Singer L.** Studies on abnormal hemoglobins. I. Their demonstration in sickle-cell anemia and other hematological disorders by means of alkali denaturation. *Blood-J. Hematology* 6:413-28, 1951.
66.	1158	77	66	39	**Sperry W M & Webb M.** A revision of the Schoenheimer-Sperry method for cholesterol determination. *J. Biol. Chem.* 187:97-106, 1950.
67.	799	53	40	35	**Stavitsky A B.** Micromethods for the study of proteins and antibodies. I. Procedure and general applications of hemagglutination and hemagglutination-inhibition reactions with tannic acid or protein-treated red blood cells. *J. Immunol.* 72:360-75, 1954.
68.	755	50	44	23	**Steelman S L & Pohley F M.** Assay of the follicle stimulating hormone based on the augmentation with human chorionic gonadotropin. *Endocrinology* 53:604-16, 1953.
69.	571	38	30	24	**Stein W H & Moore S.** The free amino acids of human blood plasma. *J. Biol. Chem.* 211:915-26, 1954.
70.	706	47	55	45	**Taylor J A.** A personality scale of manifest anxiety. *J. Abn. Soc. Psychol.* 48:285-90, 1953.
71.	619	41	22	22	**Tissieres A, Watson J D, Schlessinger D & Hollingsworth B R.** Ribonucleoprotein particles from *Escherichia coli*. *J. Molec. Biol.* 1:221-3, 1959.
72.	855	57	56	78	**Ussing H H & Zehrahn K.** Active transport of sodium as the source of electric current in the short-circulated isolated frog skin. *Acta Physiol. Scand.* 23:110-27, 1951.
73.	1440	96	81	73	**Van Handel E & Zilversmit D B.** Micromethod for the direct determination of serum triglycerides. *J. Lab. Clin. Med.* 50:L152-7, 1957.
74.	635	42	37	29	**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.* 123:451-81, 1954.
75.	1100	73	96	66	**Wachstein M & Meisel E.** Histochemistry of hepatic phosphatases at a physiological pH with a special reference to the demonstration of bile canaliculi. *Amer. J. Clin. Pathol.* 27:13-23, 1957.
76.	623	42	26	43	**Wilson T H & Wiseman A.** The use of sacs of everted small intestine for the study of the transference of substances from the mucosal to the serosal surface. *J. Physiol.* 123:116-25, 1954.
77.	800	53	62	58	**Wroblewski F & LaDue J S.** Lactic dehydrogenase activity in blood. *P. Soc. Exp. Biol. Med.* 90:210-13, 1955.
78.	868	58	56	60	**Zlatkis A, Zak B & Boyle A J.** A new method for the direct determination of serum cholesterol. *J. Lab. Clin. Med.* 41:486-92, 1953.

England, shared the 1963 Prize for their research on nerve cells.

The most highly-cited paper on the list is Scheidegger's "Method for Immunoelectrophoretic Microanalysis" (55), with a total citation count of 3,660. Its 15 year average citation count is 244, and in recent years its citation rate has hovered close to that figure.

Lest you jump to the erroneous conclusion that method papers are necessarily more frequently cited than other articles, I remind you that there is considerable evidence against this prevalent viewpoint. There are a number of highly cited method papers, but a large percentage achieve oblivion. One indicator of this is the impact observed for journals in analytical chemistry. Their impact is lower than what one would expect for methods journals. R.E. Davies of the University of Pennsylvania has recently reminded me of this point.[5]

These 78 highly-cited papers were

Figure 2. Journals that published the highly cited 1950s articles listed in Figure 1, according to number of articles. A = number of articles. (Present title of journal given in parentheses.)

A	Journals
6	J. Biol. Chemistry
6	J. Exp. Med.
6	J. Physiology (London)
4	J. Clin. Invest.
4	J. Lab. Clin. Med.
3	Biochim. Biophys. Acta
3	J. Bacteriol.
3	Proc. Soc. Exp. Biol. Med.
2	Acta Physiol. Scand.
2	Amer. J. Clin. Pathol.
2	Biometrics
2	Exp. Cell. Res.
2	J. Pharmacol. Exp. Ther.
2	Methods Enzymol.
2	Nature
1	Acta Pathol. Microb. Scand. (A)
1	Acta Radiologica (Diagnosis)
1	Adv. Enzymol.
1	Amer. J. Med.
1	Amer. J. Pathology
1	Amer. J. Physiology
1	Amer. J. Trop. Med. Hyg.
1	Anatomical Rec.
1	Arch. Biochem. Biophys.
1	Arkiv Kemi (Chem. Scripta)
1	Biochemical Journal
1	Blood-J. Hematology
1	Brit. Med. J.
1	Clinical Chemistry
1	EEG Clin. Neurology
1	Endocrinology
1	Internat. Arch. Allergy
1	J. Abnormal Soc. Psychol.
1	J. Appl. Physiol.
1	J. Immunology
1	J. Infect. Dis.
1	J. Molec. Biol.
1	J. Morphology
1	J. Neuropath. Exp. Neurol.
1	Pharmacological Revs.
1	Prog. Allergy
1	Psychol. Rev.
1	Science
1	Virology

published by a total of 44 journals, listed in Figure 2. Three journals published 6 articles each, accounting for 23% of all the articles: *Journal of Biological Chemistry, Journal of Experimental Medicine,* and *Journal of Physiology.* Overall, there is a wide distribution of articles by journals. Seven journals published 2 articles each, and 29 journals published 1 article.

The list of journals in Figure 2 includes two psychology journals which each published one paper: the *Journal of Abnormal Social Psychology* and *Psychological Review.* Both of the articles in these journals (39 & 70) were singly authored and have maintained 1974 and 1975 citation rates near their yearly averages. It is important to mention that in the early years of the *SCI®* our coverage of psychology was not as complete as today. However, the inclusion of data from our *Social Sciences Citation Index™* (*SSCI™*) has increased the citation counts for these psychology papers.

About fifteen of the papers concern hematology. This includes research into the determination of fibrinogen and fibrin in blood plasma, elements involved in blood coagulation. The data seem to confirm the assertion by Benjamin Alexander of the New York Blood Center that, "During the past decade research in coagulation, one of the vital homeostatic functions, has been in a state of intense ferment.... Knowledge has come from many disciplines--human and comparative physiology, biochemistry, physical chemistry, animal husbandry, pathology, genetics and, not least, clinical investigation--reflecting the multifaceted background required of the student of this subject."[6]

The inclusion of several papers which appeared in journals of biochemical science may be disputed. Some of these decisions were rather arbitrary in order to keep each of the three lists in the 1950s series to a manageable size. One wonders why article 4 on purification of fibrinogen was published in a chemical journal. But I suppose that if every paper appeared in the most logical journal there'd be less reason to read *Current Contents®* .

1. **Garfield E.** Highly cited articles. 39. Biochemistry papers published in the 1950s. *Current Contents* No. 26, 27 June 1977, p. 5-12.
2. ----------. Highly cited articles. 38. Physics and chemistry papers published in the 1950s. *Current Contents* No. 23, 6 June 1977, p. 5-9.
3. ----------. Highly cited articles 37. Biomedical articles published in the 1940s. *Current Contents* No. 13, 28 March 1977, p. 5-12.
4. ----------. Highly cited classics of 19th and 20th centuries. *Current Contents* No. 21, 24 May 1976, p. 5-9.
5. **Davies R E.** Personal communication, 10 June 1977.
6. **Alexander B.** Medical Progress: coagulation, hemorrhage and thrombosis. *New England Journal of Medicine* 252:432-42, 1955.