

Highly Cited Articles. 26.
Some Classic Papers of the
Late 19th and Early 20th Centuries

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Recently we presented a list of highly cited papers published in 1974.¹ To assemble the list, our computer was programmed to search for citations of '74' papers appearing in the *Science Citation Index*[®] (*SCI*[®]). The programming instruction seemed adequate until we discovered that one '74' paper could not be found in the 1974 *SCI Source Index*. Although most chemists could probably have told us why immediately, my bibliographic assistant had to do a brief investigation to explain the apparent anomaly. The article had not been published in 1974. Rather it turned out to be a 100 year old classic--Le Bel's paper on optical rotation of solutions.² A spate of research and publication during the centennial year had caused this primordial contribution to be cited more than a dozen times.

Most articles are cited only a few times. Most of this occurs within two or three years after publication. Less than 1% of all papers cited will be cited ten or more times in any annual *SCI*. We keep track of those that are. Out of the more than 40 million citations we have

processed for the *SCI* during the past fifteen years, there are about 116,400 articles that have been cited ten times or more in any one year. Almost 80% of these articles were published during the past fifteen years. About 20% were published before 1961, and 0.43% before 1930.

The 'Le Bel anomaly' prompted me to scan the list for other highly cited articles published before 1930. Out of 500, 58 of them proved to have been cited 100 or more times. And all of these 58 were still being cited in 1974 and 1975. In most cases, they were still being cited more often than most new articles will ever be cited.

The list of 58 articles follows. They were published from 1896 to 1929. For each paper listed, we have provided the total citation count for 1961-1975, and for the two-year period 1974-1975.

There can be no doubt that these 58 papers are classics. Ten of the 73 authors involved are Nobel laureates. Twenty-six are biographed in the *Encyclopaedia Britannica*.³ A check of other encyclopedias would turn up more biographies, since the

ARTICLES PUBLISHED 1896-1929
HIGHLY CITED 1961-1975

Item	↓	Times Cited 1961-1975	↓	Times Cited 1974-1975	Bibliographical Data
1.	↓	150	↓	(26)	Starling E H. On the absorption of fluids from the connective tissue spaces. <i>J. Physiology</i> 19:312-26, 1896.
2.	↓	105	↓	(13)	Stewart G N. Researches on the circulation time and on the influences which affect it. <i>J. Physiology</i> 22:159-83, 1897.
3.	↓	234	↓	(29)	Bayliss W M. On the local reactions of the arterial wall to changes of internal pressure. <i>J. Physiology</i> 28:220-31, 1902.
4.	↓	131	↓	(26)	Purdie T & Irvine J C. The alkylation of sugars. <i>J. Chem. Soc.</i> 83:1021-37, 1903.
5.	↓	206	↓	(49)	* Einstein A. Ueber die von der molekularkinetischer Theorie der wärme-geförderte Bewegung von in ruhenden Flüssigkeiten suspendierter Teilchen (Molecular-kinetic theoretic aspects of the motion caused by heat of particles suspended in motionless fluids). <i>Ann. Physik</i> 17:549-60, 1905.
6.	↓	181	↓	(21)	* Dale H H. On some physiological actions of ergot. <i>J. Physiology</i> 34:163-206, 1906.
7.	↓	227	↓	(54)	* Einstein A. Eine neue Bestimmung der Moleküldimension (A new method of determining molecular dimension). <i>Ann. Physik</i> 19:289-306, 1906.
8.	↓	521	↓	(98)	Mie G. Beiträge zur Optik trüber Medien, speziell kolloidaler Metallösungen (Contribution on optical properties of turbid solutions, with special reference to colloid metallic solutions). <i>Ann. Physik</i> 25:377-445, 1908.
9.	↓	105	↓	(15)	Hudson C S. The significance of certain numerical relations in the sugar group. <i>J. Amer. Chem. Soc.</i> 31:66-86, 1909.
10.	↓	103	↓	(21)	* Einstein A. Theorie der Opaleszenz von homogenen Flüssigkeiten und Flüssigkeitsgemischen in der Nähe des kritischen Zustandes (Theoretical aspects of the opalescence of homogeneous fluids and fluid mixtures near the critical point). <i>Ann. Physik</i> 33:1275-98, 1910.
11.	↓	158	↓	(39)	* Einstein A. Berichtigung zu meiner Arbeit, Eine neue Bestimmung der Moleküldimension (Correction to my paper on determination of molecular dimension). <i>Ann. Physik</i> 34:591-92, 1911.
12.	↓	109	↓	(33)	* Hill A V. The combinations of hemoglobin with oxygen and with carbon monoxide. I. <i>Biochemical Journal</i> 7:471-80, 1913.
13.	↓	309	↓	(24)	Lee R I & White P D. A clinical study of the coagulation time of blood. <i>Amer. J. Med. Sci.</i> 145:495-503, 1913.
14.	↓	427	↓	(47)	Michaelis L & Menten M L. Die Kinetik der Invertinwirkung (Kinetics of the action of invertine). <i>Biochem. Zschr.</i> 49:333-69, 1913.
15.	↓	170	↓	(32)	Ornstein L S & *Zernike F. Accidental deviations of density and opalescence at the critical point of a single substance. (Communicated by H.A. Lorentz). <i>Proc. Acad. Sci. Amsterdam</i> 17:793-806, 1914.
16.	↓	193	↓	(23)	DuBois D & DuBois E F. A formula to estimate the approximate surface area if height and weight be known. <i>Arch. Internal Med.</i> 17:863-71, 1916.
17.	↓	120	↓	(23)	* Lord Rayleigh (Strutt J W). On convection currents in a horizontal layer of fluid when the higher temperature is on the underside. <i>Philosophical Magazine</i> 32:529-46, 1916.

18. 214 (53) **Smoluchowski M von.** Versuch einer mathematischen Theorie der Koagulationskinetik kolloidaler Lösungen (Trial mathematical theory of coagulation kinetic in kolloid solutions). *Zschr. Phys. Chem.* 92:129-68, 1917.
19. 171 (32) ***Langmuir I.** The adsorption of gases on plane surfaces of glass, mica, and platinum. *J. Amer. Chem. Soc.* 40:1361-1403, 1918.
20. 360 (28) **Folin O & Hsien W.** A system of blood analysis. *J. Biol. Chem.* 38:81-93, 1919.
21. 119 (17) **Harkins W D & Brown F E.** The determination of surface tension (free surface energy), and the weight of falling drops; the surface tension of water and benzene by the capillary height method. *J. Amer. Chem. Soc.* 41:499-524, 1919.
22. 209 (45) ***Born M.** Volumen und Hydratationswärme der Ionen (Volume and hydration heat of ions). *Zschr. Physik* 1:45-48, 1920.
23. 220 (47) **Ewald P P.** Die Berechnung optischer und elektrostatischer Gitterpotentiale (Calculation of optic and electrostatic lattice potential). *Ann. Physik* 64:253-87, 1921.
24. 500 (101) **Griffith A A.** The phenomena of rupture and flow in solids. *Phil. Trans. Royal Soc. London A.* 221:163-98, 1921.
25. 273 (52) **McIlvaine T C.** A buffer solution for colorimetric comparison. *J. Biol. Chem.* 49:183-86, 1921.
26. 106 (23) **Prausnitz C & Küstner H.** Studien über die Ueberempfindlichkeit (Studies on hypersensitivity). *Zbl. Bakt. Parasitenk. I.* 86:160-69, 1921.
27. 166 (30) ***Fleming A.** On a remarkable bacteriolytic element found in tissues and secretions. *Proc. Royal Soc. London B* 93:306-17, 1922.
28. 145 (39) **Friedel G.** États mésomorphes de la matière (Mesomorphic states of matter). *Ann. Physique* 18:273-74, 1922.
29. 170 (26) **Long J A, Evans H M.** The oestrus cycle in the rat and its associated phenomena. *Mem. Univ. California* 6:1-148, 1922.
30. 242 (48) ***Debye P & Hückel E.** Zur Theorie der Elektrolyte. I. Gefrierpunktniedrigung und verwandte Erscheinungen (On theory of electrolytes. I. Lowering of the freezing point and associated phenomena). *Phys. Zschr.* 24:185-206, 1923.
31. 303 (22) **Hagedorn H C & Jensen B N.** Zur Mikrobestimmung des Blutzuckers mittels Ferricyanid (Microdetermination of blood sugar using ferricyanide). *Biochem. Zschr.* 135:46-58, 1923.
32. 106 (25) **Taylor G I.** Stability of a viscous liquid contained between two rotating cylinders. *Phil. Trans. Royal Soc. London A.* 223:289-343, 1923.
33. 192 (12) **Koch F C & McMeekin T L.** A new direct Nesslerization micro-Kjeldahl method and a modification of the Nessler Folin reagent for ammonia. *J. Amer. Chem. Soc.* 46:2066-69, 1924.
34. 1176 (77) **VanSlyke D D & McNeill J M.** The determination of gases in blood and other solutions by vacuum extraction and manometric measurement. I. *J. Biol. Chem.* 61:523-73, 1924.
35. 376 (43) **Abbott W S.** A method for computing the effectiveness of insecticides. *J. Econ. Entomology* 18:265-67, 1925.
36. 106 (28) **Adair G S.** The hemoglobin system. VI. The oxygen dissociation curve of hemoglobin. *J. Biol. Chem.* 63:529-45, 1925.
37. 391 (21) **Clark E P & Collip J B.** A study of the Tisdall method for the determination of blood serum calcium with a suggested modification. *J. Biol. Chem.* 63:461-64, 1925.
38. 7395 (991) **Fiske C H & Subbarow Y.** The colorimetric determination of phosphorus. *J. Biol. Chem.* 66:375-400, 1925.
39. 224 (18) **Gilman H & Schulze F.** A qualitative color test for the Grignard reagent. *J. Amer. Chem. Soc.* 47:2002-05, 1925.

40. 129 (17) **Job P.** Étude spectrographique de la formation des complexes en solution et de leur stabilité (Spectrographic study of complex formation in solution and of their stability). *Comptes Rendus Acad. Sci.* **180**:928-30, 1925.
41. 106 (29) **Dawson A B.** A note on the staining of the skeleton of cleared specimens with alizarin red S. *Stain Technology* **1**:123-24, 1926.
42. 115 (16) **Frumkin A N.** Ueber die Beeinflussung der Adsorption von Neutralmolekülen durch ein elektrisches Feld (Adsorption of neutral molecules in an electric field). *Zschr. Physik* **35**:792-802, 1926.
43. 491 (63) **Guggenheim E A.** On the determination of the velocity constant of a unimolecular reaction. *Philosophical Magazine* **2**:538-43, 1926.
44. 105 (6) **Lohmann K & Jendrusik L.** Kolorimetrische Phosphorsäurebestimmungen im Muskelextrakt (Colorimetric determination of phosphoric acid in muscle extracts). *Biochem. Zschr.* **178**:419-26, 1926.
45. 272 (49) ***Born M & Oppenheimer R.** Zur Quantentheorie der Molekeln (On the quantum theory of molecules). *Ann. Physik* **84**:457-84, 1927.
46. 791 (78) **Folin O & Ciocalteu V.** On tyrosine and tryptophane determination in proteins. *J. Biol. Chem.* **73**:627-49, 1927.
47. 126 (39) **Fowler R H & Nordheim L.** Electron emission in intense electric fields. *Proc. Royal Soc. London A Math.* **119**:173-80, 1928.
48. 174 (8) **Glaze J A.** The associative value of non-sense syllables. *J. Genetic Psychology* **35**:255-67, 1928.
49. 1026 (133) **Job P.** Recherches sur la formation de complexes minéraux en solution, et sur leur stabilité (Studies on mineral complex formation in solution and their stability). *Ann. Chimie* **9**:113-203, 1928.
50. 136 (8) **VanSlyke D D & Sendroy J Jr.** Studies of gas and electrolyte equilibria in blood. 15. Line charts for graphic calculations by the Henderson-Hasselbalch equation, and for calculating plasma carbon dioxide content from whole blood content. *J. Biol. Chem.* **79**:781-98, 1928.
51. 251 (21) ***Bethé H A.** Termaufspaltung in Kristallen (Energy level cleavage in crystals). *Ann. Physik* **3**:133-208, 1929.
52. 265 (18) **Fiske C H & Subbarow Y.** Phosphocreatine. *J. Biol. Chem.* **81**:629-79, 1929.
53. 122 (21) **Hylleraas E A.** Neue Berechnung der Energie des Heliums im Grundzustande, sowie des tiefsten Terms von Ortho-Helium (New calculation of the energy of helium in the basic state, including that of the lower energy level of ortho-helium). *Zschr. Physik* **54**:347-66, 1929.
54. 295 (24) **Kinsman J M, Moore J W, & Hamilton W F.** Studies on the circulation. 1. Injection method: physical and mathematical considerations. *Amer. J. Physiology* **89**:322, 1929.
55. 276 (46) **Morse P M.** Diatomic molecules according to the wave mechanics. 2. Vibrational levels. *Physical Review* **34**:57-64, 1929.
56. 105 (21) **Reuss A.** Berechnung der Fließgrenze von Mischkristallen auf Grund der Plazititätsbedingung für Einkristalle. (Calculation of the yield point of mixed crystals on the basis of plasticity conditions in single crystals). *Zschr. Angew. Math. Mech.* **9**:49-58, 1929.
57. 126 (13) **Tonks L & *Langmuir I.** A general theory of the plasma of an arc. *Physical Review* **34**:876-922, 1929.
58. 189 (32) **Van Vleck J H.** On sigma type doubling and electron spin in the spectra of diatomic molecules. *Physical Review* **33**:467-506, 1929.

EB tends to give short shift to natural scientists. Some of these articles are classic methods papers, which we've listed before. Most of the papers take us back to the starting points of great scientific advances. Many of them are identified with eponymic terminology--such as the Prausnitz-Küstner antibody, Ewald's sphere, Friedel's law, the Michaelis-Menten hypothesis, etc.

Twenty-six papers can be called biomedical, 17 physical, and 15 chemical. In the case of the two latter categories, the classification must be very arbitrary, since physical chemistry is heavily represented. Many of the papers reflect contributions of physics and chemistry to biomedicine. Note for example the many papers dealing with crystal structure and molecular dimensions.

I was interested to see that among those who share the status of 'secondary' authorship--some critics of statistical bibliography and bibliometrics worry about the fate of 'secondary' authors--are two Nobelists (papers 15 and 57). Also, it's amusing to learn that neither of

the authors of paper 15, Ornstein and Zernicke, could be present to deliver it. They asked a friend to present it for them. Consequently the paper was "communicated by H.A. Lorentz."

It is interesting that Sir Alexander Fleming is not represented here for the work that got him his Nobel Prize. The paper reporting his fateful observation on mold contamination of a bacterial culture is not on the list.⁴ Paper 27 is Fleming's report of his discovery of lysozyme. Incidentally, we have indicated the Nobel Prize winners with an asterisk.

It would be interesting if the appropriate graduate students would examine the recent citation record for some of these papers to determine whether they are being cited in historical accounts or for reasons directly relevant to the topic involved. After all, why after so many years, aren't citations to them obliterated? I only wish we had the *SCI* for the first half of this century so that we could see how well these papers were cited when they first came out.

1. Garfield E. The 1974 articles most cited in 1974. *Current Contents*® (CC®) No. 8, 23 February 1976. p. 5-8.
2. LeBel J-A. Sur les relations qui existent entre les formules atomiques des corps organiques et lo pouvoir rotatoire de leurs dissolutions (On the relationships between atomic formulas or organic compounds and the optical rotation of their solutions). *Bull. Soc. Chim. France* 22:337-56, 1874.
3. *The New Encyclopaedia Britannica in 30 volumes*. 15th ed. Chicago: Encycl. Brit. Inc., 1974.
4. Fleming A. On bacterial action of cultures of *Penicillium*, with special reference to their use in isolation of *B. influenzae*. *Brit. J. Exp. Pathol.* 10:226-36, 1929. -- This paper has not been cited ten times in any of the years 1961-1975.