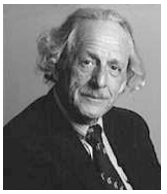
Current Comments



# Most-Cited Articles of the 1960s. 2. Biochemistry and Molecular Biology

Number 35 August 27, 1979

Recently we listed the most-cited physical sciences articles of the 1960s.[1] To continue our discussion of that decade's scientific literature we have now compiled a list of the most-cited biochemistry and molecular biology papers.

These lists of most-cited articles are selected by sorting and ranking the *Science Citation Index®(SCI®)* files for the 18-year period from 1961 to 1978. Over seventy-one million citations to authored items are included in the *SCI* data base for those years.[2] About 11 million of those citations are to papers published during the 1960s. I estimate that over 60,000 biochemistry papers were published during that time.[3] To select a limited number of papers from this massive volume of publication may seem like a futile exercise. Nevertheless, by identifying this sample I think we learn quite a bit about the main directions and logistics of biochemical research in the 60s.

I do not wish to suggest that these articles were the most "important" intellectual contributions to biochemistry in that decade. Many of the papers would qualify as such, but many authors have indicated to us that they published other papers that are more representative of their best work. Nevertheless, I find it hard to believe that it is a coincidence that these authors have so often been recognized by their peers. Put it this way—the authors of highly cited papers also tend to publish other well-cited papers.

In providing the frequency of citation I do not suggest that this is an indicator of relative "value." In the case of a theoretical paper it may be an indication of impact or influence. For a widely used method paper it may simply indicate just that. Citation data may be the only convenient means of determining the impact of a new methodology. Others might prefer to use the annual sales of a particular biochemical reagent or instrument.

If nothing else, citation frequency does allow us to make comparisons between the kinds and amounts of activities symbolized by the articles involved. I hope that the alphabetical arrangement by first author under each category will discourage invidious comparisons.

There are 101 articles listed in Figure 1 which follows this editorial. Originally, I intended to limit the study to 100 articles. Because both parts of Omura's work on liver microsomes appear on the list, I decided to add one more paper.

Every paper on the list was cited more than 564 times during the period 1961-78. Thirty-nine were cited more than 1000 times and 11 more than 2000 times. The average paper received 1294 citations. This means that it was cited at least 72 times per year. You can better appreciate the significance of this number when you consider that the average article published in a journal covered by *SCI* during this period received 3.28 citations. However, for biochemistry papers one would expect

this figure to be doubled because the average biochemistry paper now contains twice as many references as the average *SCI* paper.

The papers were published in the 25 journals lis'ed in Table 1. Fifty-two were published in five journals: *Journal of Molecular Biology, Journal of Biological Chemistry, Proceedings of the National Academy of Sciences US, Biochemical Journal*, and *Analytical Biochemistry*. None of this will surprise anyone familiar with the field.

**Table 1:** Journals that published the most cited 1960s articles listed in Figure 1, according to number of articles.

| Journal | No. of Articles |
|---|---|
| J. Mol. Biol. | 14 |
| J. Biol. Chem. | 12 |
| Proc. Nat. Acad. Sci. US | 9 |
| Biochem. J. | 9 |
| Anal. Biochem. | 8 |
| Biochemistry | 6 |
| Science | 6 |
| Arch. Biochem. Biophys. | 6 |
| Biochem. Biophys. Acta | 5 |
| Nature | 5 |
| Biochem. Biophys. Res. Commun. | 3 |
| J. Lipid Res. | 3 |
| Ann. NY Acad. Sci. | 2 |
| J. Histochem. Cytochem. | 2 |
| Acta Chem. Scand. | 1 |
| Anal. Chem. | 1 |
| Biochem. Zeit. | 1 |
| Biophys. J. | 1 |
| Eur. J. Biochem. | 1 |
| J. Am. Chem. Soc. | 1 |
| J. Am. Oil Chem. Soc. | 1 |
| J. Biochem.—Tokyo | 1 |
| J. Cell Biol. | 1 |
| J. Chromatography | 1 |
| Mol. Pharmacol. | 1 |

*Predecessor of Eur. J. Biochem.

However, this is hindsight judgment. If we consider that the first issue of the *Journal of Molecular Biology* appeared in 1959, and the first issue of *Analytical Biochemistry* in 1960, it seems unusual that they accounted for such a large proportion of the most-cited papers of the 1960s. I can well remember when Kurt Jacoby and Roselle Coviello started *Analytical Biochemistry* for Academic Press with the late Dr. Alvin Nason as its founding editor.[4] I know that he and Jim Barsky, who joined the editorial board of Academic Press in 1963, took special pride in the rapid success of this journal.

Dr. N.O. Kaplan of the University of California at San Diego, co-chairman of the editorial committee of *Analytical Biochemistry*, attributes its success to the fact that it concentrates solely on publishing methodology papers. Furthermore, the papers are reviewed quite carefully, and only those describing novel methods or developments are accepted.[5] I hasten to point out that its impact factor is not significantly different from other high impact journals. Therefore, most methodology papers it published did not achieve such high use. Methodology papers often appear among articles that are most-cited, but not all methodology papers are heavily cited.

Dr. S. Brenner of the Medical Research Council of the UK was one of the founding editors of the *Journal of Molecular Biology*. He says the success of the journal can be accounted for relatively simply. The number of leading figures in the field was not large in 1959. This made it possible for the editors to contact most of them directly. So, the journal was founded with the support of most of the people who were active and interested in the field. Subsequently, they all published in *Journal of Molecular Biology*.[6] But one could say this about many other less successful journals. The widespread and rapid impact of molecular biology is also part of the story. Certainly the *Journal of Molecular Biology* was there at the right time. But I've often wondered why it took so long after the Watson-Crick paper[7] for this to occur.

*Biochemistry*, published by the American Chemical Society, was started in 1964. The six papers it contributed are equivalent to nine or ten from a journal established before 1960. This journal, like most of the journals on this list, is a high impact journal.

Seventy-three papers on the list have two or more authors. Forty-two have two, 20 have three, and nine have four.

One paper has six authors and one has eight. The total number of authors appearing on the list is 222. Only 28 papers were written by one author. This is quite a change from the situation in the forties.[8] All papers on the list are written in English, except H. Wagner's paper in German on the separation of phospholipids by chromatography. This was published in *Biochemische Zeitschrift*, the predecessor to the *European Journal of Biochemistry*.

Sixty-three institutions (shown in Table 2) are represented on the list. Just nine institutions account for 92 of the 222 authors. The list is dominated by American laboratories, which account for 39 of the 63 research institutions. The United Kingdom follows with nine, Sweden with six, and Australia and Japan are represented by two institutions each. France, the Federal Republic of Germany, Italy, Switzerland, and Taiwan are represented by one each.

Eighteen authors have two or more papers on the list. B.N. Ames, P. Andrews, J.P. Changeux, W.W. Cleland, P. Doty, A.D. Hershey, F. Jacob, C.B. Laurell, S. Moore, M. Nirenberg, T. Omura, K.A. Piez, R.A. Reisfeld, R. Sato, and S. Spiegelman each wrote two papers. R.J. Britten, J. Marmur, and J. Monod each wrote three papers.

Thirteen papers were authored by eleven Nobel laureates. E.L. Tatum was awarded the prize for medicine in 1958 for his work on genes and heredity. The 1958 prize for chemistry went to F. Sanger for his work on the chemical composition of insulin. M.F. Perutz received the 1962 chemistry prize for defining the structure of proteins. F. Jacob and J. Monod shared the 1965 medicine prize for their study of cellular mechanisms controlling enzymes and virus synthesis. The 1968 prize for medicine was awarded to M.W. Nirenberg and R.W. Holley for their work on the genetic code and enzymes. A. D. Hershey was awarded the 1969 medicine prize for his investigation of the genetic structure of viruses. The 1972 prize for chemistry was awarded to S. Moore, W.H. Stein, and C.B. Anfinsen for their work on enzymes.

In a study I did with Irv Sher in 1965 we showed that articles written by Nobel laureates were highly cited long before they received the prize.[9] That is why we believed citation data had some forecasting value. This is true for eight of the eleven Nobel laureates on the list. E.L. Tatum received the prize in 1958. He appeared on our list of most-cited biomedicine papers of the 1940s, years before he was awarded the Nobel Prize.[10] However, his most-cited paper was published in 1962. The same is true of F. Sanger. He received the prize in 1958 and his most-cited paper was published in 1965. Sanger appeared on our list of most-cited biochemistry papers of the 1940s.[8] Lastly, M.F. Perutz received the prize in 1962. His most-cited paper appeared in 1968. Thus, as Harriet Zuckerman[11] has pointed out, many Nobel laureates continue to make highly cited contributions to science in the years before and after their award.

Ten of the articles listed have appeared as *Citation Classics* in *Current Contents®* *(CC®)*. Since most *CC* readers are familiar with this feature, I will not elaborate any further.

On the whole, methodology papers dominate the list, accounting for 68 of the 101 articles. Unquestionably, methods are the backbone of scientific research. David Gillespie of the National Cancer Institute suggests two reasons why a particular method paper is highly cited. He says, "The distinction between a classic and a quickly outmoded method lies in the ability of the investigators to see the uses to which the method will be put...and, as importantly, to take heed of the little irregularities that lead to significant improvements."[12]

It is important to note that well-cited methodology papers are in a special class. While most methodology papers do not fare better than other papers, the most successful ones are more heavily

**Table 2.** Institutional affiliations of authors of the most-cited 1960s articles, according to number of authors.

| Institution | | No. of Authors |
|---|---|---|
| National Institutes of Health | | 26 |
| National Institute of Arthritis & Metabolic Diseases | 8 | |
| National Heart Institute | 8 | |
| National Institute of Dental Research | 2 | |
| National Cancer Institute | 4 | |
| National Institute of Allergy & Infectious Diseases | 2 | |
| unspecified | 2 | |
| Harvard Univ. (Cambridge, MA) | | 11 |
| Dept. Chem. | 6 | |
| Biol. Labs. | 3 | |
| Med. Sch. | 2 | |
| Med. Res. Council, UK | | 10 |
| MRC, Univ. Cambridge, England | 9 | |
| MRC, Harwell, England | 1 | |
| Rockefeller Univ. (New York, NY) | | 10 |
| Carnegie Inst. Washington (Washington, DC) | | 9 |
| Dept. Terrestrial Magnetism | 5 | |
| Dept. Genet., Cold Spring Harbor, NY | 4 | |
| Inst. Pasteur (Paris, France) | | 7 |
| Univ. Pittsburgh (Pittsburgh, PA) | | 7 |
| Dept. Biochem. & Nutrit. | 4 | |
| Sch. Med. | 3 | |
| Michigan State Univ. (East Lansing, MI) | | 6 |
| NYU Sch. Med. (New York, NY) | | 6 |
| Dept. Microbiol. | 4 | |
| Dept. Ophthalmol. | 1 | |
| Dept. Biochem. | 1 | |
| California Inst. Technol. (Pasadena, CA) | | 5 |
| Div. Biol. | 2 | |
| N.W. Church Lab. Chem. Biol. | 3 | |
| Columbia Univ. (New York, NY) | | 5 |
| Dept. Biochem. | 2 | |
| Dept. Microbiol. | 3 | |
| Cornell Univ. (Ithaca, NY) | | 5 |
| Dept. Biochem. | 4 | |
| Med. Coll. | 1 | |
| Massachusetts Inst. Technol. (Cambridge, MA) | | 5 |
| Public Health Res. Inst. City of New York | | 5 |
| Univ. California | | 5 |
| Davis, Dept. Food Sci. & Tech. | 3 | |
| Davis, Dept. Bioch. & Biophys. | 2 | |
| Univ. Illinois (Urbana, IL) | | 5 |
| Brandeis Univ. (Waltham, MA) | | 4 |
| City of Hope Med. Ctr. (Duarte, CA) | | 4 |
| Johns Hopkins Sch. Med. (Baltimore, MD) | | 4 |
| Dept. Med. | 2 | |
| Dept. Biophys. | 1 | |
| McCollum Pratt Inst. | 1 | |
| Mt. Sinai Hosp. (New York, NY) | | 4 |
| Cell Res. Lab. | 2 | |
| Div. Neuropathol. | 2 | |
| Oak Ridge Nat. Lab. (Oak Ridge, TN) | | 4 |
| Osaka Univ. (Osaka, Japan) | | 4 |
| US Dept. Agriculture | | 4 |
| Univ. Wisconsin (Madison, WI) | | 4 |
| Biophys. Lab. & Dept. Biochem. | 2 | |
| Coll. Agriculture | 1 | |
| Dept. Biochem. | 1 | |
| Brookhaven Nat. Lab. (Upton, NY) | | 3 |
| Merck Sharp & Dohme Res. Labs. (Rahway, NJ) | | 3 |
| Stanford Univ. Sch. Med. | | 3 |
| Univ. Munich (Munich, FRG) | | 3 |
| Univ. Pennsylvania (Phila., PA) | | 3 |
| Duke Univ. Med. Ctr. (Durham, NC) | | 2 |
| Karolinska Inst. (Stockholm, Sweden) | | 2 |
| National Inst. Res. Dairying (Shinfield, England) | | 2 |
| Sloan-Kettering Inst. Cancer Res. (Rye, NY) | | 2 |
| St. Mary's Hosp. Med. Unit (London, England) | | 2 |
| St. Vincent Sch. Med. Res. (Melbourne, Australia) | | 2 |
| Univ. Cambridge (Cambridge, England) | | 2 |
| Physiol. Lab. | 1 | |
| Dept. Biochem. | 1 | |
| Univ. Glasgow (Glasgow, Scotland) | | 2 |
| Univ. Iowa (Iowa City, IA) | | 2 |
| Univ. Kentucky (Lexington, KY) | | 2 |
| Univ. Lund (Sweden) | | 2 |
| Univ. Southampton (Southampton, England) | | 2 |
| Univ. Stockholm, Wenner-Gren. Inst. (Stockholm, Sweden) | | 2 |
| Univ. Uppsala (Uppsala, Sweden) | | 2 |
| Univ. Virginia Sch. Med. (Charlottesville, VA) | | 2 |
| Yale Univ. (New Haven, CT) | | 2 |
| Albert Einstein Coll. Med. (New York, NY) | | 1 |
| Chalmers Inst. Technol. (Gothenburg, Sweden) | | 1 |
| Howard Hughes Med. Inst. (Miami, FL) | | 1 |
| Inst. Cancer Res., Chester Beatty Res. Inst., Royal Cancer Hosp. (London, England) | | 1 |
| Ist. Regina Elena (Rome, Italy) | | 1 |
| Nat. Taiwan Univ. (Taipei, Taiwan) | | 1 |
| New York Blood Ctr. (New York, NY) | | 1 |
| Nobel Med. Inst. (Stockholm, Sweden) | | 1 |
| Swiss Inst. Experimental Cancer Res. (Lausanne, Switzerland) | | 1 |
| Tohoku Pharmaceut. Sch. (Sendai, Japan) | | 1 |
| Univ. Adelaide (Australia) | | 1 |
| Univ. Colorado Med. Ctr. (Boulder, CO)* | | 1 |
| Univ. Edinburgh (Scotland) | | 1 |
| Univ. Miami (Miami, FL)* | | 1 |
| Univ. Rochester Sch. Med. Dentistry (Rochester, NY) | | 1 |
| Univ. Tennessee (Knoxville, TN) | | 1 |
| Wellcome Res. Labs. (Beckhenham, England) | | 1 |
| Woods Hole Marine Biol. Lab. (Woods Hole, MA) | | 1 |

*Second affiliation for a single authored paper.

cited than theoretical papers. Thus it would be expected that they would dominate a list that represents about one out of every six hundred published in biochemisry during the 60s.[3]

As you can see, the list has been divided into several categories—nucleic acids, protein structure, enzymology, electrophoresis, chromatography, centrifugation/sedimentation, and miscellaneous. These categories are not meant to be definitive. A simple arrangement by journal might have been equally useful.

The titles of most papers provide a better capsule description than I could provide in the space available. The rapid growth of molecular biology is reflected in the first group of 25 papers on the nucleic acids, DNA, and RNA. Seven deal with the gene's role in protein and RNA synthesis. The Jacob and Monod paper is a good example of a review article that contains new and important ideas not apparent in the sources under review. In this paper they suggested the now familiar concept of a *messenger RNA*. For this Jacob and Monod were awarded the Nobel prize in 1965.

Considering that seven papers are concerned with proteins one wonders why there is not a journal named *Protein*. Included in this group are three papers on protein structure and three on their binding properties.

Eleven papers are on enzymes, specialized proteins that accelerate or inhibit biochemical reactions. Five papers describe the preparation and properties of a variety of enzymes. Two discuss enzyme kinetics and rate equations. Two more papers discuss allosteric enzymes in bacterial metabolism.

The emphasis on methodology is reflected in the large number of papers on electrophoresis, chromatography, centrifugation, and other techniques for separating large molecules. There are 16 papers on electrophoresis alone! The papers by Davis and Ornstein on disc electrophoresis and the paper by Weber and Osborn on gel electrophoresis, among others, bring out certain points about citation frequencies above the 564 threshold. It should be clear that no greater intellectual significance should be attributed to these papers than to others on the list simply because they were cited more than 9,000 times. Many people have to be reminded of this lest they take citation counts at face value. However, the economic and policy implications of such widespread use of a new technique does tell science administrators how to make research more efficient. I should think that any future discovery that would displace these methods could have enormous impact.

The paper by Weber and Osborn is in fact the most-cited on the list. "The reliability of molecular weight determinations by dodecyl sulfate-polyacrylamide gel electrophoresis" was cited 9,509 times in just ten years since its publication in 1969. The authors experimentally confirm that electrophoresis can accurately determine the *molecular weights* of polypeptide protein chains. There are in fact only a small number of papers or books in the entire history of science cited more than 2,000 times. The classic example is the Lowry method for protein determination. What is not clear here is why people continue to cite those methods explicitly and not cite others.

Seventeen papers discuss one or more aspect of chromatography. Clearly large numbers of scientists need to estimate the molecular weights of proteins, and many use the sephadex gel-filtration method described by Andrews.

Five papers deal with centrifugation/sedimentation techniques which are instrumental in studies of protein synthesis, where RNA molecules of different size and weight must be distinguished.

The remaining 20 papers cover miscellaneous topics and methods including quantitative estimations of

biochemical substances in tissue or fluids. Three papers discuss various aspects of human and animal hemoglobin. One paper details the electron transport system in the outer membrane of liver mitochondria. Other areas dealt with include the incorporation of radioactive amino acids into proteins, the determination of cystine as cysteic acid, and a scintillation machine that measures the amount of radioactive material in biological fluids.

In the near future I will provide an additional list of life science papers of the 1960s. These will cover all aspects of biomedical research except biochemistry. Following that I hope to cover clinical papers.

I'm sure you can understand the frustration I experience in having to cut these lists off at an arbitrary point, knowing there are many additional important papers that should be listed. Science is such big business these days that even a listing of 1,000 papers would leave out many key people. So there must be an arbitrary cut-off point. *Current Contents* can't provide unlimited space for this information. That is why I look forward to our *Atlas of Science.*[13] In it we expect to identify almost every significant paper for each field and period studied. Since it has been four years since I first mentioned this project I should add that we hope to complete that project during the next year.



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**Figure 1:** 101 most-cited articles of the 1960s in biochemistry and molecular biology. Authors' affiliations follow each citation. If an article has appeared as a *Citation Classic*, a reference follows the author affiliations.

| *Total* Citations 1961-1978 | Bibliographic Data |
|---|---|
| **NUCLEIC ACIDS (DNA/RNA)** | |
| 1005 | **Ames B N & Dubin D T.** The role of polyamines in the neutralization of bacteriophage DNA. *J. Biol. Chem.* 235:769-75, 1960. NIH, NIAMDD, Bethesda, MD 20014 |
| 641 | **Britten R J[1] & Davidson E H[2].** Gene regulation for higher cells: a theory. *Science* 165:349-57, 1969. (1) Carnegie Inst. of Washington, Dept. Terr. Magnet., Washington, DC 20015 (2) Rockefeller Univ., New York, NY 10021 |
| 1441 | **Britten R J & Kohne D E.** Repeated sequences in DNA. *Science* 161:529-40, 1968. Carnegie Inst. of Washington, Dept. Terr. Magnet., Washington, DC 20015 |

740 **Burgess R R.** A new method for the large scale purification of *E. coli* DNA-dependent RNA polymerase. *J. Biol. Chem.* 244:6160-7, 1969. Harvard Univ., Biol. Lab., Cambridge, MA 02138

920 **Chamberlin M & Berg P.** DNA-directed synthesis of RNA by an enzyme from *E. coli*. *Proc. Nat. Acad. Sci. US* 48:81-94, 1962. Stanford Univ. Sch. Med., Dept. Biochem., Stanford, CA 94305

760 **Fleck A & Munro H N.** The precision of ultraviolet absorption measurements in the Schmidt-Thannhauser procedure for nucleic acid estimation. *Biochim. Biophys. Acta* 55:571-83, 1962. Univ. Glasgow, Dept. Biochem., Glasgow, Scotland

724 **Giles K W & Myers A.** An improved diphenylamine method for the estimation of DNA. *Nature* 206:93, 1965. Univ. Southampton, Dept. Botany, Southampton, England

1513 **Gillespie D & Spiegelman S.** A quantitative assay for DNA-RNA hybrids with DNA immobilized on a membrane. *J. Mol. Biol.* 12:829-42, 1965. Univ. Illinois, Dept. Microbiol., Urbana, IL 61801 [Citation Classics. *Current Contents* (11):14, 14 March 1977.]

753 **Hirt B.** Selective extraction of polyoma DNA from infected mouse cell cultures. *J. Mol. Biol.* 26:365-69, 1967. Swiss Inst. for Exp. Cancer Res., Lausanne, Switzerland

611 **Holley R W, Apgar J, Everett G A, Madison J T, Marquisee M, Merrill S H, Penswick J R & Zamir A.** Structure of a ribonucleic acid. *Science* 147:1462-5, 1965. US Dept. Agric., Plant, Soil and Nutr. Lab., Washington, DC 20250 and Cornell Univ., Dept. Biochem., Ithaca, NY 14853

713 **Huang R C & Bonner J.** Histone, a suppressor of chromosomal RNA synthesis. *Proc. Nat. Acad. Sci. US* 48:1216-22, 1962. Calif. Inst. Technol., Div. Biol., Pasadena, CA 91125 [Citation Classics. *Current Contents* (12):9, 20 March 1978.]

630 **Hurwitz J, Furth J J, Malamy M & Alexander M.** The role of DNA in RNA synthesis. 3. The inhibition of the enzymatic synthesis of RNA and DNA by actinomycin D and proflavin. *Proc. Nat. Acad. Sci. US* 48:1222-30, 1962. New York Univ. Sch. of Med., Dept. Microbiol., New York, NY 10012

2433 **Jacob F & Monod J.** Genetic regulatory mechanisms in the synthesis of proteins. *J. Mol. Biol.* 3:318-56, 1961. Inst. Pasteur, Paris, France

695 **Lerman L S.** Structural considerations in the interaction of DNA and acridines. *J. Mol. Biol.* 3:18-30, 1961. MRC Unit. Mol. Biol., Univ. Cambridge, Cambridge, England and Univ. Colorado Med. Ctr., Denver, CO 80208

736 **Lyon M F.** Gene action in the X-chromosome of the mouse (*MUS musculus L.*). *Nature* 190:372-3, 1961. MRC, Radiobiol. Res. Unit, Harwell, England

3978 **Marmur J.** A procedure for the isolation of DNA from micro-organisms. *J. Mol. Biol.* 3:208-18, 1961. Harvard Univ., Dept. Chem., Cambridge, MA 02138

1134 **Marmur J & Doty P.** Determination of the base composition of DNA from its thermal denaturation temperature. *J. Mol. Biol.* 5:109-18, 1962. Harvard Univ., Dept. Chem., Cambridge, MA 02138

957 **Nirenberg M W & Leder P.** RNA codewords and protein synthesis. *Science* 145:1399-407, 1964. NIH, Bethesda, MD 20014

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749 **Radloff R, Bauer W & Vinograd J.** A dye-buoyant-density method for the detection and isolation of closed circular duplex DNA: the closed circular DNA in HeLa cells. *Proc. Nat. Acad. Sci. US* 57:1514-21, 1967. Calif. Inst. Technol., Lab Chem. Biol., Pasadena, CA 91125

680 **Reich E, Franklin R M, Shatkin A J & Tatum E L.** Action of actinomycin D on animal cells and viruses. *Proc. Nat. Acad. Sci. US* 48:1238-45, 1962. Rockefeller Univ., New York, NY 10021

1117 **Schildkraut C L, Marmur J & Doty P.** Determination of the base composition of DNA from its buoyant density in CsCl. *J. Mol. Biol.* 4:430-43, 1962. Harvard Univ., Dept. Chem., Cambridge, MA 02138

710 **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. Oak Ridge Nat. Lab., Biol. Div., Oak Ridge, TN 37830

564 **Warner J R, Knopf P M & Rich A.** A multiple ribosomal structure in protein synthesis. *Proc. Nat. Acad. Sci. US* 49:122-9, 1963. MIT, Dept. Biol., Cambridge, MA 02139 [Citation Classics. *Current Contents* (41):11, 10 October 1977.]

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1242 **Crestfield A M, Moore S & Stein W H.** The preparation and enzymatic hydrolysis of reduced and S-carboxymethylated proteins. *J. Biol. Chem.* 238:622-7, 1963. Rockefeller Univ., New York, NY 10021

910 **Edelhoch H.** Spectroscopic determination of tryptophan and tyrosine in proteins. *Biochemistry* 6:1948-54, 1967. NIH, NIAMDD, Clin. Endocrinol. Br., Bethesda, MD 20014

1114 **Edman P & Begg G.** A protein sequenator. *Eur. J. Biochem.* 1:80-91, 1967. St. Vincent's Sch. Med. Res., Melbourne, Australia

851 **Huxley H E.** Electron microscope studies on the structure of natural and synthetic protein filaments from striated muscle. *J. Mol. Biol.* 7:281-308, 1963. MRC, Lab. of Mol. Biol., Cambridge, England

695 **Koshland D E, Nemethy G & Filmer D.** Comparison of experimental binding data and theoretical models in proteins containing subunits. *Biochemistry* 5:365-85, 1966. Brookhaven Nat. Lab., Upton, NY 11973 and Rockefeller Univ., New York, NY 10021

1821 **Omura T & Sato R.** The carbon monoxide-binding pigment of liver microsomes. 1. Evidence for its he oprotein nature. *J. Biol. Chem.* 239:2370-8, 1964. Osaka Univ., Inst. Protein Res., Osaka, Japan

645 **Omura T & Sato R.** The carbon monoxide binding pigment of liver microsomes. 2. Solubilization, purification, and properties. *J. Biol. Chem.* 239:2379-85, 1964. Osaka Univ., Inst. Protein Res., Osaka, Japan

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