Research by Clinical Chemists in the United States
A Statistical Analysis

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Publications listed in Chemical Abstracts (1962-1966) for 1539 members of the American Association of Clinical Chemists have been analyzed statistically by the "Product of Factors Law" as developed by Zener to assess research productivity. The observed data agreed well with a theoretical distribution curve for research productivity derived from the use of seven individual, uniform, statistically independent factors. The three personal factors of success in research productivity are tentatively identified as curiosity, ability to learn, and intellectual vigor. Adequate time, facilities, and technical help, and the presence of stimulating colleagues are possible extrinsic environmental factors governing the characteristic productivity distribution curve observed in this study. During this period, about 65% of the AACC membership had no papers abstracted in Chemical Abstracts and not more than 50 averaged one or more papers per year. Various prevailing scientific and sociological trends are discussed, which soon may improve this perspective.

The unprecedented growth of both basic and applied chemical research has produced correspondingly more important roles for biochemistry and its subspeciality, clinical chemistry. Clinical chemistry seems to be entering a "golden era" because of automation, federal and public attention, and the sound base of achievements in fundamental biochemistry.

The American Association of Clinical Chemists (AACC), organized in 1948, now has some 1700 members, of which about 160 have become certified by the American Board of Clinical Chemistry. This is an opportune time, therefore, to see if clinical chemists are assuming their fair share of the opportunity and responsibility for advancing knowledge in their own field. To date, clinical chemists generally have not had as ready grant support, time, or encouragement by their employers to do research as have academic or even industrial chemists. Thus, in this period of rapid scientific and technical growth, it is of interest to establish what proportion of clinical chemists are active experimenters. This initial attempt was undertaken to supply data on the distribution of research productivity among professional people within clinical chemistry.

The accumulated information should be of value to clinical chemistry researchers and educators, as well as to hospital, medical, and research administrators in planning intelligently what needs to be done if clinical chemistry is to realize fully its potential for basic and applied research (1-3). Such facts are especially timely and significant in view of the widespread (and increasing) concern...
about manpower shortages and proper use of biomedical personnel (4-6).

Procedure

I have based this analysis on the publication record (excluding abstracts, books, and patents) of 1539 members of the AACC as listed in the latest (1962-1966, 7th) "Collective Authors Index" of Chemical Abstracts. Coverage is such that publications in the more important medical journals would also be included.

The names searched were those of members listed in the 1969 Membership Directory of the AACC, excluding honorary and emeritus members and persons with addresses outside of the U.S.2

Credit for multiple-author publications was divided equally (7). For example, each person on a three-author publication received credit for one-third publication. This "weighted" scheme prevents undue credit for people who, simply by virtue of organizational position, may appear as a joint author on a large number of publications.

The format chosen for presenting the data in this report is the "cumulative distribution graph" as proposed by Shockley (7), combined with the theoretical distribution curves developed subsequently by Zener (8, 9).

Results and Discussion

The stepped curve of Figure 1 presents the "weighted" observed cumulative distribution of publication rate during 1962-1966, inclusive, for 1539 members of the AACC. Of these, 990 (64.3%) had no papers abstracted during this five-year period. An additional 24 people (1.6%) had weighted rates of only one-sixth to one-third publications for the entire five years, 145 (9.4%) had a rate of one-half, while 87 (5.7%) were credited with one publication. The cumulative number of authors with a total weighted rate of not more than one publication during 1962-1966 was 1246, a cumulative percentage of 81.0%. One hundred sixty-seven (10.9%) had 11/1 to three publications, 53 (3.4%) had 31/4 to 41/12, and 48 persons (3.1%) had five to 30 publications. Of this latter group, 14 (0.9%) had a weighted publication number of more than 10—that is, at least two publications per year during the five years. Figure 1 also shows the striking range of variation in the rate of publication—the lower and the higher groups differ by a factor of about 20.

Figure 1 is generally similar in shape to the curves for cumulative distribution rate of publication found by Shockley (7), who analyzed the research productivity distribution of professional employees within four representative large research laboratories in government and a university: the Los Alamos Scientific Laboratory, the National Bureau of Standards, Brookhaven National Laboratory, and the Physics Department of Columbia University. He used the measure of research productivity—i.e., "success"—to be the number of papers published during a four-year period.

As pointed out by Shockley, such curves have little resemblance to the symmetrical sigmoid semilog curves for normal (Gaussian) cumulative distribution. For one thing, Figure 1 is concave upwards throughout; for another, it shows a disproportionate number of individuals with publication rates higher than about eight.

Gaussian cumulative distributions are obtained for those natural phenomena in which the measured quantity varies because of the additive effects of a large number of independently varying factors of comparable importance. From the characteristic

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2 Although it would be preferable to survey the latest records (1965-1970), the lack of a "Collective Authors Index" covering this period makes the task of tabulating the data manually year-by-year for five years prohibitively laborious for a single individual. However, consult the Addendum for added information from the 1969 "Authors Index" from which it appears unlikely that a statistical analysis of 1965-1969 publication rates would be significantly different from the figures collected herein. It is to be hoped that future surveys will be formulated to assess more extensively some additional aspects of the question of scientific productivity among clinical chemists.
shape of productivity distribution curves comparable to Figure 1, Shockley deduced that research productivity, as measured by publication rate, increases approximately exponentially (rather than additively) from individual to individual, taken in order of increasing rate. Hence, the theoretical interpretation that success, S, in scientific research may be represented as a product of individual, uniform, statistically independent factors: \( S = f_1 f_2 \ldots f_n \) (with \( S \) seemingly approaching a log normal distribution as the number of factors increases) is known as the “Product Law” for scientific productivity. Moreover, the existence of a “log normal distribution” suggested to Shockley that the logarithm of the rate of publication production may be a manifestation of some fundamental personal attributes.

Zener subsequently developed a theory for use in interpreting Shockley’s data (8). In his theory, “success” (i.e., rate of publication) is represented by a product of statistically independent factors as shown above. However, the probability density \( p(f) \) for each factor \( f_i \) is taken as constant from zero up to a critical value, and is considered to be zero thereafter.

\[
p(f) = \begin{cases} 1, & 0 < f < f^0 \cr 0, & \text{otherwise} \end{cases}
\]

Zener’s “flat factor analysis of performance theory,” which uses three factors, gave a curve that was in excellent agreement with Shockley’s data. These three factors were considered to be curiosity, ability to learn, and intellectual vigor—the fundamental personal traits alluded to by Shockley.

Unfortunately, Shockley’s samples were too small to decisively differentiate Zener’s formulation of success from the more usual log normal formulation. To test the validity of Zener’s theory for the present data (Figure 1), I used log-probability graph paper. On such paper, the cumulative number of authors is expressed on a percentage scale that is distorted to increase the spread on the scale at percentages near the extremes of distribution. Consequently, the ends of a cumulative distribution graph such as Figure 1 are extended so that it becomes a straight line if the distribution itself is normal (Gaussian).

The result is shown in the stepped curve of Figure 2. There is marked disagreement with the log normal law since a straight line does not fit this curve. Contrariwise, the smooth curve of Figure 2 is a “Zener” theoretical productivity curve (seven factors) for the entire range of the observed data on research productivity. The issue of the number of factors associated with different observed rates of publication will be discussed subsequently.

One question that arises is, “Who are the individuals doing most of the research, and how can one account for this?” Although not shown in Figures 1 and 2, the relative number of individuals publishing, as well as the frequency, varied with the membership category. As would be expected, affiliates and associates made very few contributions to the literature. Only a small minority of the AACC membership has a high productivity rate of research. Of the total membership of about 1700, 550 to 600 contribute to the current literature abstracted in Chemical Abstracts. Of this group, about 300 publish not more often than the equivalent of one full paper every five to six years, about 150 average one publication every two to four years, and about 100 average one publication every one to two years. Another 20 average two publications per year, and perhaps 15 more seem consistently to average more than two.

So the data suggest that about 50 AACC members may be classified in the “at least one full publication per year” group. Table 1 summarizes pertinent information on 45 such individuals. Note that 62% of those in this category are not primarily employed directly within hospital or private clinical chemistry laboratories. They are,

![Fig. 2. Cumulative distribution of “weighted” rate of publication for 1539 members of the AACC during 1962-1966, as plotted on log-probability paper (549 authors and 1165 publications)](https://academic.oup.com/clinchem/article-abstract/16/11/877/5679397)
in fact, located in academic, government, and industrial research institutions or in university biomedical and chemistry departments. Such institutions naturally sponsor more research than do clinical laboratories and have more nearly ideal conditions for their professional staff to engage in research and development activities.

Use of number of publications (ignoring their quality) as a measure of research production requires some justification. Every scientist knows individuals who publish (and republish!) large numbers of rather trivial findings; conversely, a few outstanding contributors seem to publish little. Such wide variations may tend to raise doubt about the appropriateness of quantity of publication as a measure of “true” research productivity. This question has been considered carefully by others (7, 11), who find a surprisingly close correlation between quantity of research publication and achievement of eminence as a contributor to the scientific field. Hence, the number of publications an individual has to his credit is, indeed, generally a valid index of his scientific productivity. At least, it is the best simple index known.

How can one explain the finding that the shape of the productivity distribution curve (Figure 2) agrees closely with the theoretical curve for seven factors instead of three, as was the case of the four research laboratories examined by Shockley?

One general principle seems to be evident from the studies of Zener (9) and from the present survey as well: the more heterogeneous the group, the more factors are involved. The greatest homogeneity is found in groups working in a given laboratory that has a single purpose, such as a specialized research institute. Here, three factors appear, as demonstrated by Zener in Shockley’s survey of the four research institutes cited previously. It is quite reasonable to speculate, as Zener has done, that these three human factors of success in research are likely to be curiosity, ability to learn, and intellectual vigor. However, in a more varied group such as the AACC, additional factors begin to impinge on the likelihood of its members becoming prolific researchers. Most clinical chemists are not employed primarily for research, and whatever research is done is a secondary activity, accomplished as conditions may permit. Thus, extrinsic factors presumably must be present in addition to the three personal ones; these would reasonably include adequate time, facilities, technical help, and the presence of stimulating colleagues. In other words, the would-be investigator must be in a proper milieu if he is to exercise his research potentials.

Many factors prevent or hinder clinical chemists from doing more research: their time is predominantly consumed by the administrative and service responsibilities inherent in their position. It is difficult to conduct meritorious research with only the help of laboratory assistants, who usually lack an appropriate educational background in comparison with graduate students and post-doctoral fellows. The controversy continues over the proper roles for pathologists and chemists in clinical laboratories (12). Engineers and physicists are designing automated and mechanized equipment that, some think, may eventually replace not only the technician, but the chemical analyst as well (15). Historically, clinical chemistry has not been a very exact science (a situation that is rapidly changing). These characteristics of the profession are not attractive to scientists who are highly motivated to do research. The opinion prevails that clinical laboratories generally do not afford an environment conducive to creative research.

The aim of “basic” research is to produce new knowledge, without concern for an immediate practical objective, whereas “applied” research is directed toward some definite practical goal, and is often coupled with the improvement or development of a known material or process. Clinical chemistry attracts pragmatists, those who enjoy seeing their findings put to prompt use. Those investigators who specify clinical chemistry as their primary area of specialization seldom publish basic research, but instead the kind that can be immediately used to solve a practical problem. Indeed, this is hardly surprising, because clinical chemists are in a unique position to see where needs exist, and their greatest accomplishments have been in utilizing basic research for practical objectives. Historically, these accomplishments have changed the emphasis in medical practice. The federal government is now recognizing this in a concrete way by supporting clinical chemical research (through the National Institute of General Medical Sciences).

<table>
<thead>
<tr>
<th>Membership class</th>
<th>Age, 1970</th>
<th>Ph.D. or D.Sc.</th>
<th>M.D.</th>
<th>Ph.D. and M.D.</th>
<th>No. papers produced</th>
</tr>
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<tbody>
<tr>
<td>17 Fellows</td>
<td>54</td>
<td>39-71</td>
<td>10</td>
<td>3</td>
<td>145</td>
</tr>
<tr>
<td>28 Members</td>
<td>49</td>
<td>38-65</td>
<td>21</td>
<td>7</td>
<td>280</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>425</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Number with major job affiliation in “service” clinical chemistry laboratories.
A diverse array of specialists publishes articles pertinent to clinical chemistry, and, if one insists on adopting the broadest possible concepts of "clinical chemistry," practically any research report in the life sciences may be envisioned as having potential bearing on clinical chemistry. Hence, the total flow of research related to clinical chemistry originates from the efforts of many workers. Nevertheless, if one accepts the premise that those identifying themselves as clinical chemists also belong to the AACC, we can only conclude that clinical chemists publish rather infrequently, for whatever reasons (although perhaps no more infrequently than chemists in other subspecialties). Our profession suffers accordingly, both in terms of prestige and, more importantly, of the service to mankind that this profession so directly offers.

Since more opportunities present themselves for research in a clinical laboratory than in any other area of medicine (here is where most of the data for diagnosis and treatment is generated and where new bioanalytical needs become apparent) clinical chemists should avail themselves enough of the independent and collaborative research opportunities they have. This critical stage in the development of science and technology would appear to be an appropriate time for them to interest themselves more actively in research; each individual should review his research potentials in relation to his own particular circumstances. Clearly, support of education and research in clinical biochemistry from universities and from governmental, industrial, and private foundations is making it possible for rapid changes to occur. Already these changes have made it easier for clinical chemists to increase and improve their contributions to the fundamental structure of science, to the training of the next generation of clinical chemists, and to the welfare of humanity (14-16).

My aim here has not been to find fault and denigrate, but rather to call attention to these new favorable circumstances, to encourage each clinical chemist to think anew about what he can contribute to his science—and to challenge him to begin at once.

### Table 2. 1969 Chemical Abstracts Listings for 154 Fellows and 985 Members of the AACC

<table>
<thead>
<tr>
<th>Publication rate*</th>
<th>Number (% of total)</th>
<th>Grand total and %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fellows</td>
<td>Members</td>
</tr>
<tr>
<td>0</td>
<td>105 (68)</td>
<td>815 (83)</td>
</tr>
<tr>
<td>0.1-0.9</td>
<td>32 (21)</td>
<td>111 (11)</td>
</tr>
<tr>
<td>1.0-2.5</td>
<td>14 (9)</td>
<td>53 (5)</td>
</tr>
<tr>
<td>2.8-4.7</td>
<td>3 (2)</td>
<td>6 (&lt;1)</td>
</tr>
<tr>
<td>Grand totals</td>
<td>154 (100)</td>
<td>985 (100)</td>
</tr>
</tbody>
</table>

* 1969 "weighted" distribution of publication rate.

### Addendum

Table 2 summarizes additional data on 154 fellows and 985 members compiled from the 1969 Chemical Abstract "Authors Index" (associates and affiliates were not tallied since, as noted previously, they contribute sparsely to the literature).

Naturally, data from any given single year are not as representative as the average annual data calculated from a five-year period. However, the records for 1969 appear generally comparable to the average rates estimated from the 1962-1966 bibliographies. An interesting exception is that the 45 individuals listed in Table 1 collectively produced 60 papers in 1969, in contrast to the average of 85 papers per year during 1962-1966.

I thank Professor Clarence Zener for his invaluable mathematical consultation and criticisms, and the opportunity to preview reference 9 before publication. In addition, I thank him for constructing Figure 2, thereby ascertaining the correct number of factors applicable to the data. I also thank Dr. Paul G. Fanas for reviewing the manuscript.

### References