## REMARKS ON MR. SPRAGUE'S SUGGESTION

THE International Rules of Botanical Nomenclature are familiar to botanists. The Type-basis Code was published in SCIENCE (49: 333. 1919; 53: 312. 1921). The differences were summarized by me in the British *Journal of Botany*. In the above article Mr. Sprague proposes a compromise. Personally I am in favor of a compromise along the lines he suggests. Practically this can best be accomplished at the next International Botanical Congress if the subject has been sufficiently considered previously by the taxonomic botanists of the world.

The question naturally arises, how many adherents of the International Rules are disposed to compromise? Mr. Sprague speaks only for himself. On the other hand, how many adherents of the Type-basis Code are willing to compromise? Being chairman of the Committee on Nomenclature of the Botanical Society of America, I must state plainly that in recording my disposition to compromise I am giving my personal views only.

It can not be expected that botanists will commit themselves in advance of a definite proposition formulated at a Botanical Congress. However, much can be gained in a preliminary way by a discussion. I would suggest that taxonomic botanists in America send me a statement of their views on the compromise suggested by Mr. Sprague.

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## SPECIAL ARTICLES

### A COMPARISON OF THE MORTALITY OF CERTAIN LOWER ORGANISMS WITH THAT OF MAN[1]

THE appropriate procedure for gaining an adequate scientific description of the mortality in any aggregate of living things is well understood, and has been widely practiced for nearly three centuries by vital statisticians and actuaries. It consists fundamentally in setting up, from observations over a sufficient time, the specific death rates at ages, for a chosen time unit, which unit in the case of man is commonly taken as one year. From these age specific death-rates all other actuarial functions of the mortality, such as survivorship, absolute mortality, expectation of life, etc., are derived, by mathematical procedures which are in essence simple enough, if sometimes complicated in the practical computations.

Now, while all this is well understood, when one embarks upon a comprehensive general biological investigation of the laws of mortality and duration of life, he is presently confronted with a practical difficulty. How shall he compare the mortality of two organisms whose total life spans are so widely different in extent of time that it is in practice quite impossible to measure or express them in the same unit?

In a recent paper Pearl[2] has suggested what appears to be a valid method of dealing with this difficulty, in making a comparison of the mortality of *Drosophila* with that of man. The nature of the solution is indicated in the following quotation from that paper:

> Upon what basis shall any life table function, say $l_x$, of the *Drosophila* life table be compared with that of man? The life span of one of these organisms is best measured in days, while that of the other is measured in years. This fact, however, offers no insuperable difficulty to the comparison. What is needed is to superimpose the two curves so that at least two *biologically equivalent points* coincide. The best two points would be the beginning and the end of the life span. But in the case of *Drosophila* our life tables start with the beginning of *imaginal* life only. The larval and pupal durations are omitted.
>
> I think we can get at this starting point . . . by putting the human and *Drosophila* $l_x$ curves together as a starting point at the age for each organism *where the instantaneous death rate* $q_x$ *is a minimum*. In the case of *Drosophila*, I think we are safe in concluding, on the basis of the work of Loeb and Northrop as well as from our own observations, that this point is at or very near the beginning of imaginal life. We shall accordingly take *Drosophila* age 1 day as this point. Our life tables show that certainly *after* this time $q_x$ never again has so low a value.

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[1] Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, the Johns Hopkins University, No. 85.

[2] Pearl R.: "Experimental studies on the duration of life. VI. A comparison of the laws of mortality in *Drosophila* and in man." *Amer. Nat.*, Vol. 56, pp. 398-405, 1922.

TABLE I

*Observed and calculated $q_x$ values from Noyes's data on Proales.*

| Days of life | Observed death rate (per 1000) within interval. | Calculated $q_x$ | Calculated $l_x$ (number living at beginning of each interval) |
|---|---|---|---|
| 0- .9 | 0 | .06 | 1000.0 |
| 1.0-1.9 | 1.4 | 1.39 | 999.9 |
| 2.0-2.9 | 9.6 | 9.99 | 998.5 |
| 3.0-3.9 | 47.3 | 44.98 | 988.5 |
| 4.0-4.9 | 136.5 | 144.60 | 944.0 |
| 5.0-5.9 | 393.9 | 349.90 | 807.5 |
| 6.0-6.9 | 575.9 | 653.50 | 525.0 |
| 7.0-7.9 | 1000.0 | 956.10 | 181.9 |
| 8.0-8.9 | ....... | ....... | 80.0 |
| 9.0-9.9 | ....... | ....... | 0 |

TABLE II

*Survivorship distribution for each centile of the life span of Proales decipiens.*

| Centile of life span | Number alive at beginning of centile age interval. | Centile of life span | Number alive at beginning of centile age interval | Centile of life span | Number alive at beginning of centile age interval |
|---|---|---|---|---|---|
| 0- 1 | 1000 | 34-35 | 991 | 68- 69 | 655 |
| 1- 2 | 1000 | 35-36 | 990 | 69- 70 | 630 |
| 2- 3 | 1000 | 36-37 | 988 | 70- 71 | 605 |
| 3- 4 | 1000 | 37-38 | 986 | 71- 72 | 579 |
| 4- 5 | 1000 | 38-39 | 984 | 72- 73 | 552 |
| 5- 6 | 1000 | 39-40 | 982 | 73- 74 | 525 |
| 6- 7 | 1000 | 40-41 | 979 | 74- 75 | 497 |
| 7- 8 | 1000 | 41-42 | 976 | 75- 76 | 469 |
| 8- 9 | 1000 | 42-43 | 973 | 76- 77 | 440 |
| 9-10 | 1000 | 43-44 | 969 | 77- 78 | 411 |
| 10-11 | 1000 | 44-45 | 965 | 78- 79 | 382 |
| 11-12 | 1000 | 45-46 | 960 | 79- 80 | 354 |
| 12-13 | 1000 | 46-47 | 955 | 80- 81 | 326 |
| 13-14 | 1000 | 47-48 | 950 | 81- 82 | 298 |
| 14-15 | 1000 | 48-49 | 944 | 82- 83 | 270 |
| 15-16 | 1000 | 49-50 | 937 | 83- 84 | 244 |
| 16-17 | 1000 | 50-51 | 930 | 84- 85 | 218 |
| 17-18 | 1000 | 51-52 | 922 | 85- 86 | 194 |
| 18-19 | 999 | 52-53 | 914 | 86- 87 | 171 |
| 19-20 | 999 | 53-54 | 905 | 87- 88 | 149 |
| 20-21 | 999 | 54-55 | 895 | 88- 89 | 128 |
| 21-22 | 999 | 55-56 | 884 | 89- 90 | 109 |
| 22-23 | 999 | 56-57 | 872 | 90- 91 | 91 |
| 23-24 | 999 | 57-58 | 859 | 91- 92 | 75 |
| 24-25 | 998 | 58-59 | 845 | 92- 93 | 61 |
| 25-26 | 998 | 59-60 | 830 | 93- 94 | 49 |
| 26-27 | 997 | 60-61 | 815 | 94- 95 | 38 |
| 27-28 | 997 | 61-62 | 799 | 95- 96 | 28 |
| 28-29 | 996 | 62-63 | 782 | 96- 97 | 20 |
| 29-30 | 996 | 63-64 | 763 | 97- 98 | 13 |
| 30-31 | 995 | 64-65 | 743 | 98- 99 | 8 |
| 31-32 | 994 | 65-66 | 723 | 99-100 | 4 |
| 32-33 | 993 | 66-67 | 701 | 100 | 1 |
| 33-34 | 992 | 67-68 | 678 | | |

For the other end of the life span we may conveniently take the age at which there is left but *one* survivor out of 1,000 starting at age 1 day for *Drosophila* and age 12 years for white males.

When the above was written we were aware of the existence of complete life tables for only the two organisms *Drosophila* and man. Since then we have calculated a life table for a third form, the rotifer *Proales decipiens,* on the basis of data as to its mortality recently published by Dr. Bessie Noyes.[3] We wish to report the

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[3] Noyes, B.: "Experimental studies on the life-history of a rotifer reproducing parthenogenetically *(Proales decipiens). Jour. Exp. Zool.,* Vol. 35, pp. 225-255, 1922.

results here, and to compare them with the data for the other two organisms.

Miss Noyes provides in her paper, in two different but apparently homogeneous series, data on the life history of 1,454 individuals. The observations were taken only once in 24 hours, an interval far too long to give a smooth curve for an animal having a maximum total life span of only about eight days. This fact makes the construction of a life table more difficult and much less accurate than if the observations had been more closely spaced. It is as though one tried to construct a life table for man from data as to age at death recorded only to the nearest decade.

Taking the data as they stand, however, the central death-rates were computed and graduated with the results shown in Table I.

The $q_x$ values were graduated by the following expression (with origin at 0 age, or birth)

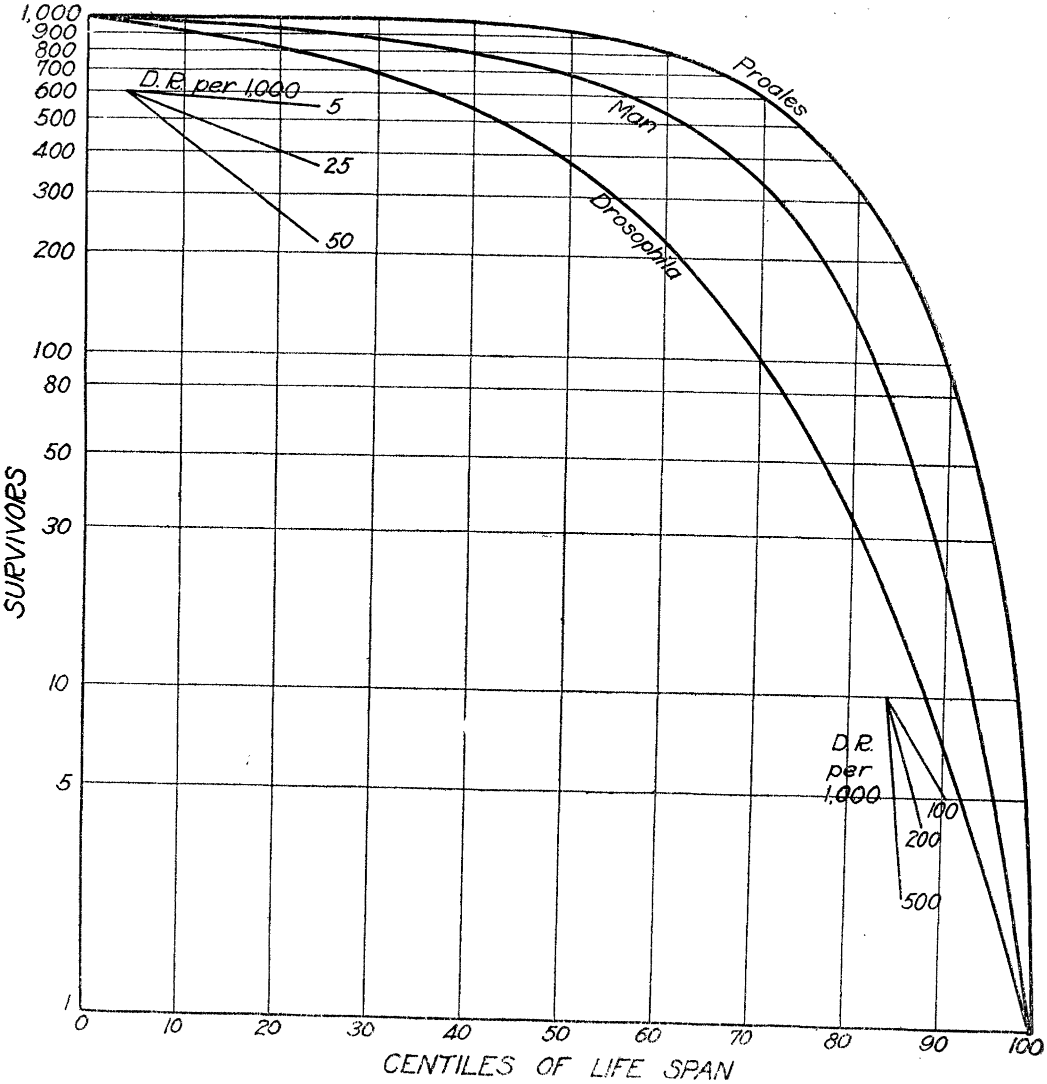

Fig. 1. Showing survivorship distributions for (*a*) rotifer *Proales decipiens*, (*b*) man (males in original registration states, 1910), and (*c*) *Drosophila melanogaster* (wild type males). The death rates corresponding to given slopes of the $l_x$ line are also given by the groups of fine lines at the two ends of the diagram.

which is of a type found useful in previous work with Drosophila life curves:

$$\log q_x = -1.0783 + .7041x - .0452x^2 + 1.5080 \log x.$$

It is evident from the data of Table I that the fit is reasonably good, probably as good as one could expect with observations so rough in respect of age at death.

The next step is to calculate a *Proales* life table in terms of centiles of the life span rather than in absolute age. This was done in the same manner as in the earlier paper, and the results, so far as concerns the survivorship function $l_x$, are shown in Table II.

In order that it may be seen how the forces of mortality operate in *Proales* as compared with man and *Drosophila,* the diagram shown as Figure 1 is presented.

Comparing the three curves, we note the following points:

1. The *Proales* curve lies above the other two at all parts of the comparable life span. This means that out of 1,000 individuals starting together at biologically equivalent points in the life span (*i. e.,* at the age when $q_x$ is a minimum for each organism) at any subsequent age centile there will be more surviving rotifers than men, and more surviving men than flies.

2. The median durations of life, or, put in another way, the ages prior to which just 500 of the 1,000 individuals starting together will have died, are approximately:

| | | |
|---|---|---|
| For *Proales,* | 74 % | of the equivalent life span. |
| For Man, | 62 % | of the equivalent life span. |
| For *Drosophila,* | 42.5% | of the equivalent life span. |

3. The comparison the other way about indicates that when 50 per cent. of the equivalent life spans have been passed there are still surviving:

| | | |
|---|---|---|
| In *Proales,* | 93.0% | of the individuals starting. |
| In Man, | 68.5% | of the individuals starting. |
| In *Drosophila,* | 38.0% | of the individuals starting. |

The outstanding thing about the life curve for *Proales* from Miss Noyes's figures is that it approaches nearer to the theoretically possible right-angled form, in which all the individuals live to a given age $x$ and then all die at once, than any other that has yet been observed. Whether this is the result of (*a*) the greater uniformity of environment, on the average, for the *Proales* under the experimental conditions than for the other forms, or (*b*) the greater uniformity of the population in genetic constitution, consequent upon the fact that *Proales* reproduces parthenogenetically and that all of Miss Noyes's cultures were descended from at most not over six different individuals, or (*c*) a combination of both, can not be definitely stated. Both of the factors mentioned undoubtedly do in some degree operate to produce the form of life curve exhibited. There is need for data regarding the mortality of other organisms. It is an interesting commentary on the development of biology that the distribution of mortality in respect of age is known for only three species of animal life with sufficient accuracy to permit the formation of age-specific death rates, and hence of a life table. Into every discussion of the problem of evolution, and into every attempt to determine its causes, there must necessarily enter the question of the mortality of the forms being dealt with. There seems no good reason for indefinitely continuing to handle the matter by the current methods, which are either to make large *a priori* guesses about the distribution of mortality in the particular case, or to assume that it is the same as that of man. In the nearly universal neglect of the problem of mortality and duration of life, biologists have missed an interesting and obviously important field.

RAYMOND PEARL
CARL R. DOERING

# THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

## SECTION M—ENGINEERING

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Engineering was represented at the fourth Boston meeting of the American Association for the Advancement of Science in two of the sections—in Section K (Social and Economic Sciences), of which Dr. Henry S. Graves, of the Yale Forest School, Yale University, is vice-president and chairman, and in Section M (Engineering), of which Mr. F. M. Feiker,