bacteria-counting chamber showed no significant difference from those made with a hemacytometer.

The data presented indicate that prolonged homogenization will destroy liver cell nuclei, and that, in order to obtain accurate DNA values per average nucleus from homogenate suspensions, the homogenization time must be reduced to such an extent that the DNA in the nuclei-free supernatant fraction is negligible.

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Grouping in Spatial Distributions

A number of procedures have been developed in recent years for measuring departures from randomness in the spatial distribution of points, but few analytic attempts have been made to separate the factors responsible for these deviations. Lack of randomness in a distribution of points over a given space may result (i) from the influence, on the location of the points, of regional differences in the nature of the space, and (ii) from the influence of the points on the position of one another. Evaluation of the importance of these two sources of nonrandomness in a given population has been complicated by the fact that current measures of nonrandomness are simultaneously sensitive to both of them. It is the purpose of this paper (*1*) to suggest a method whereby grouping in spatial distributions can be exhaustively described and by means of which, under certain circumstances, the afore-mentioned causes of nonrandomness can be distinguished.

It has been shown by Clark and Evans (*2*) that in a random distribution in two-dimensional space the proportion of points for which the relation of nearest neighbor is reflexive—that is, points which are the nearest neighbor of their nearest neighbor—is .6215. This expected proportion of reflexive relationships is independent of whether the density of the distribution is constant over the space occupied by it, but it is increased by any tendency for the formation of groups of two. It often happens, however, that distributional factors result in the formation of groups larger than two without appreciably affecting the number of pairs. The following generalization of the concept of reflexiveness is applicable to groups of any size.

In a random distribution in k-dimensional space, consider the point X_0 and its 1st, 2nd, . . . , nth nearest neighbors, designated $X_1, X_2, \ldots, X_n$. The relation of nth nearest neighbor is reflexive for X_0 if X_n is closer to X_0 than to any other points except $X_1, X_2, \ldots, X_{n-1}$. Morisita (*3*) has obtained the probability distribution of the distance, r, to the nth nearest neighbor for a random distribution of density ρ in two-dimensional space. In k dimensions it is formula 1. Consequently, employing the reasoning of Clark and Evans (*2*), the proportion of points for which the relation of nth nearest neighbor is reflexive in a k-dimensional random distribution is formula 2, which upon integration becomes formula 3.

$$dP = \frac{k}{(n-1)!}\left[\frac{\rho\pi^{k/2}}{\Gamma(k/2+1)}\right]^n r^{kn-1} e^{-\frac{\rho\pi^{k/2} r^k}{\Gamma(k/2+1)}} dr$$

Formula 1

$${}_kP_n = \int_0^\infty \frac{k}{(n-1)!}\left[\frac{\rho\pi^{\frac{k}{2}}}{\Gamma(\frac{k}{2}+1)}\right]^n r^{kn-1} e^{-2r^k\rho\left[\frac{\pi^{\frac{k}{2}}}{\Gamma(\frac{k}{2}+1)} - \frac{\pi^{\frac{k-1}{2}}}{\Gamma(\frac{k+1}{2})}\int_{\frac{1}{2}}^{1}(1-x^2)^{\frac{k-1}{2}}dx\right]} dr$$

Formula 2

$${}_kP_n = \left[\frac{\frac{1}{2}\Gamma(\frac{k+1}{2})}{\Gamma(\frac{k+1}{2}) - \pi^{-\frac{1}{2}}\Gamma(\frac{k}{2}+1)\int_{\frac{1}{2}}^{1}(1-x^2)^{\frac{k-1}{2}}dx}\right]^n$$

Formula 3

For 1, 2, and 3 dimensions we have, respectively,

$${}_1P_n = (2/3)^n$$
$${}_2P_n = \left(\frac{6\pi}{8\pi + 3^3/_2}\right)^n$$
$${}_3P_n = (16/27)^n$$

Values of ${}_2P_n$ for $n = 1$–21 are given in Table 1.

For the purpose of this discussion, it is convenient to define a group as a collection of points in which every individual is closer to some member of the collection than to any individual outside of it. The concept of a group, as so defined, is a hierarchical one, large groups containing smaller ones within them. Groups occur in random, as well as in nonrandom, distributions. Nonrandom distributions differ from random ones in the extent to which the groups are isolated, increased isolation of groups being characteristic of aggregated distributions and decreased isolation, of distributions that tend toward uniformity. A group may be said to be completely isolated if each of its members is closer to every other member than to any individual outside of the group, from which it follows that every group of two individuals is completely isolated. The delimitation and counting of groups is not likely to facilitate distributional analysis unless the groups are highly isolated.

Although the group is ordinarily not a useful unit in distributional studies, a measure of the tendency for isolation of groups of specified size in a population is of value in describing spatial pattern. The tendency for isolation of groups of size n in a population may be called *grouping of order n,* positive, neutral, and negative grouping implying tendencies for isolation respectively greater than, equal to, and less than that expected in a random distribution. It is apparent that the observed proportion of individuals for which the relation of

Table 1. Proportions of individuals for which the relation of nth nearest neighbor is reflexive for populations in two-dimensional space.

	Size of sample		
	∞	184	179
n	Random distribution	*Lespedeza*	Prairie-dog burrows
1	.6215	.609	.642
2	.3863	.435	.246
3	.2401	.152	.134
4	.1492	.168	.084
5	.0927	.098	.028
6	.0576	.060	.011
7	.0358	.065	.006
8	.0223	.027	.006
9	.0138	.038	.000
10	.0086	.027	.000
11	.0053	.038	.000
12	.0033	.087	.000
13	.0021	.022	.000
14	.0013	.043	.000
15	.0008	.049	.000
16	.0005	.033	.000
17	.0003	.060	.000
18	.0002	.027	.000
19	.0001	.049	.000
20	.0001	.147	.000
21	.0000	.098	.000

*n*th nearest neighbor is reflexive in a given population corresponds with grouping of order $n+1$, the proportion being less than, equal to, or greater than that expected in a random distribution, depending on whether grouping of order $n+1$ is negative, neutral, or positive. The significance of differences between these proportions can be tested by chi-square if the points for which nearest neighbor relationships are ascertained represent a proportionately small random sample of the entire population under investigation. It should be noted that the proportion of reflexive relationships is increased in the vicinity of distribution borders and that the relation of *n*th nearest neighbor is reflexive for every individual in a completely isolated group of $n+1$ points.

Negative grouping is nearly always attributable to the influence of the points on the position of one another, whereas positive grouping can result both from this cause and from discontinuities in the nature of the space. Discontinuities in the space usually result in positive grouping of higher order than that induced by interaction between points. Information about such discontinuities usually enables one to attribute positive grouping below a certain order to the influence of the points on the position of one another.

As an illustration of the foregoing ideas, the proportion of individuals for which the relation of *n*th nearest neighbor is reflexive, for $n = 1$–21, was ascertained (*4*) for a natural distribution of the grassland plant *Lespedeza capitata* Michx. occurring on an abandoned field near Ann Arbor, Michigan (*5*), and for the distribution of burrow openings over part of a prairie-dog town in the Black Hills of South Dakota (*6*). As is shown in Table 1, positive grouping is predominant in the *Lespedeza* distribution, whereas negative grouping characterizes the distribution of prairie-dog burrows. Positive grouping in *Lespedeza* probably results from its reproductive habits. The negative grouping of the burrows is a consequence of the social behavior of prairie dogs.

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Effect on Meloidogyne hapla of Excised Tomato Roots Treated with Alpha-Methoxyphenylacetic Acid

A method that permits root portions to be tested quantitatively for their effect on the soil stage of plant-parasitic nematodes was recently described (*1*). It was shown that the excised distal portion of the tomato root consists of three regions with respect to its effect on larvae of *Meloidogyne hapla,* Chitwood (Nematoda): (i) apical 2 mm (calyptra and meristematic region), repellent; (ii) following 6 mm (region of elongation), attractive; (iii) remainder, up to 16 mm behind the root apex, neutral or slightly repellent. Since the nematodes proved to be extremely sensitive, one of the conclusions reached from this work was that plant-parasitic nematodes could be used as test subjects for the detection of excretion from roots of substances given off in very small amounts. This might be of value in connection with experimental work on compounds that (i) can be sprayed on the aboveground parts of susceptible crop plants, whence they are transported downward and excreted through the roots and (ii) are at the same time nematode-repellent. So far no such compound that is not at the same time harmful to the plants has been found. However, in the search for such a compound, the method I described (*1*) might be useful in determining whether a chemical being tested is or is not nematode-repellent.

It has been shown that alpha-methoxyphenylacetic acid (MOPA) causes growth responses (*2*) and that it is transported from the upper parts of several kinds of plants downward and that the compound or a derivative of it is excreted through the roots (*3*). The fact that MOPA moves downward in tomato stems and out of the roots has been demonstrated more recently. This was shown by first growing MOPA-treated tomato plants (*4*) and comparable untreated ones separately in beakers containing aerated water and then, 4 days later, replacing the tomatoes with young bean plants. After 7 days, the trifoliate leaves of the bean plants in water that had supported growth of MOPA-treated tomatoes were typically malformed and smaller (52 percent) than those of beans in water that had supported growth of untreated tomatoes.

A further clue of downward transport is provided by the reaction of the nematodes. The results are shown in Fig. 1. A summary of the method employed follows (the details have been reported, *1*). Egg masses of *M. hapla* are placed in the center of a sand-filled dish. One of the halves of the dish contains a root piece, the other does not. The results are expressed as the percentage of hatched lar-

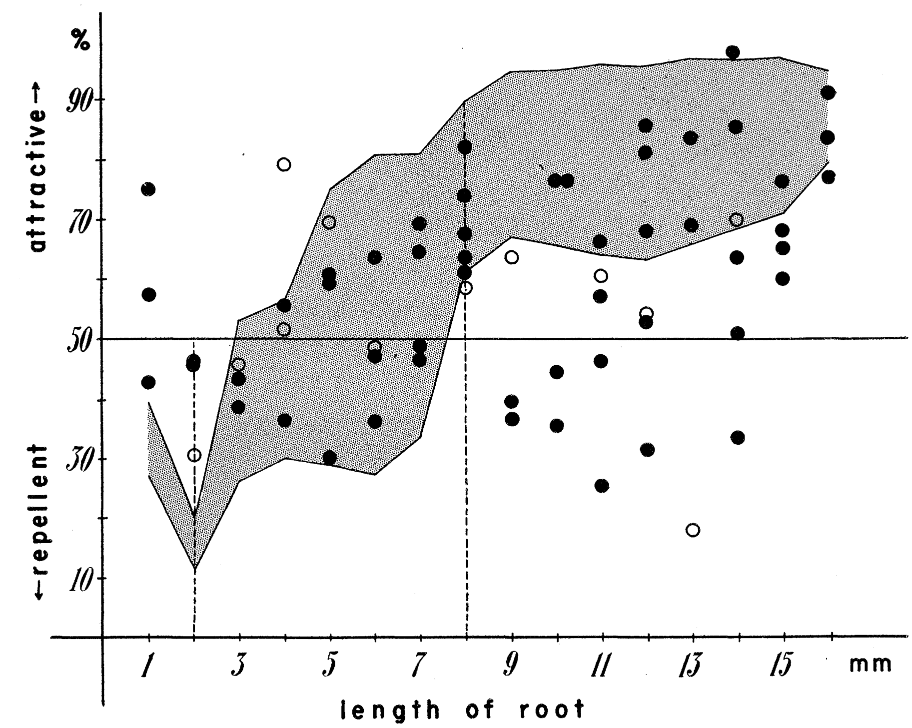

Fig. 1. Effect of excised root ends from tomatoes treated with alpha-methoxyphenylacetic acid (MOPA) on larvae of *Meloidogyne hapla.* Samples were taken 1 to 3 days (filled circles) or 5 to 7 days (open circles) after treatment. Stippled field: range of variability of effect of excised roots from untreated plants. Abscissa: length of root end. Ordinate: percentage of nematodes found in the half of the dish occupied by the root end.