jected as untenable. It does not appear from the present experiment, despite the reasonableness of the assumption, that attraction for the group is a determinant of social conformity.

References

1. CARTWRIGHT, D., and ZANDER, A. *Group Dynamics: Research and Theory.* Evanston, Ill.: Row, Peterson, 140, 1953.
2. BOVARD, E. W., JR. *J. Abnormal Social Psychol.*, **46**, 398 (1951).
3. ———. *Ibid.*, 521 (1951).
4. ———. *Science*, **117**, 361 (1953).

Manuscript received July 27, 1953.

The Tetrakaidecahedron as the Basis for the Computation of Cell Volume and Density

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Studies by various authors (*1–6*) on the shape of central cells in compact tissues have shown that the average number of cell surfaces closely approaches the number 14 characteristic of the Archimedean tetrakaidecahedron or 14-hedron. Despite the fact that the pattern of cell faces is only infrequently identical with the arrangement of hexagonal and cubic faces definitive of the orthic form of this polyhedron (*1*) its shape may still be useful as a basis for volume determination since ". . . this is the form about which the observed shapes hover . . . it may properly be regarded as the typical shape of cells in masses. There is no rival uniform pattern" (*3*).

In sectioned tissues composed of essentially isodiametric cells randomly arranged in the plane of section the only readily measured dimension is the mean chord. It has been found (*7*) that this parameter is equal to 4 volume/surface for any solid and to π area/perimeter for any plane figure. From the data given by Matzke (*5*) it can be determined that the surface of the orthic 14-hedron of side s is $6s^2 + 8 \times 2.598s^2$, or $26.78s^2$, while the volume is $(6s^2 \times 1.414s + 8 \times 2.598s^2 \times 1.225s)$ 1/3, or $11.32s^2$. The mean chord is then equal to $1.69s$ and $s^3 = 0.207c^3$. Substituting this last equation in the original volume equation we obtain a second in which $v = 2.34c^3$.

From data available for regular polyhedra it can be shown that volume is equal to $2.91c^3$ in the 8-hedron, $2.36c^3$ in the 12-hedron, and $2.12c^3$ in the 20-hedron. It is apparent that in the range between 12 and 16 faces, regarded as most frequent in compact tissues (*1*), the average volume of orthoid cells will not vary greatly from $2.34c^3$.

A test of the applicability of this formula to cell volume measurements was made on a section of amphibian liver. Camera lucida drawings of cells in the hepatic plates were superimposed on a pattern of equiangular radiating lines, and the intercepts of these lines by the cell cross sections were measured as

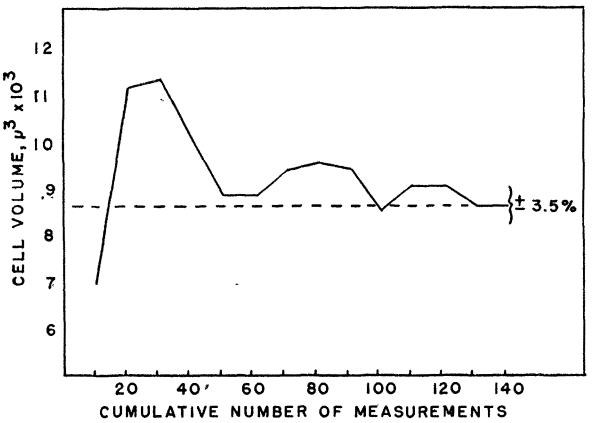

FIG. 1. Cumulative estimates of amphibian liver plate cell volume from successive measurements of the length of the mean cell chord. After 100 measurements fluctuations do not exceed ± 3.5% of the final value.

chords. Cumulative estimates of the volume of the average cell as the number of chord measurements increased are shown in Fig. 1. At the final mean chord value of 15.5 μ the volume was 8730 μ³. Cell volume can also be determined in this tissue by multiplying the average volume of the essentially spherical nuclei by one plus the cytoplasm/nucleus ratio as determined by the multiple pointer method (*8*). Fluctuations between successive cumulative estimates of the ratio became and remained less than ± 2% of the terminal value of 4.73 after 1800 pointer hits had been registered. Similar fluctuations in estimates of the average diameter of the nucleus never exceeded 1.5% of the terminal value of 14.6 μ in 100 measurements. The volume obtained by this method was 9340 μ³. The volumes obtained by the two methods differ from their mean by less than ± 4%.

If the orthic 14-hedron is cut by a plane perpendicular to any edge the surface of the polyhedron intercepts a hexagonal section of the plane (*5*) in which the area a is $5.66s^2$ and the average width $w = 2.77s$. Substituting $s = 0.361w$ in the area formula it becomes $a = 0.737w^2$ (for a regular hexagon $a = 0.746w^2$) and and a right prism of height w has the volume $0.737w^3$. The orthic 14-hedron has a maximum height of $1.08w$ and a volume of $11.316s^3$ or $0.532w^3$ so that its volume differs from that of a right prism of identical central cross section and height by $0.264w^3$. Alteration of the length of the edges of the 14-hedron perpendicular to a hexagonal right cross section produces squamous and columnar 14-hedra in which $v = w^3$ $(0.737\ l/w - 0.264)$ where l/w is the length/width ratio at values greater than 0.722. At lower values of l/w the tetrahedral caps of the 14-hedron would be deformed.

This formula was tested on the same group of amphibian liver plate cells used as a test of the mean chord method. The average width of 50 cells was 26.3 μ. Assuming that the cells are orthic and have a l/w ratio of 1.08, their average volume is 8620 μ³ (compare with the volumes obtained above).

In leaf palisade epithelium the cumulative estimates

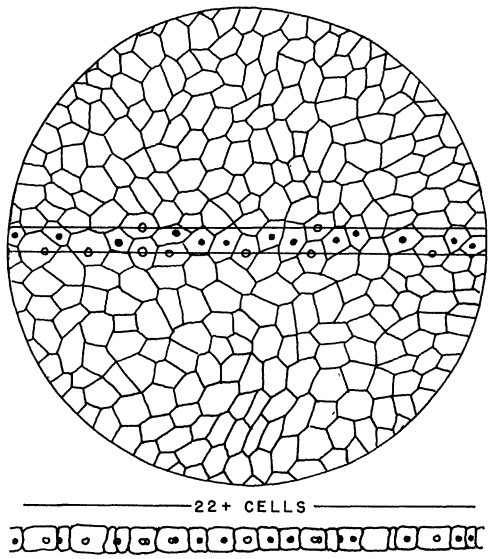

FIG. 2. Surface and hypothetical sectional views of a layer of amphibian epidermal cells.

of length stabilized within ±1% of 53.5 μ and those of width within ±1% of 12.5 μ after 100 measurements. The cumulative estimates of the length of the long (7.6 μ) and short (5.6 μ) axes of the oblately spheroidal nuclei stabilized within ±1% after 40 measurements. Equal stability of the cytoplasm/nucleus ratio (28.7) was not obtained until after 1800 hits had been registered. Palisade cell volume by the length/width formula was 5540 μ^3 and by the nuclear volume–cytoplasm/nucleus ratio method was 5025 μ^3. The two values differ by less than ±5% of their mean.

In sections tangent to the surface of an epithelium, the number of cells per unit area can be determined by direct counts per field or per unit area of an ocular counting grid. When it is necessary to make similar determinations on tissues section at right angles to the surface these can be based on measurements on the mean chord of the cell cross section measured in a plane parallel to the epithelial surface. Cross sections of epithelial cells have, in general, the six sides of the 14-hedron cross section. Since the area a of any regular polygon with n sides of length s can be expressed as $a = \frac{1}{4}ns^2 \cot 180/n$ we can substitute this for a in the mean chord formula, $c = \pi a/ns$, and obtain $c = \pi/4 (ns^2 \cot 180/n)/ns$. Simplifying we get $s = (4c \tan 180/n)\ \pi$ which, substituted in the original area formula yields $a = (4nc^2 \tan 180/n)\pi^2$ or, $0.405\ nc^2 \tan 180/n$ for any polygon, $1.405c^2$ for the hexagon and $1.460c^2$ for the pentagon.

In the stretch preparation of frog epidermis outlined in Fig. 2, an average of 23 cells is intercepted along the field diameter ($2r$) and the length of the mean chord is $0.087r$. Assuming the number of sides per cell to be 6, the area of the cross section of the average cell is $0.0106r^2$ in a field of area of $3.142r^2$. The number of cells per field is then 3.142/0.0106 or 296. If the cell outline is assumed to be pentagonal the count is 286. The actual count in the field is 287. With either assumption, the error does not exceed 3%.

The assumption that closely packed cells in parenchymatous and epithelial tissues are 14-hedra permits formulation of the cell volume and density in terms of parameters easily measured by ocular micrometry or camera lucida methods. In general these parameters are the largest linear dimensions of the cell or can be measured in terms of numbers of cells intercepting a line of optimal length (*7*). In contrast, the check method, while more applicable to cells of highly irregular shape, requires an assumption as the shape of the smaller and hence less easily measured nucleus. Other methods applicable to cells regardless of shape (*9*) are dependent upon the use of special apparatus.

References

1. DUFFY, R. M. *Am. J. Botany,* **38**, 393 (1951).
2. LEWIS, F. T. *Proc. Am. Acad. Arts Sci.,* **68**, 251 (1933).
3. ———. *Am. J. Botany,* **30**, 74 (1943).
4. MARVIN, J. W. *Ibid.,* **26**, 487 (1939).
5. MATZKE, E. B. *Bull. Torrey Botan. Club,* **54**, 341 (1927).
6. ———. *Am. J. Botany,* **36**, 799 (1949).
7. CHALKLEY, H. W., CORNFIELD, J., and PARK, H. *Science,* **110**, 295 (1949).
8. CHALKLEY, H. W. *J. Natl. Cancer Inst.,* **4**, 47 (1943).
9. ———. *Anat. Record,* **103**, 17 (1949).

Manuscript received July 27, 1953.

An Effect of Negative Assortative Mating on Gene Frequency[1]

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In the theory of the genetic structure of populations it is a common consideration that a change in mating system does not result in a change in gene frequency, selective mating excepted. Although this relation holds for inbreeding and for positive assortative mating, it can be shown that under at least some conditions it does not hold for negative assortative mating. One of such conditions is that involving a single autosomal gene-pair in which one member is completely dominant over its allele. The common point of departure for discussion of the effect of assortative mating (either positive or negative) on a population so composed is that deviation from panmixia occurs on a phenotypic basis, while within the dominant phenotype mating remains at random when it occurs at all (*1–6*). The simplest example is afforded by complete negative assortative mating, wherein matings occur only between phenotypically unlike individuals.

Suppose, as have Hogben (*2*) and Li (*4*), that the initial population consists of genotypes *AA, Aa,* and *aa,* and that, as defined, the only matings occurring be $AA \times aa$ and $Aa \times aa$. Then the next generation will consist of *Aa* and *aa* and the only mating occurring will be $Aa \times aa$. Regardless of the frequencies of these

[1] Supported in part by funds provided for medical and biological research by the State of Washington Initiative Measure No. 171.