of print, from the American Association for the Advancement of Science.

The National Gallery of Art is unable to record much progress for the year due to the lack of a building for the exhibition of material, other than the small space available to it in the Natural History Building. The outstanding gift of the year was the Thomas Moran painting of the Grand Canyon of the Yellowstone, presented by Mr. George Dupont Pratt.

SPECIAL ARTICLES

THE SHAPE OF CORK CELLS: A SIMPLE DEMONSTRATION THAT THEY ARE TETRAKAIDECAHEDRAL

IN SCIENCE, June 18, 1926 (pp. 607–609), the author reviewed his papers which seem to show conclusively that cells in masses are typically tetrakaidecahedral—a shape significant since Lord Kelvin had found that tetrakaidecahedra solve the problem of dividing space, without interstices, into uniform bodies of minimal surface. Lord Kelvin's mathematics was called in question in SCIENCE, September 3, 1926 (pp. 225–226), and, as expected, was promptly vindicated (Matzke, *Bull. Torrey Bot. Club*, 1927, 54: 341–348; Gross, SCIENCE, August 5, 1927, 66: 131–132). But that massed cells are tetrakaidecahedral seems to have found no general recognition since its announcement in 1923, based then on the forms in elder pith only. Accordingly an inescapable and extremely simple demonstration that a cork cell, on the average, makes fourteen contacts with the cells which surround it, is here presented.

A tangential section of commercial cork shows that the cells when cut in that plane are, as an average, hexagonal. But when these cells are cut lengthwise, which happens when cork is sectioned either radially or transversely in relation with the tree-trunk, then—in the words of Hooke's "Micrographia"—the cells or pores are seen to be "not very deep, but consist of a great many little boxes separated out of one continued long pore by certain diaphragms." Thus eight surfaces are accounted for—an inner and an outer diaphragm, and six lateral surfaces. But it is readily seen that each lateral surface usually makes contacts with *two* cells—sometimes with only one, sometimes with three, yet on the average with two—so that there are twelve lateral contacts. These, with the two diaphragms, complete the count of fourteen. There are, however, innumerable exceptions, and it is expedient to verify our premises.

In a recent paper on the epidermal cells of the cucumber, we have discussed, with the aid of a mathematician, the geometrical requirements of an epithelial mosaic.[1] Thus we are prepared to find that the average number of sides of cork cells in cross section—that is, in a tangential section of cork *in situ* on the tree—is slightly less than six, the deviation depending on the frequency of tetrahedral angles. Such angles, or places where four cells meet at a point, are somewhat more common in the thick-walled and apparently less mobile cork cells than in those of cucumber rind when cut in the same plane. A count of the sides of one thousand cork cells yields results shown in the accompanying table. Though less than half of the cells are hexagonal, the average number of sides is 5.978. Accordingly no error has been made in assuming that the typical cork cell is six-sided in cross section.

1000 CORK CELLS IN CROSS SECTION

Number of cells with						
4 sides	5	6	7	8	9 sides	Average
18	250	491	213	27	1	5.978

Turning next to the vertical sections of cork cells, it is seen that they, too, are commonly hexagonal. Of a thousand taken at random, 521 were hexagons. But tetrahedral angles are more frequent in this plane than in the other, so that the average number of sides is only 5.877. The distribution of the various types of polygons, yielding this average, is shown in Table 2.

1000 CORK CELLS IN VERTICAL SECTION

Number of cells with							
3 sides	4	5	6	7	8	9	10 sides
2	50	241	521	152	31	2	1

What is perhaps a typical vertical section of a cork cell has been drawn in Fig. 1, *g*. It is oriented so that its "diaphragms," or inner and outer surfaces, are above and below in the picture. Each lateral surface is in contact with two cells. With the production of a tetrahedral angle, one of these surfaces would be eliminated. Thus cell *a* in the figure is in contact with cell *e*,

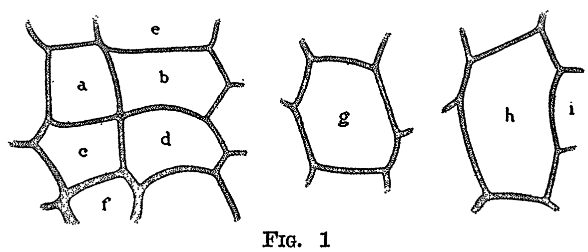

FIG. 1

and *f* with *d*, but cell *c* has lost the corresponding contact with *b*, and cells *a*, *b*, *c* and *d* meet at a point. Cell *b*, therefore, has only one contact on its left side, which is true also of cells *a* and *i*. But cell *h* has three contacts on its right, as would be true of cell *a* if it should expand toward *d* and thus avoid the tetrahedral

[1] *Anatomical Record*, 1928, 38: 345–350.

angle. Three lateral contacts are not rare, and sometimes four may be observed; the only decagonal cell encountered had four contacts on both sides.

Since the average cork cell in vertical section has 5.877 sides or contacts, and two of these are the top and bottom diaphragms, it follows that the average number of lateral contacts is one half of the remainder, or 1.938. The average number of sides in cross sections of the cell was found to be 5.978. Accordingly the average total number of contacts per cell, $(1.938 \times 5.978) + 2$, is 13.59. That this average is not precisely 14 is due to the frequent elimination of a surface accompanying the production of a tetrahedral angle. The computation indicates that 40 per cent. of the cells have lost a side in this way.

Pending the outcome of reconstructions which are now being attempted, the cork cell as a whole may be pictured provisionally as follows. An orthic tetrakaidecahedron is shown in Fig. 2, and beside it a prismatic tetrakaidecahedron of the same volume and of minimal surface for the prismatic form. A shorter or taller prism would have greater surface for its volume. Cork cells, according to the season of the

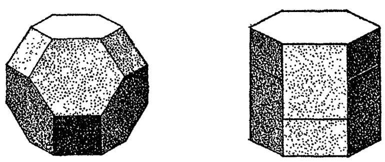

FIG. 2

year, are both shorter and taller, relatively, than the prism here pictured, which, however, is well within the limits actually observed. Although cork cells were described and figured by Hooke as if their lateral sides were flat, *i.e.*, as if they were true prisms, and although subsequently they have often been drawn in that way, it is evident that they are intermediate between the orthic and prismatic forms of the tetrakaidecahedron.

It seems impossible that this conclusion has not previously been presented elsewhere. Eminent authorities with other views as to the shape of cells might readily be cited, and also scores of cytologies where one looks in vain for a correct statement of this fundamental matter. What, however, is less obvious is the further conclusion which we have presented in other papers, namely that when a tetrakaidecahedral cell divides, whether transversely or vertically, it will produce a pair of cells each of which has eleven sides, or together twenty-two sides—an increase of eight over the original fourteen. At the same time six surrounding cells each receive an added side, making fourteen new surfaces the result of a cell division, and thus maintaining the average count of fourteen. This result, so characteristic of cells, is simply the necessary outcome of the avoidance of tetrahedral angles in every plane; and this avoidance is indeed the entire morphological explanation of the tetrakaidecahedral form. If tetrahedral angles are avoided to the *maximum possible extent,* the geometrical patterns shown in the figure will be produced. The shape becomes therefore a measure of surface tension. If, on the average, the cells are hexagonal both in transverse and vertical section, nothing in biology is easier than to prove that their average number of contacts with surrounding cells is fourteen.

FREDERIC T. LEWIS
HARVARD MEDICAL SCHOOL

THE NATIONAL ACADEMY OF SCIENCES. II

Orientation, differentiation and cleavage in the early development of the egg: EDWIN G. CONKLIN. Thirty years ago I called attention to the importance of "Protoplasmic Movement as a Factor in Differentiation" (1899). Since that time many other studies have served to confirm the importance of such cytoplasmic movements in the orientation and localization of developmental processes in eggs and cleavage cells. The actual mechanism of such movements is largely unknown but they may be stopped or modified by cold, pressure, various chemical substances, absence of oxygen, etc. On the other hand strong radiation with ultra-violet light, with X-rays or with radium does not modify appreciably these intra-cellular movements of the cytoplasm, and even a direct current of 200 mil. amp. acting for several hours has apparently no effect on these movements.

During the past summer I found that the normal movements within the eggs and cleavage cells of Crepidula plana could be greatly modified by subjecting them to a temperature of approximately 0° C. for a period of from four to six hours. The first noticeable effect of such treatment is the suppression of the vortical or rotary movements within the cells and the consequent failure of the cell body to divide and the cell contents to assume their usual positions. A second effect is the formation of many local aggregations of finely granular cytoplasm. This "hyaloplasm" or "ground substance" is normally found in the cortical layer, the asters and the astral radiations of the Crepidula egg but low temperatures (or hypertonic solutions) cause it to gather into patches or islands.

If such eggs are then returned to normal conditions some of them may develop quite normally, especially if they were in the resting condition at the time of the experiment, or if the temperature was low enough to stop all developmental processes. But if they were dividing at the time of the experiment or if the temperature was not low enough to stop all differentiation the further development is very abnormal, owing to the fact that different developmental processes are differently affected. Thus nuclear growth and division may pro-