A Cell in the Third Dimension: Tetrakaidecahedron Realized

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The purpose of this article is to show that a useful demonstration model of a "typical" parenchyma cell can be built for classroom use. Many of the cells which specialize in space-filling in plants are known as packing tissue or parenchyma. Being that parenchyma cells are common, this model can serve to illustrate the shape of a parenchyma cell in the third dimension. Not only can it demonstrate the size and position of the main parts of a mature parenchyma cell, but it can also serve as a model to lead to a general understanding of shapes and structures of other cells as they appear in the third dimension. Further ideas may lead to the building of students' own models to test stacking ability, stability of angles, and surface with reference to volume.

History

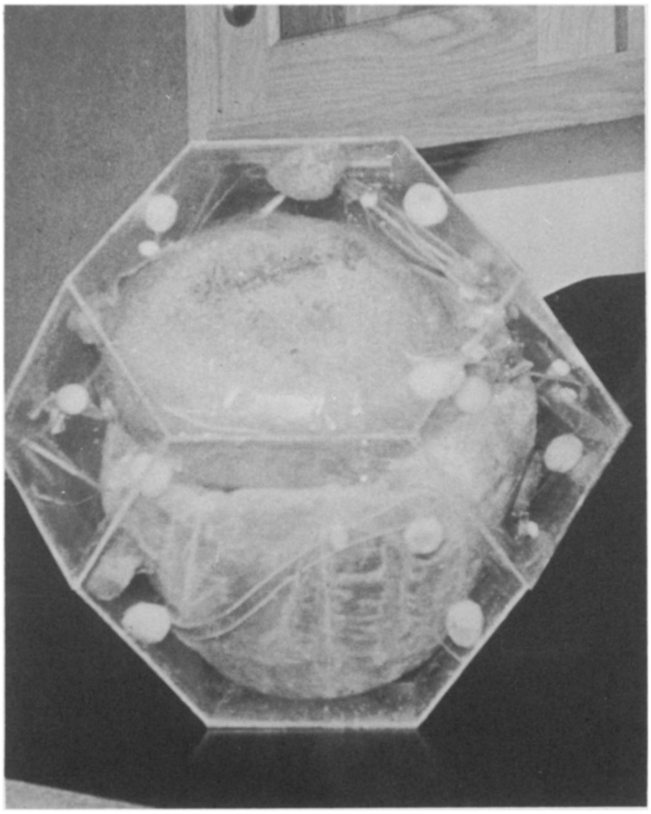
The idea of the division of space into polyhedra having fourteen faces, eight hexagonal and six square, was conceived by Lord Kelvin, as early as 1887, in a philosophical essay. The biological implications of Kelvin's ideas were left unappreciated until Lewis published his findings on the three dimensional shapes of massed cells. The shapes were not all exactly hexagonal and square, but the concept of Kelvin's tetrakaidecahedron was realized. Many people have studied cell shape in undifferentiated tissue. Marvin, Matzke, and Duffy have used lead shot, soap bubbles, and interphase plant cells to determine cell shape. In many of the experiments, the average number of faces occurring is close to fourteen, which corresponds with the tetrakaidecahedron, but none could be described as the most typical. The perfect, fourteen sided polyhedron with eight hexagonal and six quadrilateral faces is rare, but it does have fourteen faces which is a close average to what has been shown in the literature. It is as representative of the "typical" shape of undifferentiated parenchyma cells as any other figure.

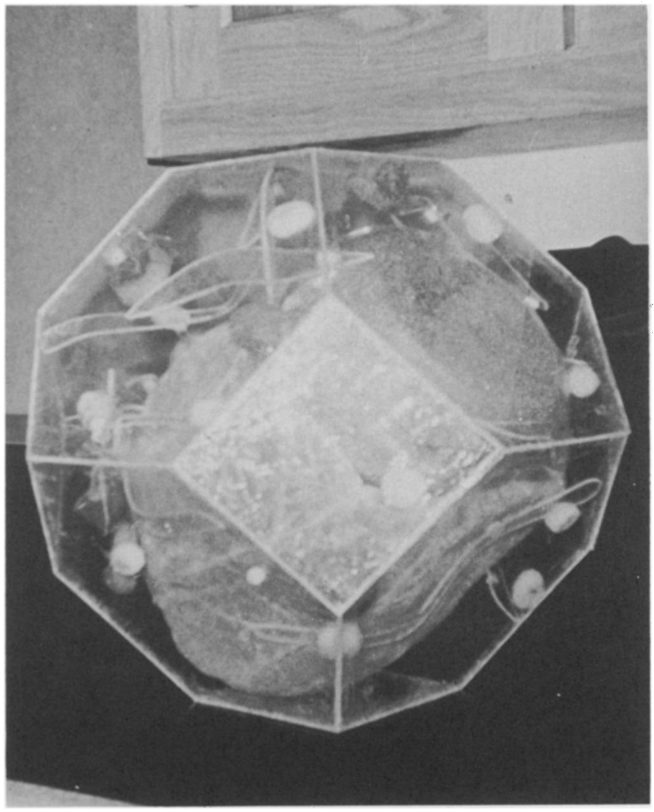
Model

The model was constructed by cutting out six squares and eight hexagons with each side being six inches. These were cut from an ⅛ inch, clear plastic material called plexiglass. The edges of the figures were bevelled for tight fitting. Each of these plastic figures, which were to be the cell wall, were lined with a clinging food wrap as reflected by the center square in Fig. 2. The wrap, representing the cell membrane, was glued on the edges. A clear wrap was used so that the transparency would remain.

As a great deal of a mature parenchyma cell is occupied by a vacuole, one large vacuole was constructed by sewing strips of fine netting together to form a sphere. A plastic bag full of foam rubber was inserted to fill the netting. The netting was covered with fiberglass; and after the fiberglass had set, the plastic bag and foam rubber were removed. The vacuole is the largest structure resting on the bottom of the cell in both figures.

The nucleus was cut from styrofoam and sprayed lightly with red paint so that it could easily be recognized. It is seen as a large flattened disk in the top hexagon of Fig. 1 and on the right side of Fig. 2. This nucleus was also wrapped with the food wrap to represent the nuclear membrane. The mitochondria, ribosomes, and chloroplasts were also made from corresponding sizes of styrofoam. The mitochondria were made from a light blue styrofoam and are the largest white-appearing balls seen throughout





both figures. The ribosomes also appear white, but are much smaller than the mitochondria and are usually associated with the clear, flat irregular-shaped plastic objects which represent the endoplasmic reticulum. A ribosome can be seen below the nucleus in Fig. 1 and also to the lower left of the center square in Fig. 2. The chloroplasts were painted green and are much larger than the ribosomes. One is clearly visible at the top of Fig. 1 directly above the nucleus.

To illustrate the continuity between the cell membrane, nuclear membrane, and the endoplasmic reticulum, the endoplasmic reticulum was constructed of various shapes of clear plastic. The bending effect of the double membrane was obtained by heating the various pieces and bending them to desired shapes. The reticulum can be seen as flat irregular shapes throughout both figures, particularly in the upper left hand corner of Fig. 2.

The dictysomes were constructed from clear plastic also. They were made by bending after heating, and then strung on a red hot nail. The result was a grouping or flower-like arrangement. The top of a dictysome can be seen in Fig. 1 in the lower corner of the right hand square. These could also be referred to as the golgi apparatus in comparing to an animal cell.

After all of the parts were constructed, two halves were made by taping the edges of four hexagons to a square. These edges were then glued. Some of the endoplasmic reticulum, ribosomes, mitochondria, chloroplasts, and dictysomes were glued in place in each half. The nucleus was glued in place in the upper half so that it could easily be seen. The vacuole was then carefully placed in the lower half and the top half was glued to the bottom. This left four squares to be placed; they were glued after last minute adjustments had been made.

Conclusion

A model has been constructed which can be easily duplicated. It can serve as a useful classroom demonstration to help any general science or biology class conceive the shape of a "typical" parenchyma cell in the third dimension. It will also lead to an understanding of positions and relative sizes of cell parts in general. The basis for related further study and investigation can be easily built by starting with this visual concept.

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