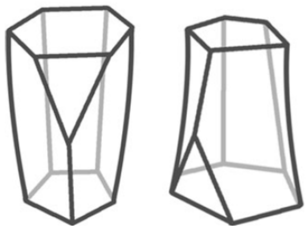
Here is the Scutoid

The Discovery of a New Shape



Marianne Bossema

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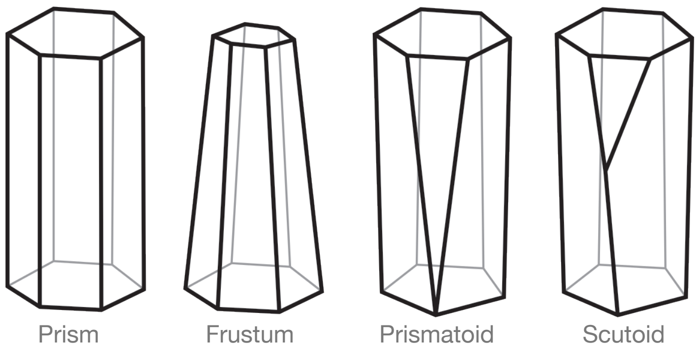
Here is the Scutoid

In the summer of 2018, articles in the news reported that scientists from the University of Sevilla had discovered a new shape. This puzzle and booklet are made to explore and explain that new shape and its features.

The story is about a geometric three dimensional solid called a ‘scutoid’. We already know a lot of different geometric solids. Some of those can be found in a block box, like spheres, cylinders, cubes and pyramids. Others are more complex like the Archimedean solids. Mathematicians have described geometric solids by their characteristic properties. They have studied these shapes and their distinctive features for centuries: the earliest regular solids were discovered in the 6th century BC. Over time more and more shapes have been added, and the scutoid is the most recent contribution.

The shape of a scutoid

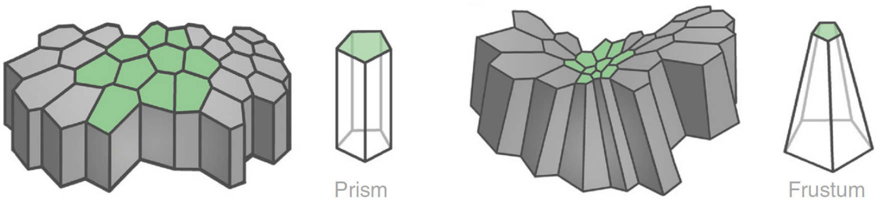
Scutoids are related to prisms and pyramids. The image below shows a scutoid and its ‘family members’.



A **prism** has two similar parallel faces called bases. The other sides are always rectangles or parallelograms. It is named by the shape of its base, e.g. a hexagonal or pentagonal prism. A **frustum** is a clipped pyramid with the upper part cut off. A **prismatoid** connects two parallel faces that can be different, e.g. a hexagon and a pentagon. The other sides can be parallelograms, trapezoids or triangles. The **scutoid** is similar to the prismatoid but has at least one extra point between the surfaces, which gives it a characteristic Y-shaped rib. As a result, the lateral faces are not planar but slightly curved and twisted.

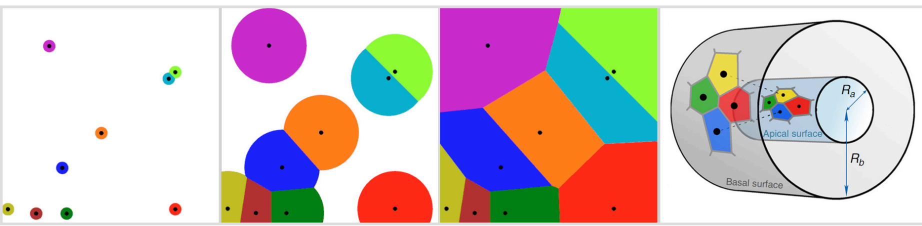
Discovery of the scutoid

Living organisms are made of different kinds of tissue, and one of these is called epithelial tissue. It forms the inner and outer surfaces of organs and blood vessels in a body. An example of epithelial tissue is the epidermis: millions of cells are packed together to create human skin, that covers the body, grows with us, is bendable and protective.



Biologists always assumed that epithelial tissue consisted of prism and frustum shaped cells that seemed optimal for forming a flexible and strong surface. This theory explained the structure of tissue folds that biologist could see in their microscope. But the research team from the University of Sevilla saw other tissue formations that they did not understand and they observed epithelial cells sometimes 'exchanging neighbors'. Some cells had different neighbors on the outer side of the tissue than they had on the inner side, especially in curved forms. The team asked mathematicians to help them to explain this.

The scientists used a computer model to calculate possible shapes of epithelial cells in different formations. Many times, the patterns you see in nature are Voronoi tessellations, and the team assumed that the surfaces of epithelial tissue would also follow that pattern.

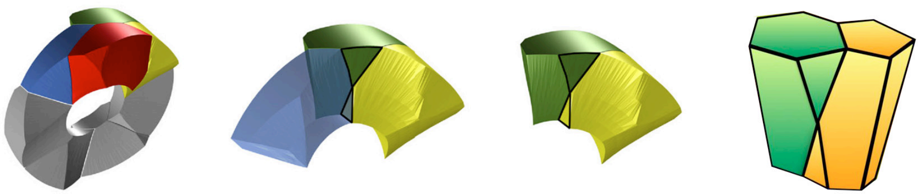


The three images on the left show how a Voronoi pattern evolves. Consider a set of points randomly placed on a surface. A Voronoi cell is then defined by the set of points around it and cannot grow more than unto halfway the distance of the neighboring cells. The image on the right shows how a curved surface has different Voronoi tessellations on the outer and inner surfaces of the tissue.

The researchers generated voronoi patterns to simulate the curved surfaces of the epithelial tissue and calculated the shapes of the cells in between. They looked at how cells would form while trying to minimize the energy, but find a stable arrangement and pack together as efficient as possible. That is where they found the scutoid.

Special features of the scutoid

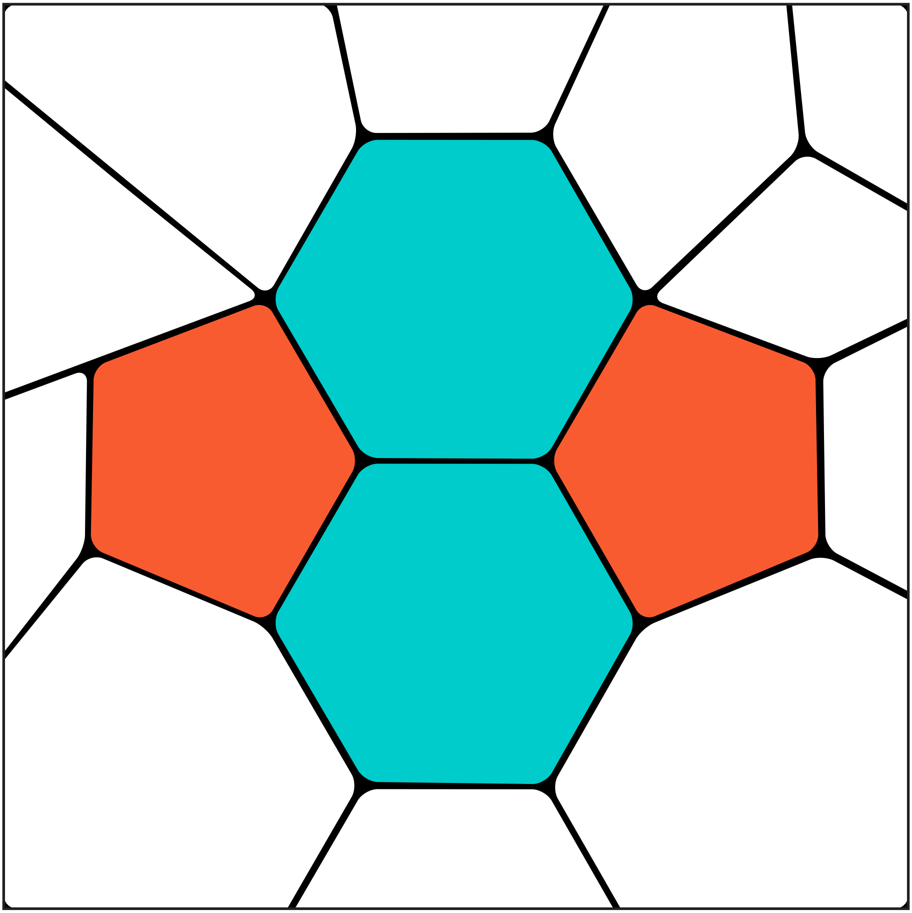
What is so special about the shape of the scutoid? In epithelial tissue, only a percentage of the cells are scutoid shapes, but they are more often found in curves. Scutoid cells can be packed in groups, have different neighbors on the outer and inner surfaces, and connect to each other by the Y-shaped side. Packed scutoids seem to hug each other firmly and form a stable construction because of the diagonal connection and the curved planes. That's why nature 'invented' them.

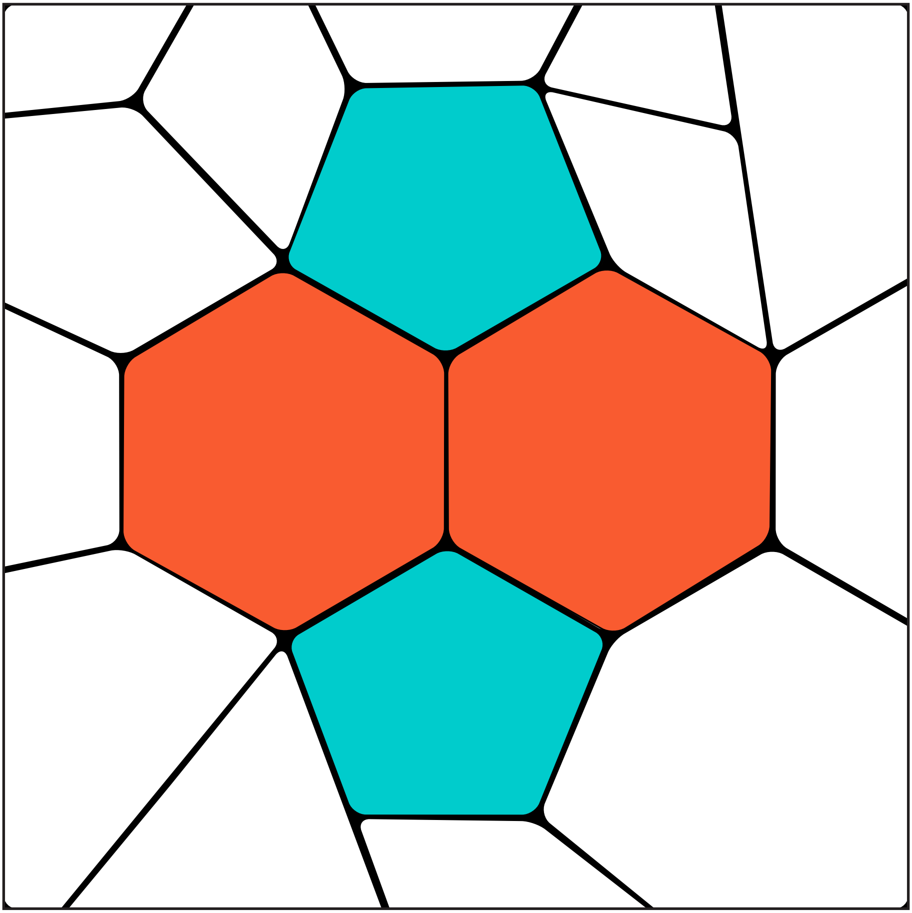


Once they knew that it was very likely that scutoid cells could be found in epithelial tissue, biologists from the team started looking and discovered them in the tissue of fruit flies and zebrafish. Actually, scutoids were there forever, but we never had seen them or given them a name. In the future, scutoids may help scientists to predict if cells are growing normally or not, or may help developing knowledge on how we can make artificial tissue.

A Scutoids Puzzle

Explore how scutoids form a group of four by placing them on the Voronoi maps on these pages. The map on the left shows the scutoids from the top, the map on the right shows them from the bottom.

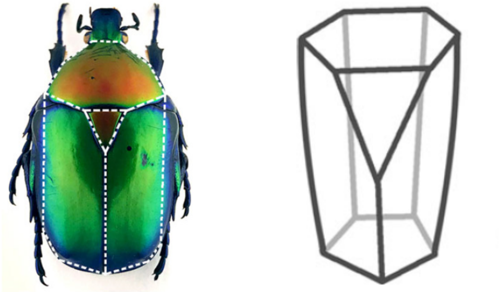




References

Gómez-Gálvez, P. et al. (2018). Scutoids are a geometrical solution to three-dimensional packing of epithelia. Nature Communications, 9(1). doi: 10.1038/s41467-018-05376-1

Scutoid. (2019). Retrieved from https://en.wikipedia.org/wiki/Scutoid



The scutoid was named after a triangle-shaped part of a beetle's thorax called the scutellum.