SHAPE SHIFTING

Lipid monolayers with similar composition adopt a flat shape.

Several factors interact to determine the three-dimensional structure of cells and organelles. First and foremost, the physical properties of the molecules that comprise the structure have preferred positions that minimize the energetic costs of the shape they take. If both layers of a lipid membrane have an identical composition, for example, that membrane will naturally lay flat 1. Membrane monolayers composed of different lipids, on the other hand, may curve 2.

Proteins also play a key role in determining cell and organelle shape. In the endoplasmic reticulum (ER), BAR domain proteins and reticulons insert into the lipid membrane, causing it to bend 3. The proteins have an affinity for curved surfaces such that their attraction to the ER membrane overcomes the energetic cost of the bending.

Lipid bilayer

(cell membrane)

CYTOPLASM

Finally, some basic mathematical principles can dictate shape. For example, surface-to-volume ratio, which is a function of organelle size, can influence how spherical a structure is. The ER, which has a high surface area and a relatively low volume, takes the shape of a stack of pancakes 4. The connections between these layers is once again determined by the physics of the system, with spiral connecting structures resulting in minimal energy output from the ER's lipid membranes.

g BAR domain proteins and reticulons help to dictate the tubular shape of the ER.
Defects in these proteins impair the ability of lipids to exchange between ER and mitochondria.

Lumen

ER tubules

Endoplasmic reticulum (ER)

The ER comprises stacks of flat membranous sacs connected to each other by a twist of membrane, similar to the ramped connections between levels of a parking garage. The spiraling structure of these ER stack connectors minimizes the energetic state of the ER's lipid membranes.

Monolayer areas of

different composition

adopt a curved shape.

Reticulon

Mitochondrion and other cell organelles

BAR proteins

Lumen