MECHANICS OF STACKED MEMBRANE COMPARTMENTS

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Many cellular processes depend on complex relations among the cytoskeleton and the membrane of cell organelles. In order to gain an insight into mechanics of these complexes, we performed a theoretical analysis of stacked membrane compartments, such as the stack of the Golgi cisternae. As the first approximation of the problem, the analysis takes into account the membrane mechanical properties and the interaction between membranes of the neighboring compartments. Membrane properties are described by the commonly accepted general bilayer couple model which combines the membrane bilayer structure and its resistance to bending. The interaction between membrane compartments is considered to be attractive and uniform along all the contact of the membranes. Also, all the compartments in the stack are taken to be identical and axisymmetrical. The stable equilibrium shapes of the stack of membrane compartments are calculated as the shapes corresponding to its minimal total energy. The analysis predicts that at high compartment volumes the membrane compartments in the stack have equatorial mirror symmetry. At lower compartment volumes, however, the mirror symmetry breaks and the membrane compartments become cup-shaped. The point of symmetry breaking depends on the strength of the interaction between the compartments – the compartment volume of the symmetry breaking decreases with increasing interaction strength. The cisternae of Golgi apparatus are in fact asymmetrical, which most likely reflects their role in oriented intracellular transport pathways. The present study indicates that the properties of the lipid membrane alone are sufficient to produce this type of asymmetry. The results are also used to discuss the rouleau formation of erythrocytes.