Ruled surface underlying KcsA potassium channels

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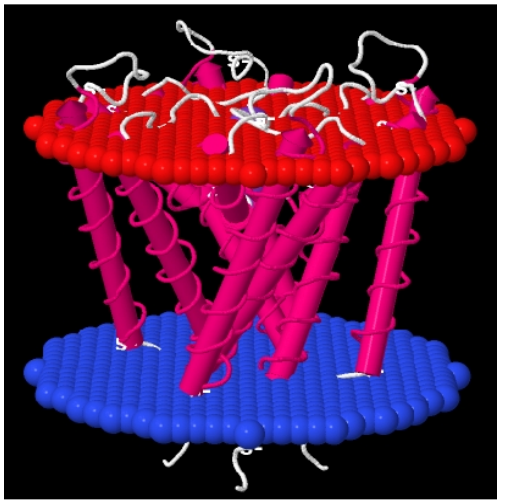
Ion channels are pore-forming proteins across the plasma membranes of cells that regulate the passage of ions, a crucial process in cell biology. Specifically, potassium ion channels represent an important class of ion channels that are responsible for the stabilization of the membrane potential. Central to this function is the ability of such channels to control the transmembrane ion flux via a gating mechanism, to open and close the channel pore. KcsA potassium channel has an elegant backbone structure of four-fold symmetry that is decorated by various chemical groups, as schematically shown in the left colored figure below. Recent experiments have revealed that the opening and closing of the channel is controlled by concertedly rotating and tilting the ends of the alpha-helices composing the KcsA ion channels. We recognize these transmembrane alpha-helices as the generating lines of the ruled surface: the hyperboloid of one sheet. The twist-to-shrink feature of the hyperboloid is adopted by KcsA channels in gating the pore as observed in experiments. Our model may shed light in understanding nature's design principles of ion channels. Conclusions drawn from this study have implications in the design of artificial channels.



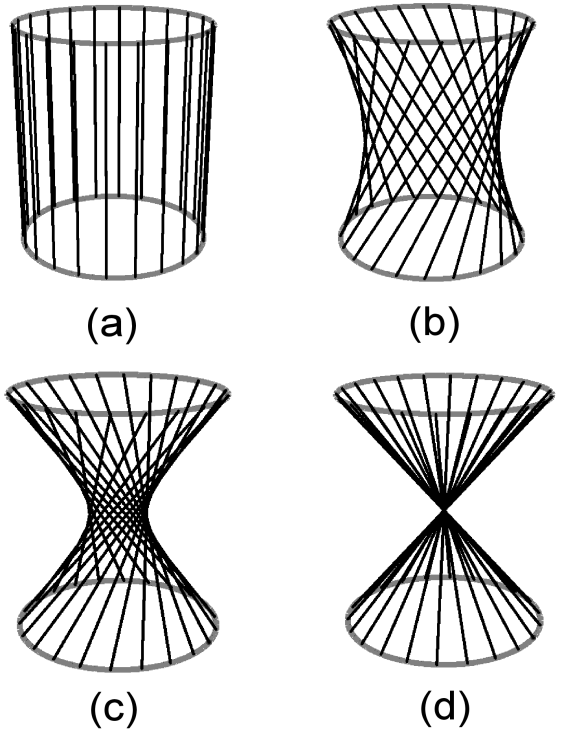


Figure *(Left) The sideview of the TM1 (the outer four rods) and TM2 (the inner four rods) helices, represented by rods wrapped by spirals, between the membranes. (Right) Straight lines span the two boundary circles. By twisting the upper circle, the surface evolves from cylinder (a), hyperboloid of one sheet (b, c) to double cone (d).*

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