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## Which type of morphospace does work well?: dimensional artifacts revisited

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Theoretical morphological models have been used for morphometric analyses as well as for simulation studies of organic morphogenesis. Among a number of theoretical morphological models, the most widely applied one is Raup's (1966) model, in which molluscan shell form is defined by whorl expansion rate, relative width of umbilicus, and rate of translation of the whorl along the coiling axis. The Raup's morphospace is usually depicted as a geometric hyperspace in which a particular shell form is plotted with orthogonal axes representing his model parameters. However, recent specialists on theoretical morphology are highly critical of the Raup's parameters because they are not algebraically independent one another and the dimensions of his morphospace are not truly orthogonal (Schindel 1990; Stone 1996; McGhee 1999). Such a property of his model makes the range in the morphospace unreliable as a metric for disparity or morphological variation.

Here I assessed the impact of algebraic interdependency among parameters for the following models theoretically and empirically. In Okamoto's (1988) model, a positive correlation is theoretically supposed between standardized curvature and enlarging ratio of the generating curve; this type of correlation was observed in biometric data obtained from ammonoids specimens. In Schindel's (1990) model, the umbilical expansion rate should be equal to the whorl expansion rate in the case of logarithmic spiral; a positive correlation between them was found in actual ammonoids. In Ubukata's (2000) model, translation rate of the generating curve should be correlated with the position of the center of the translation due to the dimensionality of the morphospace; the dimensional artifact well explains the distribution of actual data collected from limpet shells. The algebraic interdependency among parameters may be a common defect of most theoretical morphologic models ever proposed.

Keywords: theoretical morphospace