FORAMS-2006
SYSTEMATICS AND EVOLUTION OF PROTISTS: FOSSILS, MORPHOLOGY AND MOLECULES
A CUSHMAN SYMPOSIUM IN MEMORY OF ALFRED LOEBLICH AND HELLEN TAPPAN
Special Session co-chaired by Jere Lipps and Susan T. Goldstein

THEORETICAL MORPHOSPACE OF FORAMINIFERAL SHELLS: EVOLUTIONARY IMPLICATIONS

JAROSŁAW TYSZKA

Institute of Geological Sciences, Polish Academy of Sciences, Cracow Research Centre,
ul. Senacka 1, 31-002 Kraków, POLAND; e-mail: ndtyszka@cyf-kr.edu.pl

The theoretical morphospace of foraminiferal shells (tests) is constructed based on the moving reference model. The model has introduced apertures as reference points into modeling polythalamous foraminifers [1-3]. The morphospace includes all forms created by the model with systematically varying parameter values. Some of morphologies are possible others not, in consequence, the overall morphospace splits into the 'possible range' and the 'forbidden range'. The 'possible range' includes existent and nonexistent foraminiferal forms separated into 'vacant', 'dysfunctional', and 'deficient' ranges. Analyses of these ranges provide additional knowledge on morphogenesis of foraminifera [3]. It is surprising that nearly all theoretical foraminiferal morphologies are possible and have been selected in reality. We can therefore suppose that most theoretical morphologies are functional because they were successfully tested by real evolution. That raises a fundamental question whether or how far shell patterns are subjected to natural selection. Biserial foraminifers give an instructive example because they have efficiently colonized the water column, sediment surface, and subsurface sediment. Their elongated test shape seems to facilitate burrowing, nonetheless, this shape does not disturb surface dwelling and floating abilities. We can speculate that evolution of small foraminifera may choose from an enormous variety of shell shapes that may have low or even neutral adaptive values. On the other hand, foraminiferal species usually show relatively stable morphotypes that are most likely controlled by genetic codes. They do not choose morphologies by random as it could be expected from assumption of neutral values of shell patterns.

The classical view considers gradual evolution of foraminiferal morphologies. Cryptic speciations recorded by molecular studies seem to support this paradigm. Nevertheless, the theoretical morphospace of foraminifera reveals regions of the morphospace that include similar morphologies. These specific fields in the morphospace, called *morphophases*, are separated from each other by *morphophase transitions*, which involve sharp or gradual changes in morphology controlled by changes of the model parameters. The morphospace acts as a phase space in which all possible states of a system are represented [3]. Analysis of the morphospace reveals that similar morphologies may be located in distant parts of the morphospace defined by very different parameters. On the other hand, very different morphologies may be closely related, representing similar parameters. The straightforward conclusion is that small gradual change of parameters may cause abrupt changes of morphologies. Evolutionary consequences are essential supposing that gradual genetic changes may sometimes generate nongradual morphologic modifications. In this case, optimised emplacement of foraminiferal apertures is responsible for these nongradual morphologic changes represented by *morphophase transitions*. Shall we ask whether Darwin's *natura non facit saltum* has exceptions?

The presented model and its resulted morphospace include morphologies resembling foraminifers classified to Textulariida and Rotaliida. Both groups use the same rules to create similar morphologies. The classical taxonomy based on the wall composition keeps them aside; nonetheless, molecular biologists have proven both groups to be very closely related. Other taxa show similar trends (e.g. miliolids, rzehakinids, ammodiscids) quite consistent with the taxonomic scheme presented by Mikhalevich & Debenay [4]. Further integrated studies seem to be necessary for a comprehensive understanding of foraminiferal "fossils, morphology and molecules". *This research is sponsored by the Polish Ministry of Education and Science (Grant nr 3 PO4D 048 24).*

[1] Topa, Tyszka, 2002 - *Lecture Notes in Comp. Sci.* 2329: 97–106. [3] Tyszka, Topa, 2005 - *Paleobiol.* 31(2): 526–541. [3] Tyszka, 2006 - *Lethaia,* 39(1): 1–12. [4] Mikhalevich, Debenay, 2001 - *J. Micropal.*, 20: 13–28. See: http://www.eforams.icsr.agh.edu.pl/