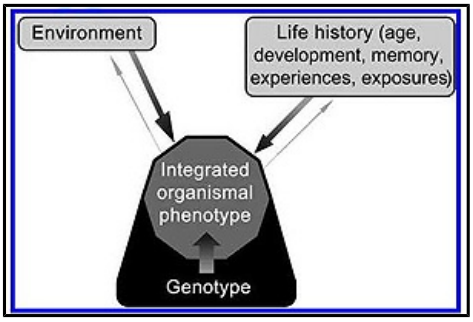
Concept paper emphasizes environmental influences on individual organisms

By Nancy Lamontagne

University of California, Davis (UCD) Superfund Research Program (SRP) grantee Dietmar Kültz, Ph.D., *(http://ucanr.edu/sites/superfund/Personnel/DietmarK%C3%BCltz/)* is first author of a new concept paper *(http://cichlid.biosci.utexas.edu/assets/2013.k%C3%BCltz-et-al.pdf)* calling for renewed emphasis on organismal biology - the study of structure, function, ecology, and evolution at the level of the organism. Kültz and colleagues argue that their approach will help scientists better understand how environmental exposures, experienced at various life stages, produce specific biological outcomes, or phenotypes.



According to the authors, the three principal actors defining organismal phenotypes are the genotype of the individual, the environment in which the individual is embedded, and the life history experienced by the individual. The life history represents the sequence of environmental exposures during the course of the individual's life - in particular, during early development - which are recorded as cellular and higher forms of memory. Organisms vary in their propensity for recording life history. (Photo courtesy of Dietmar Kültz)

As the authors describe their holistic approach, organismal biology reveals general organizing principles of physiological systems and behavior, particularly in complex multicellular animals. The authors contend that biology has shifted too much toward studying genes, rather than organisms, and that genetic variation alone cannot explain the physiological and behavioral variations of complex organisms.

"Phenotyping tools and approaches for studying environmental influences on individual organisms are not nearly as mature, powerful, or trendy as approaches targeting genetic blueprints," Kültz said. "However, a greater emphasis on in-depth, high-resolution phenotyping is critical for understanding the individual nature of an organism's complex physiologies and behaviors."

Kültz's paper appeared in the journal Bioscience, a publication of the American Institute of Biological Sciences *(http://www.aibs.org/home/index.html)* that highlights synthetic overviews of current biological research. The paper presents the results of analyses and discussions from a 2011 workshop on the future of organismal biology, which was supported by the National Science Foundation.

Understanding how memories influence the organism

Kültz explained that complex physiologies and behaviors vary greatly among individual organisms, because of the many theoretical combinations in which an individual genome, the full set of genetic material, can be expressed. The way a genome is expressed is greatly influenced by learning, training, development, and other life experiences that depend on the environment an organism is exposed to at particular times.

"Thus, personalized medicine may be informed by an individual's genetic blueprint," Kültz said. "But life history experiences, or memories, which are recorded in the form of specific molecular, cellular, and higher-order phenotypes, must also be considered."

According to the authors, it is important to understand how the unique sequence of environmental exposures experienced by an individual organism over its lifespan is memorized, and how the organism retrieves these memories to inform responses to subsequent environmental challenges and scenarios. This knowledge will help explain complex physiologies and behaviors, such as disease susceptibility, immunity, stress resilience, coping ability, and aging that are central to human health.

Kültz and the other authors point to needs for improved tracking technologies to monitor organisms and their natural environment, more powerful and widely accessible high-throughput phenotyping tools, and a flexible and dynamic infrastructure for storing and sharing large phenotypic data sets. They also say that effective interdisciplinary communication and cross-disciplinary training will be key for developing a stronger community of biologists who focus on integrating the distinct facets of whole-organism biology.

High-resolution phenotyping

UCD SRP researchers are advancing organism-level research, by exposing vertebrates to environmental contaminants during critical periods of development and adult life, and then studying how this exposure affects complex physiological and

behavioral phenotypes, as well as the overall health of the organisms. One method they use for high-resolution molecular phenotyping is quantitative proteomics, which provides information about all the proteins in a sample.

In the Kültz lab,
(http://kueltzlab.ucdavis.edu/)
investigators use certain fish as vertebrate models for this research. Fish have less complex life histories, can be more readily monitored than many mammals, and are often naturally exposed to contaminants that are relevant to humans.

"Dissection of complex phenotypes, at high spatiotemporal resolution, represents an enormous task," Kültz said. "High-throughput phenotyping technology, such as metabolomics, proteomics, or imaging-based technologies, are being pushed to new limits, and new tracking technologies using miniaturized sensors are now being developed to enable environmental monitoring in more natural contexts."

Citation: Kültz D, Clayton DF, Robinson GE, Albertson C, Carey HV, Cummings ME, Dewar K, Edwards SV, Hofmann HA, Gross LJ, Kingsolver JG, Meaney MJ, Schlinger BA, Shingleton AW, Sokolowski MB, Somero GN, Stanzione DC, Todgham AE. *(http://cichlid.biosci.utexas.edu/assets/2013.k%C3%BCltz-et-al.pdf)*
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(Nancy Lamontagne is a science writer with MDB Inc., a contractor for the NIEHS Division of Extramural Research and Training.)

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