**National Science Foundation**
**Directorate for Biological Sciences**
**Division of Integrative Organismal Biology**

# Integration of Development and Physiology: Mechanisms Shaping Animal Phenotypes

Dear Colleague,

A workshop entitled "An Integrative Developmental Biology" was held in November, 2004, and sponsored by the Division of Integrative Organismal Biology (IOB) in the Directorate for Biological Sciences at the National Science Foundation. That workshop drew our attention to what we now recognize as an emerging area of research that spans the traditional areas of developmental biology, and ecological and evolutionary physiology presently supported by IOB. With this letter we wish to inform a broader community of scientists about this emerging area.

The workshop participants took a broader view of animal ontogeny than is often held by developmental biologists, as described in the workshop report, http://www.nsf.gov/pubs/reports/idbwsreport.pdf. This broader view comprises more than the unfolding of a genetic and signaling cascade triggered at fertilization. The unfolding of the animal phenotype, its variation within a species and the causes of the differences between species, are much more complex and less understood processes. This view considers the physiological regulation and environmental inputs as well. The general questions that follow are in some cases taken directly from the workshop report, and reflect the scope of this emerging effort.

**How are complex phenotypes built?**
It is well known that complex phenotypes are determined through the interaction of many and diverse genetic and environmental factors whose effects accumulate over long periods of time. Yet, the development of cells and tissues are typically studied in isolation and over brief time periods. As a consequence, little is known about how the development of different cells and tissues is integrated to produce complex organs and physiological systems, and how the ever-changing organism remains functionally well integrated throughout its development.

**What are the interacting developmental and physiological bases of phenotypic variation?**
The genetic and environmental determinants of development and physiology naturally vary in space and time. As a consequence, phenotypic variation has both environmental and genetic causes. Physiological variation as a consequence of environmental variation is well studied. These latter studies have described mechanisms of short-term physiological adjustments to environmental challenge (i.e., acclimation, phenotypic plasticity) within the lifetime of the animal. Fewer studies have mechanistically connected genetic variation, physiological variation, and evolutionary physiological adaptation to the environment. Although the relative effects of genetic and environmental variation can be assessed statistically, the developmental mechanisms through which normal genetic and environmental variation produce natural phenotypic (i.e., morphological) variation are virtually unexplored and therefore remain poorly understood. Clearly, the interaction of developmental and physiological processes produce natural variation in morphological and physiological sets of characters, and both of these kinds of processes are influenced by genetic and environmental variables.

Thus an important and emerging conceptual area is focused on mechanistic processes at the interface of development and physiology to understand phenotypic variation.

**How are developmental and physiological systems integrated?**
As development proceeds and the animal grows in size, the coordination of development of distant parts becomes increasingly a problem of physiology rather than cell biology. Integration of development must occur on a spatial scale, in that developmental progression to different stages in a life cycle must be regulated. The mechanisms by which spatial and temporal coordination of development occur are largely unknown.

Additional questions that are relevant to this new area are shown below:

**What are the mechanisms of homoplasy? What are the mechanisms by which the same suite of physiological or morphological characters arises despite variations in developmental mechanisms?**

**How do variations in gene regulatory networks express themselves in altered animal phenotypes across and within species?**

**How does a given developmental genetic mechanism give rise to variations in morphological or physiological states within or between species?**

**What are the physiological determinants of developmental progression?**

**Does physiological variation differentially influence developmental genetic mechanisms, and lead to phenotypic variation in animals within and between species?**

As we become aware of other emerging areas of research within the Directorate for Biological Sciences, through workshops or other means, we intend to alert the broad community of scientists about them as a way to increase consideration of, and eventual participation in, these newly emerging areas.

Sincerely,

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