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Implementing the Organismal Agenda

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If your reaction to the title of this article was, "I didn't know organismal biologists *had* an agenda," then you've grasped the problem. Those of us who study biology at the organismal level usually identify ourselves as something else—herpetologist, evolutionist, or ecologist, for example. Our professional societies are similarly arranged. It is therefore unsurprising that organismal biology perennially has been given short shrift in research support, not to mention faculty appointments and professional prestige. As a group, we've fallen far since the days of scientists such as Richard Owen (the celebrity comparative anatomist who founded the British Museum of Natural History). Despite occasional chest pounding, organismal biologists have failed to act en masse, while other fields have loudly proclaimed their primacy in the biological hierarchy. This failure is all the more tragic because organismal information is increasingly recognized as both the crux of critical biological questions and the bottleneck in our attempts to answer them (e.g., NRC 2009).

In 2009, the National Science Foundation (NSF) asked the Society for Integrative and Comparative Biology (SICB) to identify the "grand challenges in organismal biology" (GCOB). There was a sense of urgency under the new presidential administration, and the NSF was setting its own funding priorities. After broad discussion, SICB's executive committee conceived a set of critical research areas (see Schwenk et al. 2009 for details):

- Understanding the organism's role in organism-environment linkages
- Utilizing the functional diversity of organisms
- Integrating living and physical systems analysis
- Understanding how genomes produce organisms
- Understanding how organisms walk the tightrope between stability and change

Here I propose a personal view of four elements necessary in any plan to implement the organismal agenda as set forth in the grand challenges.

Research support

Limited resources mean that financial support must be selective. Federal agencies such as the NSF should create targeted programs specifically aimed at funding GCOB initiatives. Eligible proposals should be linked explicitly to GCOB particulars. Program directors and committee members should be guided by principles established by an advisory board.

Federal agencies should remove or mitigate barriers to appropriate research. These barriers include laws affecting the use of vertebrate animals in research and teaching, often so narrowly interpreted by institutional animal care and use committees that even noninvasive fieldwork is thwarted by red tape. Arbitrary rules that discourage interdisciplinary integration need to be relaxed (e.g., a "rule" dictating that research involving humans can be administered only by the National Institutes of Health was the reason cited for the return of a colleague's unreviewed NSF proposal; he had proposed to exploit biomedical advances in human cell culture to address organismal questions).

A key question for any funding strategy is whether to fund fewer large grants or a greater number of smaller, more diverse, mostly single-investigator grants; the NSF currently favors the former approach. Yet history shows that a great deal of innovation emerges from single-investigator research or loosely networked labs where flexibility is not structurally constrained and rapid changes in direction are possible. Funding a greater number of smaller labs is also a way to increase the diversity of species studied, a critical component of the GCOB. I see a GCOB-informed funding program as one that apportions a larger segment of its funds to individual investigators than the NSF does now, while also supporting some large, interdisciplinary proposals that receive matching funds from other programs.

A final issue in funding policy for GCOB is the need to consider high-risk and exploratory research (with smaller sums) and to end the imposition of a strict hypothetico-deductive framework for proposals—a potentially stifling practice. The requirement for extensive "preliminary data" should also be relaxed for exploratory proposals, since the goal is to encourage novelty and creativity.

Fostering interdisciplinary research, collaboration, and synthesis

A universal theme emerging from efforts to visualize future biological endeavor is the need for interdisciplinary research (e.g., Wake 2008a, 2008b, NRC 2009, Satterlie et al. 2009, Schwenk et al. 2009, Tsukimura 2010). In a world of explosively expanding information and increasing specialization, how can interdisciplinary thinking be fostered?

The idea is not new, but a logical first step is the creation of an organizational framework that brings diverse investigators together to share ideas and information from across disciplines. This approach can engender new collaborations and research directions through centralized organizations such as the National Evolutionary Synthesis Center and the National Center for Ecological Analysis and Synthesis, or through a series of small, special-topic conferences. I favor an organized hierarchy of conferences and committees. Unlike most such systems, there must be strong top-down orientation to each working group, and the investigators involved at each level must accept responsibility for creating a document that is passed upward for amalgamation and synthesis. At the top of this hierarchy would be a smaller but equally diverse committee that sets policy and determines current funding priorities. Each lower-level working group would determine how research in its area could best contribute while higher-level groups would organize the findings into a larger framework. With the exception of the top-tier advisory committee, such a system could be organizationally fluid yet advance the agenda through its requirement for tangible outcomes. People might be encouraged to participate in such a process if they were paid for their time.

Information centralization and accessibility

For organismal data to be maximally useful to investigators across a broad range of applied and basic research disciplines, we must centralize as much information as possible within a searchable, Web-based database. The success of such a database depends on five attributes: (1) it must accommodate diverse types of organismal information (e.g., morphological, ecological, genetic, etc.); (2) it must be flexible in its search capability to accommodate workers in divergent fields; (3) it must be built and maintained by experts (in consultation with the GCOB advisory board) within a stable organization—it cannot depend on the unpredictable altruism of individuals (Halanych and Goertzen 2009); (4) it must be user-friendly; and (5) data entry must be compulsory for investigators funded by a GCOB program and encouraged for others.

I envision a system in which a medical researcher investigating a new cancer drug from a particular plant can search the database for close relatives or species with certain attributes, a policymaker can determine the functional role of plants and animals within an ecosystem before writing legislation, or an engineer can ascertain what organisms perform specific mechanical tasks in order to examine them for design inspiration.

Education

Every avenue of education about organisms and the societal value of basic research on them must be exploited (Halanych and Goertzen 2009)—education for the lay public and children, as well as students and professional colleagues. Full recognition of the value of organisms by society will probably take generational turnover.

Children do not evince an early interest in voltage-gated ion channels or the tertiary structure of proteins; they prefer dinosaurs, dolphins, and furry things. We should nurture this early fascination with organisms by reaching out to schools and teachers. We need to publish more popular press articles, and "nature" television channels must highlight the researchers who generate the knowledge they popularize and profit from. But the most difficult task will be to restructure the way we train our replacements.

We tend to train PhD scientists as research specialists. Promotion, tenure, funding, and advancement favor the rapid publication of narrowly focused, often unremarkable research divided into least publishable units. Although scientists and university administrators frequently pay lip service to "integrative biology," the system often penalizes people who practice it by labeling them as dilettantes.

There is no simple solution—GCOB is an integrative endeavor, and few researchers can master several fields. However, if we design interdisciplinary graduate programs that train students in two or more traditionally separate areas (e.g., mathematics and ecology, morphology and engineering, physiology and ecosystem ecology) we might create interdisciplinary thinkers who will advance biology. I believe it's less important for such students to master every field than for them to learn the tools and discipline-specific processes needed to pursue novel ideas. Creativity can be fostered by a suitable educational and professional structure.

It is feasible to begin implementing such programs at the institutional level, but the much harder question is how to shift the monolithic culture of professional science. Like most of society, academe has been overtaken by a corporate management model—a system that promotes short-term gain over the long-term pay-offs of quality and advancement of the greater good. We need to move toward a scientific culture that rewards creativity and service to the community as well as individual accomplishment. Then we can truly advance the organismal agenda.

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