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John C. Wingfield, an environmental endocrinologist at the University of California, Davis, was appointed by National Science Foundation (NSF) director Subra Suresh as head of the foundation's Directorate for Biological Sciences, known universally as BIO, last September. BioScience *editor in chief Timothy M. Beardsley interviewed Wingfield in his office at NSF headquarters in Arlington, Virginia. The interview has been edited for clarity.*

Beardsley: *As a former president of the Society for Integrative and Comparative Biology, you obviously appreciate the value of research that integrates biological subdisciplines. Do you envision new interdisciplinary programs being launched from here at the intersections with the physical and social sciences, mathematics, and engineering?*

Wingfield: Yes, I certainly do. These are developing all the time and have been over the year while I've been here as division director. In the past year, we initiated BioMaPS, which is an interaction of BIO and the mathematical and physical sciences. That is to promote more mathematical and biophysical approaches to biology.

There are lots of programs that will evolve over the years. We have ongoing interactions with the NSF's Directorate for Computer and Information Science and Engineering and with the NSF's Office of Cyberinfrastucture in relation to CIF21, the *Cyberinfrastructure Framework for 21st Century Science and Engineering*. I see these developing more and more.

One thing I see being discussed among many of the assistant directors, and also within the directorates, is the need to tackle problems associated with data-intensive science and computation-intensive science. These are huge bottlenecks for many science and engineering endeavors,

particularly biology. There are all sorts of programs that are ongoing, like iPlant [*www.iplantcollaborative.org*], which is doing a tremendous amount to solve some of these problems, or the National Institute for Mathematical and Biological Synthesis. All of these are funded to varying extents by NSF, including BIO.

So people are addressing these enormous problems of managing data. How does one manage data sets that contain a lot of images or animal behavior? Genomics data are a bit more straightforward; we've been doing that for a long time. But how do you put these out there in some sort of cloud that a PI [principal investigator] could access as well as draw on totally different data sets to ask a completely individual question? These are issues that all of the directorates are tackling head-on, and we are talking to one another.

Beardsley: *Will there be mandates on open access to data?*

Wingfield: Yes. I can't give you any details, because I don't know them yet, and they are evolving, but somehow NSF is going to have them. As you know, we have now a two-page data management plan, which needs to go in with each proposal. That's really a beginning. It's going to evolve tremendously as we gain more experience and as principal investigators tell us how they'd like to see the data managed.

Beardsley: *More generally, what do you see as the three greatest priorities, or opportunities, for the biological sciences research community?*

Wingfield: I expand the three to the five grand challenges *[Research at the Intersection of the Physical and Life Sciences, National Academies Press, 2010]* that the National Academy of Sciences put forward. BIO is very actively engaged in all of those. I think perhaps *the* grand challenge is how to integrate all these. For example, one of the grand challenges is genomes to phenomes: How could one predict from a genome the phenotypes that could develop? And it goes beyond that, because then

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once you have a phenotype, it can learn, gain experience, from the social environment and the physical environment. I think we're a long way from being able to predict anything about that from the genome. I like to say the organism in its environment is the ultimate frontier. How we are going to understand the organism–environment interaction in a changing world is a huge challenge. Going from genomes to phenomes is one way; also, the other way, top-down, from phenome back to genome, is a useful way to look at it.

Also emerging from these approaches come many contributions to synthetic biology, which has all sorts of implications for bioeconomy and biofuels.

Beardsley: *I've started to hear the word bioeconomy more recently.*

Wingfield: Bioeconomy and jobs—how fundamental biology, which is what NSF funds, contributes to the economy. One example I could make is the recently reported research [by Karen and Louis Burnett of the College of Charleston] that involved a shrimp on a treadmill. Actually, that project turns out to be a way in which one can assess the health of shrimp populations, both in the field and in aquaculture. Given that the shrimp commercial world is a multibillion-dollar industry employing thousands of people, these sorts of things can have—*do* have—an impact on the bioeconomy.

There are many other examples in BIO. For example, the plant genome research program and BREAD (the Basic Research to Enable Agricultural Development program), which is a partnership with the Bill and Melinda Gates Foundation. These are projects that are using fundamental research at the molecular, genomics, and metabolomics levels to actually develop crops that will serve the world in the future. They involve very basic investigation of organism–environment interaction—in this case, environment–crop interaction. For example, we have projects that are trying to develop varieties of rice that are flood resistant. We're used to thinking that rice likes to grow in water, but it is susceptible to floods. We're also looking to develop other crops that are drought resistant; that tolerate salt; that are cold tolerant, heat tolerant… all of these are classic questions of organism–environment interaction that can only be answered at a very fundamental level. That is what BIO is doing more of.

Also, I am hopeful we'll be able to enable similar sorts of coordinated interactive research with genomics, bioinformatics, and organismal biology to do the same with animal research—and with microbes and fungi as well. There's considerable progress on these fronts that I see as enabling organismal biologists, so that PIs and their students who're working with nonmodel organisms—whether it be an arctic fox or some spider or crustacean or worm—can take their research into the postgenomics era. This is becoming more and more possible. Given that there are bioinformatics and data-management issues that need to be solved, we see the future as extremely exciting. We'll be able to study so many interesting organisms that will answer so many of the fundamental questions of biology.

I didn't mention understanding the brain, and dimensions of biodiversity, which are all part of the same mix. We're looking to a more unified biology, instead of molecular, cellular, organismal, then environmental. I see the boundaries between these getting very blurred, and I see the future is going to be the interactions between these—and with other directorates.

Beardsley: *Research budgets are falling, and the number of proposals submitted is increasing. BIO announced this summer that the Division of Environmental Biology and the Division of Integrative Organismal Systems would move to an annual preproposal and (if approved) an annual full-proposal submission process. Yet it looks as if the near-term funding picture will include still-lower budgets. Are there other tactics you are thinking about to manage proposal loads, should this pattern continue?*

Wingfield: Let me start with proposal solicitation. In recent years, budgets have been flat, rising a little bit, but now they are going down again. But the numbers of proposals have increased as much as 40 to 50 percent. So obviously, the funding rate is down, unless we were going to give much smaller grants—which is also a problem, since there is a limit beyond which the PI cannot do the research. So we don't like to reduce the budgets that much, if possible. About two years ago, BIO put together a working group to look at mitigating the workload not only within NSF but also for the community that is doing the ad hoc reviews—and also working on the panels, which is a tremendous amount of work. In Integrative and Organismal Systems alone last year, we had something like 14,000 requests for ad hoc review. So you can figure five or six requests to get one to three reviews. Because people are so busy, they can't do it. I had a beginning investigator e-mail me a few weeks ago, saying he'd just received three requests to do an ad hoc review. That's an awful load for a person who's also trying to write their own proposals and grants. So we were looking for a way to reduce that load.

We were also seeing a lot of proposals coming back in, having been denied, but with virtually no changes. That's partly because the investigators did not have time between receiving the panel summaries of the ad hoc reviews to revise the project fully and get it back in by the next deadline. The reason they are so late is that there are so many proposals. It takes time. So this whole thing starts to snowball. We think this new solicitation is an experiment. Molecular and Cellular Biosciences, for example, went to eight months out. So there are now three deadlines in two years. The Divisions of Environmental Biology and Integrative and Organismal Systems decided to go with the preproposal and one cycle.

The reason for that is that the preproposal is short: four pages addressing the intellectual merit—that is, the actual idea and its feasibility, and the broader impacts. We limit those to two per PI. Molecular and Cellular Biology, by the way, is now down to one per PI. These preproposals will be assessed by three people on a larger panel. Because each preproposal is just four pages, each panelist will have more of them than they would normally have had, but then again, they're much shorter proposals to read.

One unknown right now is how many proposals we're going to get. We have planned for considerably more than we'd get at a normal deadline. For example, if we got 1400, we could run 14 panels with 100 proposals each. Some 20 to 25 panelists would handle those. If you then get chosen to go into the next round, we will have a reduced number of proposals going into that final round, which will also receive ad hoc reviews, as well as a panel, in the normal way that we've always done. So once you make it through the first round, the funding rate will be much higher than it is now, which for those core individual PI proposals, is about 8 to 10 percent—and it's falling.

People say, "If I don't get selected, I will have to wait a year before I can submit another proposal." That is obviously true, but the individual will get a lot of feedback from the panel, and we recommend that they talk with their program officer about developing their proposal for the next round. There are a lot of concerns about beginning investigators, who are trying to get established and only have this one cycle per year. We tend to think that in the long run, these investigators will be funded in about the same timescale as they were with the two cycles per year. The reasons for that are that it takes two to three cycles for most people to get funded. Some take more; some get it first time. On average, that takes two to three years, especially if someone drops out of one cycle to revise their proposal. You expect that with this system, where you have more time to assess the reviews, time to talk with the program officer, over the same timescale, you'll get funded, and you'll get a lot more feedback. One thing we're reminding people of is that despite this new cycle, we will still be funding the same number of grants and the same number of beginning investigators each year. We still try to fund the same number of underrepresented minorities as we had—hopefully more—and will maintain the same distribution of these grants across Research I universities, liberal arts colleges, minority-serving institutions, and so forth.

Beardsley: *What will you do if the foundation and the directorate have to face substantial cuts?*

Wingfield: There are always a lot of initiatives that come through. Without actually knowing what the budget is, it's hard to say. Right now, we are preparing for the 2013 budget. Who knows what that's going to be like, but one of the things we try to do is plan for certain scenarios. The best-case scenario for 2012 will, I think, be flat funding; that's been made public. But we may get cut substantially, so we do look at what we could possibly do for cuts of various sizes. One thing we always try to do is to protect the core. These are the programs within each division. In the worst-case scenario, if Congress really does cut NSF, then fewer grants or smaller grants are things we are debating all the time. The final decisions will be made when we get to that point. I am sorry I can't be more specific.

Beardsley: *We've established a lot of synthesis centers for biology in recent decades with NSF funding, NCEAS [the National Center for Ecological Analysis and Synthesis], for example, and most recently SESYNC [the National Socio-Environmental Synthesis Center]. Is it going to be a priority to establish more?*

Wingfield: There's always discussion. How many of them get funded without taxing the core too much is always the problem. The ones that we have—NEON [the National Ecological Observatory Network], for example, if you can call that a center—well, construction is under way with 2011 funds and it is clearly something we would like to see completed. But depending on the budget, we don't know how quickly that will happen. There's also [SESYNC], launched in 2011. All of these serve a very important function for the research community, and they do provide tremendous resources. For example, iPlant is proving to be absolutely invaluable in providing bioinformatics tools and databases—essential not only for the plant community but now also for the animal and microbial communities. So NSF will do everything it can to keep going the ones that are already going.

But new ones may be delayed. That does not mean we cannot plan. One of the things I've been telling everybody in BIO is that despite these disastrous economic times (we don't know how long it's going to take before we come out of this), it is an opportunity to stand back and think about what it is we want to do, what the community wants to do, and how we are going to get there—how we are going to position ourselves 2 years down the line and 5 years down the line and even 10 years down the line—so that when the money comes back, we can initiate the most effective programs. These might be new centers or other types of initiatives; it will change constantly as we talk with the community. This is all community driven. We just enable; we ask and advise.

Beardsley: *Any specific ideas for new initiatives coming down the pike?*

Wingfield: Sure. We had a workshop last week—"Systems biology and adaptation in a changing world"—basically, [on] the systems biology of organism–environment interaction. There will be a white paper forthcoming on that and hopefully a paper in a high-profile journal too. It follows on from a workshop held earlier this summer on genomes to phenomes, though that was more plants and USDA [US Department of Agriculture] related.

These sorts of workshops don't cost a whole lot of money, but you bring people together who don't normally talk. And exciting things happen: new ideas addressing sometimes very old, fundamental problems that have been around for a while. Also identifying emerging problems: How are we going to approach those? We are using those workshops to help us plan how we are going to organize the divisions and the programs for when the money comes back. Whether that might lead to a "Dear colleague" letter requesting proposals addressing a specific problem, or whether it would be some other mechanism, is yet to be determined.

Beardsley: *So are you suggesting systems biology in a changing world is a theme that could lead to a new center?*

Wingfield: It could, yes, although it's very early days yet. One of the things that is becoming apparent, not only in BIO but in the other directorates, is that when you bring these people together from very disparate fields and they talk, they get past the barriers of not talking the same language, and all sorts of exciting things start to develop. Then they go back to their institutions and do other things, so nothing happens. So one of the big issues we see is how you build the sort of community that keeps these people talking to one another, that allows these new ideas to blossom.

Beardsley: *Do you see more big science projects in the future, as compared to individual PI projects?*

Wingfield: I would say no. Big projects will continue in BIO, but we try to protect the core. This is our goal, [since] it is where all the innovation comes from: Individual PIs collaborating and working with their students is where the really big, fundamental ideas come from. They may be communicated through synthesis centers, but it's individual PIs working at the bench or synthesizing data, talking with one another, in the community, who originate them. And that is why we have to protect the core. It's not true of all directorates, because they have very different cultures, very different ways of doing things. But by and large, you think about the core programs, the regular grants; that's where innovation comes from. I think it would be a disaster if that was to fall by the wayside and we supported only big science.

Beardsley: *Is the necessary funding to build NEON going to come from the MREFC [Major Research Equipment and Facilities Construction] account?*

Wingfield: As far as I know, that is the plan.

Beardsley: *A lot of NSF-funded research helps inform more applied research by other federal agencies and ultimately society's response to problems. Do you expect that BIO will work more closely with the mission agencies?*

Wingfield: I think BIO should. We've always had a working relationship with the NIH [National Institutes of Health], and we have always had one with USDA and others as well. I see a need for more interaction with NASA; there's a lot of common ground there. In my three weeks as assistant director, I have not become as aware of others as I probably should have, but I know for a fact there are ongoing meetings about potential collaboration where people from many government agencies are represented.

Beardsley: *Is expanding collaboration with other agencies an initiative?*

Wingfield: I would not say it is an initiative right now, [because] everyone is thinking more about how they are going to deal with the cuts than with initiating new things. But there are meetings underway that are testing common ground for future collaborations, certainly with USDA and NIH—also, partnerships with organizations such as the Bill and Melinda Gates Foundation. We have some international collaborations going too. There is a computational neuroscience initiative, CRCNS [Collaborative Research in Computational Neuroscience], which involves NSF, NIH, and the German Federal Ministry of Education and Research. There are interactions of BIO with the Biotechnology and Biological Sciences Research Council in the United Kingdom, and JST (the Japanese Science and Technology Agency), so we have ongoing collaborations.

Beardsley: *Do you think we currently have the right funding models in place, broadly, to develop the solutions we need for problems related to climate, biodiversity conservation, food security, and safety? If not, how would you like to see things change?*

Wingfield: I am learning a lot more about this, and probably can't give you as comprehensive an answer as I might in another few months. The new director, Dr. Suresh, has expressed much interest, proposing a "One NSF," where all the directorates and the offices are interacting more intensively to address issues such as the bioeconomy, jobs, and education at all levels. For example, there's the recent announcement of the new program I-Corps [the Innovation Corps Program]. These are small grants, but they are the way for a PI who develops a product that they could see being perhaps marketed in some way and made available to the public at large to partner with an entrepreneur who can provide advice on how they would assess marketing, how they would partner with ongoing businesses, or perhaps form a startup. It could be a materials- or conservation-related issue. I think that's a good idea. NSF has always had some programs associated with that approach but nothing quite so focused. So there are movements coming from the initiative of our new director that address the problems, and I fully expect to see those. Another was announced on Monday by Michelle Obama, the first lady [the NSF Career–Life Balance Initiative; *www.whitehouse.gov/blog/2011/09/26/first-lady-michelle-obama-when-you-make-life-easier-working-parents-it-s-win-everyon*]: more family-friendly practices, aimed particularly at increasing the numbers

of women in science and engineering, at all levels from postdocs to deans of colleges.

Beardsley: *But biology can claim to have done better than other sciences in terms of participation of women, can't it?*

Wingfield: It can. At my institution, the University of California at Davis, women are at least 60 percent of undergraduates, and some of the courses I taught were all women. There are at least 50 percent women going on to graduate school in many biological sciences, and in many places, recruitment at the assistant professor level may be as high as 40 to 50 percent. But after that, it nosedives. The attrition of women in science—even in biology, where we've done so well up to that point—is tremendous.

The first bottleneck is tenure. The second is [the transition from] associate professor to full professor. That is a problem I encountered when I was chairman of my department. I think these new policies that NSF has instituted, and the partnerships with the institutions, will go a long way to help resolve that. It's basically just a cultural change.

One thing that was pointed out this week is that this is not just for women: It's also for their male partners. In some cases, it is the husband who may choose to be the stay-at-home parent, whereas the woman continues her career. This would also apply to that case and [to] cases of same-sex couples.

Beardsley: *The lack of representation of racial minorities in science—in biology—is a more serious problem, though, isn't it?*

Wingfield: Very much so. It's a serious, serious problem.

Beardsley: *Is it within the scope of NSF to do more than you're doing now to alleviate it?*

Wingfield: That's one reason we're having a workshop in BIO in two weeks. There are actually two programs going on. One is the working group in BIO for broadening participation. Then there's a more focused workshop that is bringing together all of the broadening-participation officers and committee chairs for 10 of the major professional societies. It's being led by the American Society for Plant Biologists, and they are mostly people from underrepresented minorities themselves. We really hope to hear from them what they see as the problem—why NSF is not making a difference in this particular case—and what we need to do, what we need to try. This may be experimental, but I think we need to try new things to make a difference.

NSF, foundation-wide, does have a minority postdoctoral fellowship program. I've served on that panel several times. It's a wonderful program because NSF is very committed to funding, if the science is good, as many of those proposals as it possibly can. But then one asks the following questions: Where do those people end up? What are the statistics on the return? Do these people actually get academic positions, so they stay in academia? Is it making a difference? I think some information on that will be forthcoming at some stage, but we are hoping that the workshop and the working group in BIO will really identify what the issues are.

I think we need some pretty hard questions to be asked, and we need to think carefully about even making some cultural changes to really broaden participation. I am sorry I don't have any answers. There have been all sorts of initiatives over the years, but those percentages of underrepresented minorities are just floating along at the same level, at least in BIO. It is an issue across the foundation. Everybody is very concerned about it, including our new director, who has talked to the foundation in general about how we're going to improve.

Beardsley: *In recent years, the National Academies, at the request of NSF and others, have produced reports, such as the "grand challenges" report [mentioned above], making recommendations for how the biological sciences should contribute to the solution of society's grand challenges. These reports have also included recommendations for new funding models for federal research. Do you see these reports and recommendations having an influence on NSF BIO programs?*

Wingfield: At BIO, we've encompassed the "five-grand-challenges" report to make major decisions on how we're going to move forward in the future. In think the workshops are reflecting the challenges. We've also challenged the major societies, including the Society for Integrative and Comparative Biology, to provide us with their views of what the grand challenges for integrating the biological sciences are at that level. So that report in particular has had quite an influence. It provides us with a good framework.

Beardsley: *And the* New Biology for the 21st Century *report?*

Wingfield: I think there were some useful things in there. It had a bit of a mixed reception here at NSF. The "grand challenges" report was much more useful for us to use as a framework. The *21st Century* one, I think, has precipitated a lot of discussion—particularly in relation to outreach to the public. In that case, it was very useful, and we can use that framework to do a much better job of educating the public about what we do.

Beardsley: *How will you make the case that investing in biology is critical for the long-term economic health of the nation?*

Wingfield: We very much feel that basic research is fundamental for applied research, so we don't go too far in the applied direction. We see our mission as doing fundamental research that can then be taken by the NIH or the USDA or other

organizations to apply to societal problems. I see that being a central mission that is very core to NSF. We will defend that as much as we can. Take the BREAD program. That's a classic case of taking fundamental agricultural research and fast-tracking it to societal needs, enabling agriculture in emerging countries.

Another thing that I want to see in BIO that I have already initiated is much closer links with the Office of Legislative and Public Affairs to raise the profile of fundamental research in BIO and how it can serve society. So we have some AAAS [the American Association for the Advancement of Science] fellows and others coming in that are dedicated to doing that. We've been working with public affairs, and I think we need to do a much better job on a much broader front. We have to be careful, because NSF must not show any indication or hint of lobbying, but we can educate the public about the benefits, and hopefully, that will trickle down and across and up.

Beardsley: *Do you have one or two things that you really want to accomplish during your tenure—legacy goals?*

Wingfield: I want to enable the true integration of biological sciences from genomics to the organism in its environment, so that we really understand how environment and genomes interact to create organisms that interact and acclimate to changing conditions. The other one is to broaden participation and educate the public. Those two actually go somewhat together, to make biological sciences and sciences in general a much more exciting day-to-day passion for the public at large, for all nations and all ethnic groups. Biological science is not something you should be afraid of. You can embrace it and learn and understand so much more.