Dream Team Science

The Silos are Coming Down

In most Western societies, the twentieth century will be remembered as the century of the individual. In particular, the U.S. experienced a steady progression toward individualism when the "freedom of expression" movement of the 1960s gave way to the self-absorption of the 1970s, and finally to the greed and self-promotion of the 1980s. Many U.S. institutions were affected by these shifting values, and although the influences of global market forces pushed some companies to adopt more team-based, Eastern approaches, most academic institutions in the U.S. retained tenure and promotion systems designed to recognize and reward individual contributions.

The result was an explosion in research prowess, but the scientific research enterprise also developed a "cottage industry" mentality in which the individual was king. In this system, individual investigators directed postdoctoral fellows and graduate students pursuing independent research projects. While this "siloed" approach has been highly effective at turning out generations of self-motivated investigators, today's research problems call for a shift in this paradigm. This change is necessary because many of the problems currently facing biomedical researchers are so complex that the solutions span several different scientific disciplines, many of which are still emerging. Nowhere is this situation more apparent than in the application of the relatively new science of nanotechnology to cancer research.

Recognizing the need for physicians and basic research scientists to collaborate, the National Cancer Institute (NCI) has established a new "team science"[1] model for cancer research by aligning funding mechanisms, organizational culture, and strategic investments to accelerate interdisciplinary research. This team-oriented model lies at the core of the new programs that form the Alliance for Nanotechnology in Cancer.

"Team science is about developing new ideas, forging new partnerships and collaboratively using new tools to understand cancer as a disease process and a highly complex system," explained Anna D. Barker, Ph.D., the deputy director of NCI. "The model includes teams of experts who can not only view the many elements of the cancer process, but can integrate that knowledge and design an innovative and targeted strategy of drugs, biologics and even devices that can be used at all phases of the cancer process in an integrated fashion. Although the individual investigator will continue to drive innovation, the old model of cancer research taking place in isolated silos is fading away."

Courtesy: Sadik Esener, Ph.D., University of California-San Diego (UCSD)

Scientists from the Center of Nanotechnology for Treatment, Understanding, and Monitoring of Cancer (NANO-TUMOR).

Interdisciplinary Teams at the Centers of Cancer Nanotechnology Excellence (CCNEs)

Although decades of individual investigator-initiated research have yielded best practices for traditional scientific working groups, the complex social and intellectual processes required for successful interdisciplinary teams have yet to be fully elucidated. Many questions remain, including:

- What are the appropriate drivers of team formation?
- Should a team be built around specific parameters or allowed to self assemble?
- Which type of expertise should be represented?
- How do teams learn to speak the same language?
- What is the role of leadership and trust?

Since one of the major initiatives within the NCI Alliance for Nanotechnology in Cancer emphasizes interdisciplinary team efforts, Nano.Cancer.Gov asked the directors of three of the NCI's Centers of Cancer Nanotechnology Excellence (CCNEs) to provide their insights regarding how these questions are already being successfully answered within and across the various CCNEs. Those interviewed were: Sadik Esener, Ph.D., principal investigator of the

Courtesy: Sadik Esener, Ph.D., University of California-San Diego (UCSD)

Members of the Center of Cancer Nanotechnology Excellence (CCNE) at the University of California-San Diego (UCSD).

Center of Nanotechnology for Treatment, Understanding, and Monitoring of Cancer (NANO-TUMOR) based at the University of California-San Diego (UCSD); Sanjiv Gambhir, M.D., Ph.D., principal investigator of the Center for Cancer Nanotechnology Excellence Focused on Therapy Response based at Stanford University; and Rudolph Juliano, Ph.D., principal investigator of the Carolina Center of Cancer Nanotechnology Excellence based at the University of North Carolina at Chapel Hill (UNC).

How Should Teams Form?

All three directors agreed that the problems or applications brought forth by clinical oncologists or surgeons actually drive team formation. "The most important thing is to find out about their problems," said Esener. "Most basic research scientists are simply not aware of the needs of clinicians. Understanding their problems is often slightly more difficult than solving them. Teams sometimes self-assemble and other times they are put together deliberately. In the beginning [of our efforts here at UCSD], I meet with each of the project principal investigators one-on-one to discuss ideas. This series of meetings is followed by talks involving two principal investigators. From there, new teams start to nucleate."

Gambhir noted that "primary project teams are often pre-formed or seeded by pairing someone with clinical/cancer knowledge with someone with expertise in nanotechnology. However, spin-off projects that often develop are allowed to self assemble without dictating any of the team members involved."

In an effort to foster more interdisciplinary collaborative research, develop infrastructure and build teams, UNC has developed its own initiative, the UNC Roadmap, which mirrors many of the collaborative goals of the NIH Roadmap. "We sponsor seminars, workshops, and training courses on interdisciplinary topics in order to build bridges between the physical and biomedical sciences," explained Juliano. "In fact, one of the first of these workshops was on nanotechnology and medicine, which became the genesis of our CCNE on campus."

Complementarity

In her book, *Creative Collaboration*,[2] Vera John-Steiner defines complementarity as productive interdependence – the ways in which researchers with different backgrounds, training, and modalities of thought complement each other in joint endeavors. Through collaboration, groups or teams of researchers address a problem and find solutions that they wouldn't be able to find as individuals.

Collaborations benefit from complementarity in skills, experience, perspective, and the use of diverse methodologies, and so the right mix of expertise is crucial for a highly effective interdisciplinary research team. "People with different backgrounds should be utilized on teams, and there should not be duplication of scientific background within a given team," said Esener. "When you put people with different backgrounds on a given problem, they come up with several solutions, each based on their own unique perspective. Not only do you have to have interdisciplinary technology experts in the group, but you also have to have people in the group that can understand the applications and define the problems.

"It is also important to have expertise in the commercialization process, including those with experience in intellectual property, marketing, cost accounting, and manufacturing," he added. "These people enable the group to 'prune' away impractical solutions at an early stage and establish a commercially viable roadmap for success. They also reassure scientists that the team can succeed by assuming responsibility for areas in which many basic researchers and clinicians have little familiarity."

Communication

One large, potential roadblock to successful team building is communication – or lack of it. "In the very beginning, it is difficult for newly formed teams to function because many members do not understand the concepts, vocabulary, or the methodologies of the different disciplines," explained Esener. One way to overcome this communication barrier is to have group leaders pretend that they are unfamiliar with terms or concepts so that the group can get a concise explanation from the speaker without the risk of embarrassment. It is also important to manage expectations because different disciplines are more or less conservative and progress at different rates.

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> *Author, Creative Collaboration*

It is not only internal communication that presents a challenge, but also communication with external partners. The CCNE at Stanford University, for example, brings together researchers at the University of California, Los Angeles (UCLA), Cedars-Sinai Medical Center, Fred Hutchinson Cancer Research Center, University of Texas at Austin, Intel, and General Electric. With such a large and geographically diverse group of partners, communication can be difficult. "Although there is some physical travel to and from the different sites, we also use conference calls to exchange information with external partners," noted Gambhir.

"Forums and video conferences are also used to communicate interesting research problems throughout the CCNE at UCSD and to offsite partners," remarked Esener. Gambhir explained, "However, conference calls are a poor substitute for the cross fertilization of ideas that occur between the various research groups. In our Center, it is the postdocs that play this important role because they are the ones that physically move between laboratories."

Leadership and Trust

After the communication barriers have been broken down, the team still faces the challenges of charting the correct course and remaining motivated for the long haul. For this direction, group members look to the team leaders. "The leadership team must be proactive in dedicating a substantial amount of their time to meetings," said Esener. "They must also be able to communicate their shared vision to members at all levels within the group, from graduate students and postdocs to principal investigators."

Partly for motivation, successes by one group are often communicated to other groups to create some friendly internal competition and pride. Such positive publicity can also serve as a recruiting tool to entice renowned – and busy – scientists to become part of a team.

Strong and committed leadership breeds trust. "For success, one needs to create an atmosphere of trust in which people believe that no one is going to steal their ideas," explained Esener. "In order to establish this trust, the team must be led by a person that is well-respected by the group." In short, team members need to know that this person could be counted on to settle conflicts fairly.

Interestingly, it has been somewhat harder to develop trust across the CCNEs when it comes to sharing research results. "Within our own consortium, trusting relationships between people have already been established," noted Gambhir. "Indeed, the whole process of building and applying for the CCNE grant built a great deal of trust between members, and between the university and companies involved." Until more personal relationships across Centers can be developed, more formal mechanisms may need to be employed. "There has been some recent discussion on the use of standardized confidentiality agreements as a method for sharing information and research results between the various CCNEs," stated Juliano.

Courtesy: Lanzie Rivera, Stanford University School of Medicine

A team of scientists from the Molecular Imaging Program at Stanford University.

Commitment to Shared Objectives and Passion

In the past, one of main difficulties with fostering and sustaining interdisciplinary team efforts arose because of the actions of opportunists who sought to use the program as a method for increasing the budgets of their own individual research programs. Fortunately, with an important disease such as cancer, selfish needs do not surface as often. "With cancer, everyone on the team believes that we need to work together for the common good to solve this problem," remarked Esener. "The passionate interest so crucial for joint endeavors is always there."

There is also a great deal of excitement generated by the fact that the application of nanotechnology to cancer research is such a new field. Most researchers have also begun to self-realize that individual principal investigator-lead research does not produce exceptional solutions to the problems in cancer research.

Remaining Challenges

Despite their promising starts at team building, each CCNE is still blazing new trails along the path to a different, more collaborative research model. "In academia, it is still difficult to get recognized and rewarded for team science," noted Juliano. "In the traditional model, one gets rewarded for building up an individual laboratory, becoming well known in a given specific area, and publishing papers with a single principal investigator as author."

How do you get credit for your contributions in team science? How will credit be equitably shared? These are fundamental questions that tenure and promotion committees, funding agencies, and editors of scientific journals must now confront. Clearly, a shift in the current academic cultural and research paradigms will need to occur if the 21st century is to be remembered as the century of community, in which interdisciplinary research teams are required to solve increasingly complex problems in science.

—David Conrad

Selected Notes and Referencescs

[1] It is important not to confuse the term "team science" with the term "big science," which often carries a negative connotation. In the latter, multiple researchers from the same discipline work together in groups to justify and leverage the high costs of experimentation. In team science, researchers from different disciplines work together to solve complex problems that require expertise across many fields.

[2] John-Steiner, V. Creative Collaboration; Oxford University Press: New York, 2000; Chapter 2.