TEAM SCIENCE

The Road We Must Take: Multidisciplinary Team Science

Mary L. Disis[1,2]* and John T. Slattery[1]

Published 10 March 2010; Volume 2 Issue 22 22cm9

Translational research is acknowledged to be complex and to require a diverse skill set. Many organizations, particularly academic institutions, have invested in educational programs, facilities, and enhanced resources to encourage translational research. Critically needed, however, is an emphasis on creating and sustaining multidisciplinary research teams. It is through the power of many and a diverse approach to our health care problems that we will realize lasting solutions.

INTRODUCTION

The past decade has brought an enormous increase in our knowledge about the etiology and pathogenesis of many human diseases. Why aren't we realizing more substantial clinical benefits from this explosion of discovery? When will we see sustained and tangible improvements in human health? Numerous roadblocks have been identified that impede bench-to-bedside translation, ranging from a lack of critical research and clinical infrastructure to a need for more directed education for the translational research workforce (*1*, *2*). We are so far from consensus about how to move forward that we haven't even settled on a uniform definition of translational research (*3*). Initially, use of the term was limited to basic discoveries that were translated to the clinic; now it has evolved to include the full spectrum of health care innovation, ending in economic effects and policy changes caused by established interventions (*3*). If the public is most interested in seeing science improve health at an affordable cost (and we will take that in place of a definition of translational research), the gamut of disciplines, specialties, experts, and educators that must closely coordinate and intimately engage to achieve the goal imposes the most important barrier to successful translational research: the inability to create and sustain dynamic and innovative multidisciplinary research teams.

TEAM SCIENCE

There is an increasing realization that "team science" is needed to tackle and conquer the health problems that are plaguing our society. As an example, solving the obesity epidemic most likely requires the integrated interactions of researchers who study lipid metabolism, genetics, and cell growth; endocrinologists; pediatricians; internists; surgeons; exercise physiologists; nutritionists; behavioral researchers; psychologists; and economists—to name just a few types of specialists. Academic research institutions are not purposefully arranged to cause such diverse teams to coalesce. Collaboration is common; true coordinated teamwork is rare. Effective problem-focused organization across disciplines or departments is far from the norm; training and mentoring with the expectation that the trainee will have a successful career in such a team environment are virtually nonexistent. Most often, in academics or industry, the lone inventor/innovator or the multifunded "independent" laboratory head is seen as the pinnacle of success. We are wrong to persist in this single ideal if the goal is to translate scientific discovery into improvements in human health.

Most of us believe that breakthroughs with substantial effects come from a single person's "ah-ha" moment. In academic research, one has only to check e-mail to see multiple solicitations for grant applications that are looking for that one idea or concept from a single investigator, no data needed, that will lead to cures. But what evidence is there that the lone innovator is the source of most of our important discoveries?

Business researchers have attempted to address that question by studying patent data derived from the U.S. Patent and Trademarks Office (*4*). This data set is unique because it allows the study of teams versus individuals, is robust over a long period of time, and contains many data points across multiple types of inventions (*4*). Using an end point of how many times an individual patent is cited by future patents as a measure of its influence and success, investigators evaluated the success of lone versus team inventors. The number of citations for an individual invention has been shown to correlate with patent value and renewal rates (*4*). Studying a decade's worth of data, investigators found that patents generated by inventors with a team or organization were more likely to represent breakthroughs than those from lone inventors. Patents from teams were 28% more likely to be in the 95th percentile of cited patents than those from lone investigators. Moreover, team patents were 22% less likely to have no citations as compared with inventions by individuals. Overall, patents from teams, or investigators associated with organizations, were twice as likely to be cited than were patents associated with a single inventor (*4*).

THE VALUE OF A DIVERSE TEAM

Teams are effective innovators and are the most effective mechanism to translate discoveries made at the molecular level into measurable improvements in human health. It has been postulated that diverse teams—those that are multidisciplinary—are the most successful in accelerating innovation (*5*). This hypothesis is related to how creative ideas are developed. The evolutionary theory of creativity proposed by David Campbell over four decades ago defines three key phases of innovation (Fig. 1). The first phase, variation, entails creating new insight by combining existing knowledge in an innovative way. A variety of paths by which a goal might be attained emerge. The second phase, selection, prioritizes the possible paths for action by their probability of success. The final phase is retention. Retention defines successful innovation: New replaces old and societal practices are changed (*6*).

Diverse research teams enhance and accelerate the success of innovation and discovery in several ways (Fig. 1). If innovation begins with new combinations of existing knowledge, intellectually diverse teams not dominated by a single view will be more successful than an individual is ever likely to be. Furthermore, a diverse team knowledge base is potentially more robust than that of a single innovator. During the selection phase of innovation, a diverse team

[1]School of Medicine, University of Washington, Seattle, WA 98195, USA. [2]Tumor Vaccine Group, Center for Translational Medicine in Women's Health, University of Washington, Seattle, WA 98195, USA.
*Corresponding author. E-mail: ndisis@u.washington.edu

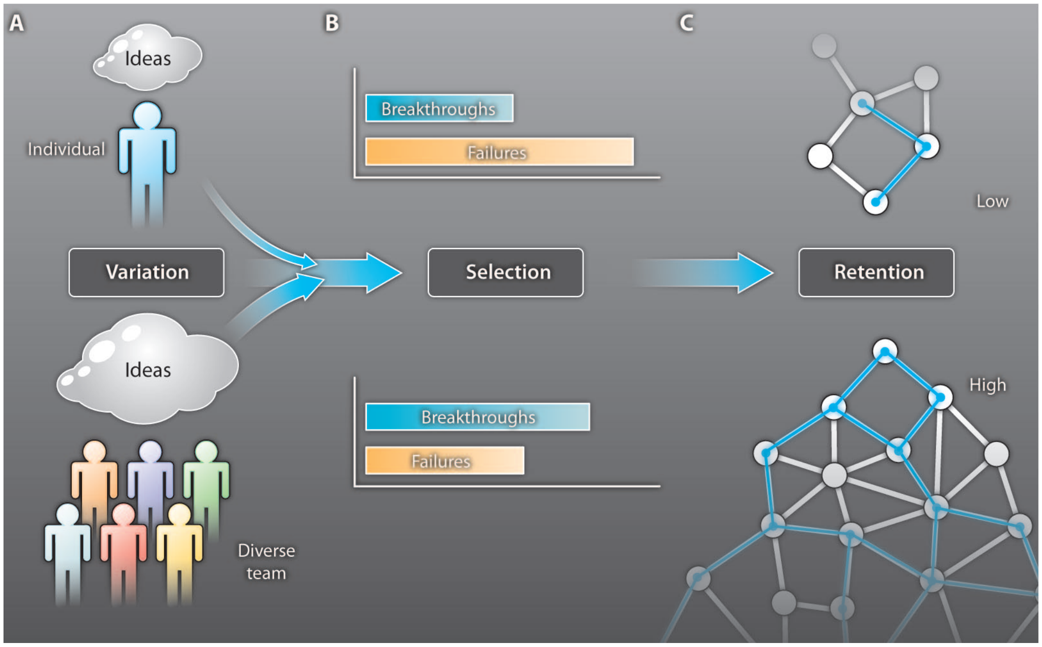

Fig. 1. The effect of team research on phases of innovation. (**A**) Teams augment innovation during the variation phase because more ideas are generated by robust team input than by individuals. (**B**) Team review of potential discoveries optimizes breakthroughs and limits failures as compared with an individual's evaluation of his or her own ideas without outside input. (**C**) The networks associated with each individual team member speed adoption of the idea within the community, resulting in high retention of the discovery.

will filter poor ideas more efficiently, resulting in fewer failures (*4*). Finally, a diverse team includes extended networks, associated with each member, facilitating retention of the discovery (Fig. 2).

The diversity of the team is also critical for sustaining innovation. Teams composed of individuals with similar backgrounds and education are more likely to develop a shared mind-set that results in sequential thinking (Fig. 2) (*5*). Sequential thinking leads to an unimaginative plodding method of problem-solving, using techniques common to a single discipline or field. Teams with shared mind-sets are more likely to come up with innovations that are of incremental benefit (*5*). Diverse teams are associated with a higher likelihood of connective thinking, during which members dynamically make connections between very different ideas. In this type of team, one member may have an innovative idea, and by the time it is fully evaluated by all members, that idea has become a sum of all their input and is likely to be substantially enhanced. Diverse teams that operate using connective thinking are more likely to develop radical innovations (*5*).

How do we create, and more importantly sustain, research teams of diverse individuals from multiple disciplines? Putting people in a room and giving them money to solve a problem is not the answer. Successful multidisciplinary research teams require transformational leadership that is capable of developing a shared vision within the team and sustaining the team over time; infrastructure that is of value to all team members; facile communication based on collaborative education and respect that allows constructive disagreement; and finally, the recognition that the dynamic structure of a team, in and of itself, requires work to maintain.

TEAM LEADERSHIP

Transformational leadership describes leaders who are motivators, moderators, and mentors and who have the ability to connect disparate groups. Studies have shown that transformational leadership is required for the successful performance of teams made up of diverse members (*7*). This leadership style will hold the group together during its formation, when members don't yet have the trust and interdependence required to self-sustain. A transformational leader has the ability to sacrifice self-interests, control dominant individuals, ensure that all members are acknowledged, and guarantee that projects and resources match the interests and priorities of the team.

The importance of the mentoring role of the initial team leader cannot be understated. It should be assumed, during the connective thinking process, that all members may eventually take a role as leader of the group at some time as new projects are developed with shifting focus. The bidirectional flow of translational research, from the bench to bedside and back to the bench, demands shared leadership. Shared leadership is one way in which groups prevent the shared–mind-set problem and ensure dynamism (*8*). As an example, in an academic medical center, an employment strategy that embeds a newly hired clinician in a multidisciplinary research group with a transformational leader could result in that clinician scientist initially playing a supportive role while learning the key concepts of the team's research. The expectation would be, however, that within a period of time, that clinical scientist would be driving group projects tackling the disease-associated problems from his or her unique perspective using the full resources of the team. Leadership dedicated to mentoring would facilitate this progression (*9*). Although the individual would be new to the scientific process, the connective thinking of the diverse team would not only optimize his or her chances of experimental success, but would also allow the individual to have many choices to modify the research concept to suit his or her strengths (*10*). To influence the development of cross-multidisciplinary resources, this type of transformational leadership must be present at the highest levels of the organization. Transitioning to team science is a culture change that requires intensive commitment. Organizations need to identify their transformational leaders and foster multidisciplinary team development with their help.

INFRASTRUCTURE

Infrastructure must support the team (*11*). Resources are commonly allocated to the

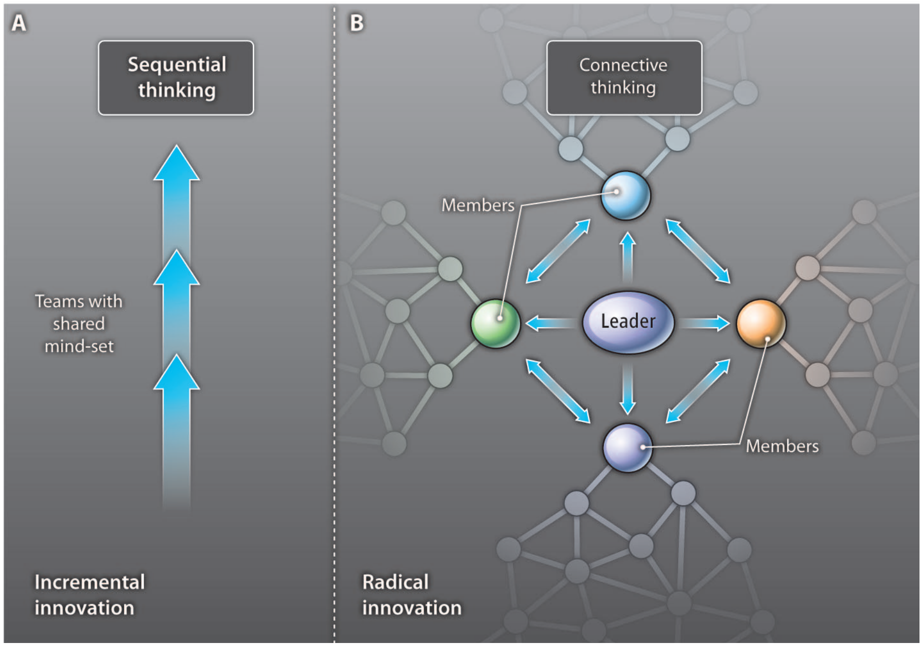

Fig. 2. Differences in creative thinking between homogenous and diverse teams. (**A**) Teams with a shared mind-set think sequentially and approach problems with ideas (blue arrows) that result in standard solutions. (**B**) Diverse teams develop ideas (blue arrows) connectively, as members learn new material to communicate and new connections are made. Further, ideas are enriched by each member's own network.

loudest and most powerful proponents of a particular want. This method runs a substantial risk of the organization spending valuable capital on a resource that serves only a fraction of individuals working on the problem that the resource was developed to support. For example, a group of investigators working on rare blood disorders might convince leaders at their institution that they need support for leukapheresis, a laboratory procedure that separates white blood cells from whole blood. In this example, the investigators wish to collect large numbers of blood cells from a few individual patients. The instrument, technical support, and space are secured at substantial cost. However, if leaders of that organization had looked beyond this group of investigators, they might have found additional groups studying similar disorders in other departments. Further queries might have demonstrated that a high-throughput collection system, allowing the acquisition of small samples from numerous patients rather than large samples from a few individuals, would have been the more useful resource. Furthermore, other leaders in various departments might have contributed to the development of such a resource, minimizing the costs for any single group. Duplication of resources would markedly decrease as well. Finally, the process would potentially identify the components of a multidisciplinary team.

This type of strategic infrastructure planning requires that organizational leaders begin to think of their membership as diverse teams focused on broad topics rather than individual investigators and small groups focused on their own specific niches within a broad topic. Moreover, if the culture is to be changed, organizational leaders must develop incentives for participation in team science. Common metrics should be developed to assess and reward participation in a team, as well as team performance. Shared space and institutional monies should be used to facilitate team development. Diverse multidisciplinary teams will not be sustained unless the message is clear from the top: This is where we are heading for the future.

TEAM LEARNING

The final element for successful multidisciplinary teams is team learning. Shared learning enhances team intimacy and trust (*12*). Education is the great common denominator that can bring diverse groups and individuals together, senior as well as junior members. Furthermore, members must learn to be part of a team (*13*). Once, during a frustrating multidisciplinary team meeting, when the group was trying to figure out why our interactions weren't as efficient and productive as we had hoped, one of the members quipped, "You collaborate with the people you have lunch with" (*14*). This statement stopped people in mid-conversation as we realized that although we met regularly with each other, few of us had developed that intimate "lunch buddy" relationship that allows easy and trustful communication. We decided to learn more about each other and what we were doing as individuals. Each member of the team had to be willing to be both teacher and student. For some members, being a student required leaving their egos and expertise at the door. Taking on the teacher role enhanced the confidence and leadership skills of other members. Shared education facilitates connective thinking and innovation (Fig. 2). Most important, easy communication fosters authentic disagreement, which is the key component for optimizing breakthroughs and diminishing the chance of failure during the idea-selection process (*5*) (Fig. 1). If teams cannot critically evaluate their own innovations in a safe, shared, intellectual space, they are doomed.

CONCLUSION

There are many roadblocks to successful translational research (*1*). Reading the litany of problems expressed in a variety of opinion papers is reminiscent of the old tale of the blind men and the elephant, which describes how each man, touching a different part of an elephant, reaches a wildly different conclusion about the nature of the entire animal. Likewise, each proposed solution to the problems in translational research addresses one component of the whole. Until we begin the hard work of developing a vision of the entire animal, with a multidisciplinary viewpoint that encompasses the complete translational research spectrum, we will only discover bandages while futilely seeking cures. To achieve our goal of improving human health at low cost, multidisciplinary team science must progress from the rare chance success to a purposefully constructed common feature of public and private research enterprises, with the full support and backing of institutional leadership and funding agencies. Adherence to current thinking and funding mechanisms will only perpetuate the dominant organizational characteristic of our academic health centers: 500 independent fiefdoms united by a common air conditioning system. We can be more than that.

REFERENCES AND NOTES

1. N. S. Sung, W. F. Crowley Jr., M. Genel, P. Salber, L. Sandy, L. M. Sherwood, S. B. Johnson, V. Catanese, H. Tilson, K. Getz, E. L. Larson, D. Scheinberg, E. A. Reece, H. Slavkin, A. Dobs, J. Grebb, R. A. Martinez, A. Korn, D. Rimoin, Central challenges facing the national clinical research enterprise. *JAMA* **289**, 1278–1287 (2003).
2. C. Lenfant, Shattuck lecture—Clinical research to clinical practice—lost in translation? *N. Engl. J. Med.* **349**, 868–874 (2003).
3. S. H. Woolf, The meaning of translational research and why it matters. *JAMA* **299**, 211–213 (2008).
4. J. Singh, L. Fleming, Lone inventors as source of breakthroughs: Myth or reality? *Manage. Sci.* **56**, 41–56 (2010).
5. C. Post, E. DeLia, N. DiTomaso, T. Tirpak, R. Borwankar, Capitalizing on thought diversity for innovation. *Res.-Technol. Manage.* **52**, 14–25 (2009).
6. M.-H. Chen, G. Kaufmann, Employee creativity and R&D: A critical review. *Creat. Innov. Manag.* **17**, 71–76 (2008).
7. E. Kearney, D. Gebert, Managing diversity and enhancing team outcomes: The promise of transformational leadership. *J. Appl. Psychol.* **94**, 77–89 (2009).
8. C. L. Pearce, C. C. Manz, H. P. Sims Jr., Where do we go from here? Is shared leadership the key to team success? *Organ. Dyn.* **38**, 234–238 (2009).
9. J. Cohn, J. Katzenbach, G. Vlak, Finding and grooming breakthrough innovators. *Harvard Bus. Rev.* **86,** 62–69 (2008).
10. C. E. Shalley, J. E. Perry-Smith, The emergence of team creative cognition: The role of diverse outside ties, sociocognitive network centrality, and team evolution. *Strategic Entrepreneurship J.* **2**, 23–41 (2008).
11. N.-W. Chi, Y.-M. Huang, S.-C. Lin, A double-edged sword? Exploring the curvilinear relationship between organizational tenure diversity and team innovation: The moderating role of team-oriented HR practices. *Group Organ. Manage.* **34**, 698–726 (2009).
12. A. McCarthy, T. N. Garavan, Team learning and metacognition: A neglected area of HRD research and practice. *Adv. Dev. Hum. Resour.* **10**, 509–524 (2008).
13. J. Sargeant, E. Loney, G. Murphy, Effective interprofessional teams: "Contact is not enough" to build a team. *J. Contin. Educ. Health Prof.* **28**, 228–234 (2008).
14. D. Buchwald, personal communication.

15. M.L.D. is supported by National Center for Research Resources grant U54 RR24379. J.T.S. is supported by National Institutes of Health grant P30 CA15704.

10.1126/scitranslmed.3000421

Citation: M. L. Disis, J. T. Slattery, The road we must take: Multidisciplinary team science. *Sci. Transl. Med.* **2**, 22cm9 (2010).

Science Translational Medicine

The Road We Must Take: Multidisciplinary Team Science

Mary L. Disis and John T. Slattery

Sci Transl Med **2**, 22cm922cm9.
DOI: 10.1126/scitranslmed.3000421

Science Translational Medicine (ISSN 1946-6242) is published by the American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005. The title *Science Translational Medicine* is a registered trademark of AAAS.