Promoting Team Science at University of Colorado Denver

Prepared by the

Leadership for Innovation in Team Science (LITeS)

2012-13 Participants

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Introduction.

Team Science: What and Why?

We are not students of some subject matter but students of problems. And problems may cut right across the borders of any subject or discipline.

-Karl Popper

I. Current Trends

As the scientific problems of the 21st century grow ever more complex and resources ever more restricted, the models of innovation and discovery of the last century are changing. Although independent investigators working on problems in their own laboratories in near-isolation with plentiful resources may in rare instances continue to occur, for most research institutions this approach is largely unsustainable. Moreover, some scientific questions, such as the extent of genetic variation in the human species, are unanswerable by single scientists working in isolation and require the collaboration of investigators working in locations and with populations around the world (e.g., Thurman et al., 2012[1]). As with the biological sciences, in the social and behavioral sciences recent efforts such as "The Foundations of Human Sociality" project (Henrich et al., 2005[2]), hailed by Nobel Prize winner Elinor Ostrom as one of the most important works of the last 100 years, was a highly collaborative enterprise involving numerous economists, anthropologists and psychologists working collaboratively. That project involved about 20 investigators and, although still not the norm, scientific papers with >50 authors have started to burgeon, particularly in the last 10 years (see Figure 1).

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[1] Thurman RE, Rynes E, Humbert R, Vierstra J, Maurano MT, Haugen E, Sheffield NC, Stergachis AB, Wang H, Vernot B, Garg K, John S, Sandstrom R, Bates D, Boatman L, Canfield TK, Diegel M, Dunn D, Ebersol AK, Frum T, Giste E, Johnson AK, Johnson EM, Kutyavin T, Lajoie B, Lee BK, Lee K, London D, Lotakis D, Neph S, Neri F, Nguyen ED, Qu H, Reynolds AP, Roach V, Safi A, Sanchez ME, Sanyal A, Shafer A, Simon JM, Song L, Vong S, Weaver M, Yan Y, Zhang Z, Zhang Z, Lenhard B, Tewari M, Dorschner MO, Hansen RS, Navas PA, Stamatoyannopoulos G, Iyer VR, Lieb JD, Sunyaev SR, Akey JM, Sabo PJ, Kaul R, Furey TS, Dekker J, Crawford GE, Stamatoyannopoulos JA. The accessible chromatin landscape of the human genome. Nature. 2012 Sep 6;489(7414):75-82.

[2] Henrich J., Boyd R., Bowles S., Camerer C., Fehr E. and Gintis H. 2005. Foundations of Human Sociality: Economic Experiments and Ethnographic Evidence from Fifteen Small-Scale Societies. Oxford: Oxford University Press.

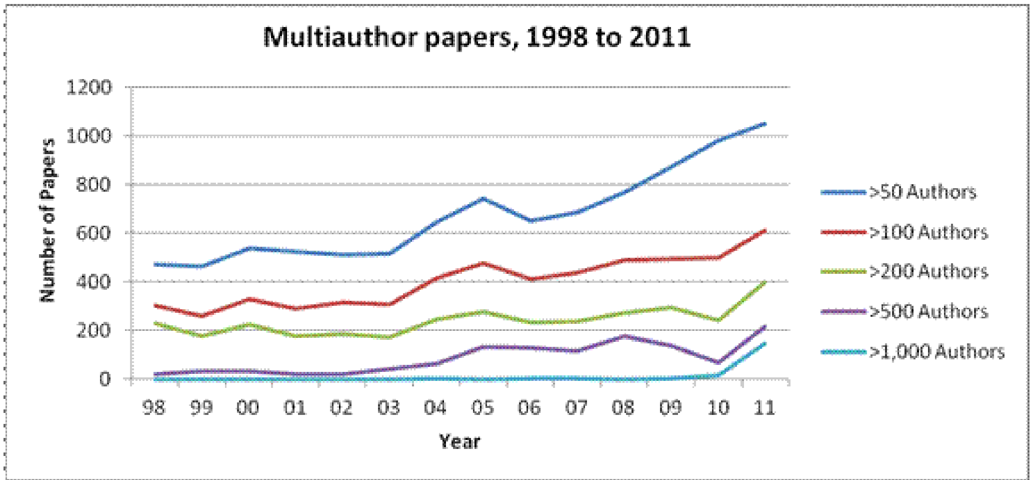

Fig.1: Trends in multiauthorship reflecting scientific collaboration, 1998-2011. Source: King, 2012. Multiauthor papers: Onward and upward. ScienceWatch July 2012. Thomson-Reuters.

Even as the necessity for collaboration in science has grown, so have the opportunities for funding collaborative research. In 2006, the National Institutes of Health (NIH) introduced "Clinical and Translational Science Awards (CTSA)" with the explicit purpose of promoting interdisciplinary science teams and, the following year, NIH began instituting multiple-PI grant mechanisms (Bennett et al., 2010[3]). The National Science Foundation (NSF) has followed suit with its Office of Integrated Activities, which just last year began its "Integrated NSF Support Promoting Interdisciplinary Research and Education" (INSPIRE) program to explicitly address "complex and timely scientific problems that lie at the intersection of traditional disciplines" (NSF Program Solicitation NSF 13-518). Clearly, research, publication and funding trends are moving in the direction of more collaboration and teamwork.

II. A Corporate Analogy

The move from independent work to a more collaborative, team-based approach has been shown to be productive and profitable in the private sector. Google, Inc. is perhaps the best example of how collaborative, team-based approaches can yield dividends in both finances and innovation. The company is one of the most profitable, with a net income in 2012 of $2.89 billion, and it is also arguably at the forefront of high tech innovation. What began as the developer of a modest search engine tool is now considered a world class innovator in the domains of email, mapping, file sharing, social media, eBooks, finance and much more. Google's director of human resources and its chief "culture officer," Stacy Sullivan, has been quoted as saying that the company's success is in large part a product of its culture. Google's culture is one that stresses a flat, horizontally-oriented hierarchy in which employees

[3] Bennett L.M., Gadlin H. and Levine-Finley S. 2010. Collaboration and Team Science: A Field Guide. Bethesda: NIH Publications.

share in decision-making and ownership of those decisions. She characterizes it as "team-oriented, very collaborative" (Scott, 2008[4]). Moreover, Google intentionally designed physical spaces for work, eating and socializing that promote members of the organization coming together and sharing ideas. Indeed, few of the most innovative ideas at Google were hatched at desks and work cubicles; most emerged out of interactions in these more informal spaces.

III. Team Science Defined

Even as research has morphed over time from an independent enterprise to one that involves increasingly larger groups of scientists, so too has the terminology morphed. Research once described as "collaborative," "interdisciplinary," and "multidisciplinary" is now referred to as "Team Science." As seen in Figure 2, team science is conceptualized as a continuum that varies in the extent to which team members interact and, perhaps more importantly, are integrated with one another. At its finest, team science involves all team members setting goals and objectives, making significant contributions, and sharing in responsibility, authority and, in the final analysis, credit for the research.

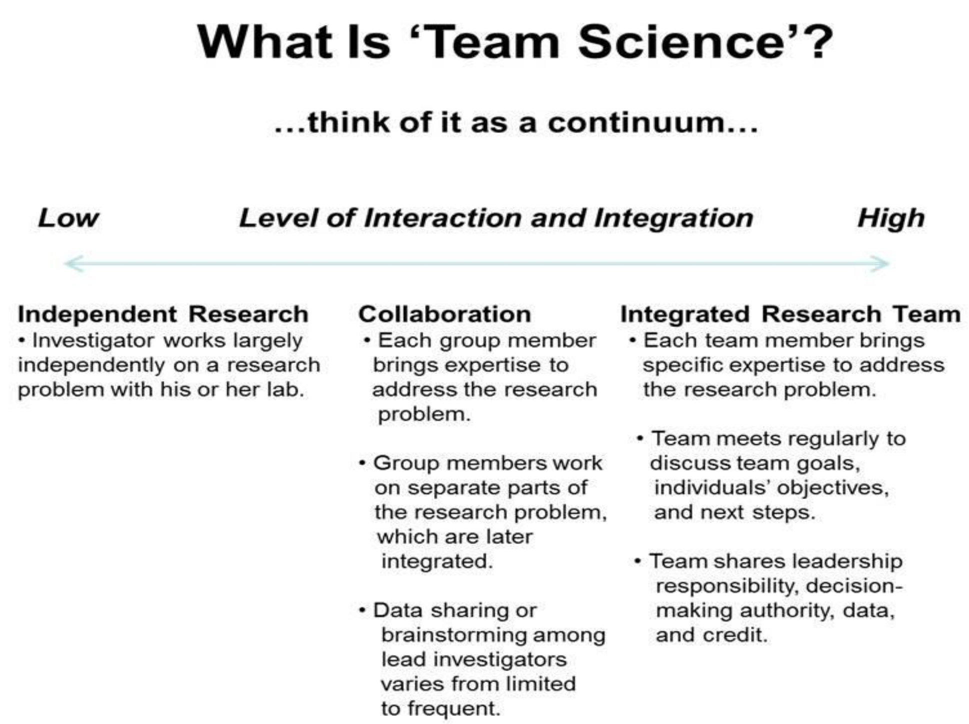

Fig. 2: Team science schematized as a continuum of interaction and integration. Source: Bennett, Gadlin and Levine Findlay, 2010. Collaboration and Team Science: A Field Guide. NIH and DHHS Publications.

[4] Scott, V. 2008. Corporations that Changed the World; Google. Google eBook.

It is critical to note that not all scientific projects necessarily require or benefit from the full integration represented by team science. There are still places in the academy and in scientific research for independent investigators and lower levels of collaboration. But as "team science" grows in importance, proportional representation and external funding opportunities over time, it becomes incumbent upon scientific and academic institutions to find ways to plan for and promote it so as not to be left behind. Among the ways that this may be done is through modest changes in (1) education and training, (2) internal funding opportunities and mechanisms, (3) facilities and physical structures, and (4) the construction of virtual "toolkits" – web-based repositories of information that bring investigators with diverse but complementary expertise together.

The purpose of this report is to present summaries of the work conducted by four team science groups that participated in the Leadership for Innovative Team Science (LITeS) training program in 2012-23. LITeS is a year-long program designed for senior and mid-career faculty and academic administrators who aspire to improve their management and leadership skills. Sponsored by the Education, Training and Career Development (ETCD) Core of the CCTSI, this program provides professional and executive training tailored to the needs of academics and in the biomedical, clinical, and health sciences, An important goal of the program is to create and sustain at Anschutz and UCD a strong network of colleagues who, in addition to their own work, will train the next generation of clinical and translational scientist.

Chapter 1.

Education and Training

Challenge:

What changes are needed in graduate and professional education to ensure training in and expansion of team science? What types of curricular changes might be recommended for specific programs – or even across disciplines and programs?

Team Members:

Suzanne Brandenburg, MD – Professor of Medicine; Vice Chair for Education and Residency Program Director, Department of Medicine
Amy Brooks-Kayal, MD – Professor of Pediatrics, Neurology and Pharmaceutical Sciences; Ponzio family Chair in Pediatric Neurology, Children's Hospital Colorado, Co-Director, Translational Epilepsy Rseearch Program.
Lynn Heasley, PhD – Professor and Chair of Craniofacial Biology, SODM
Alison Lakin, PhD– Assistant Vice Chancellor for Regulatory Compliance
Jill Norris, MPH, PhD– Professor and Chair of Epidemiology
Eric A. F. Simoes, MBBS, DCH, MD – Professor of Epidemiology and Pediatrics; Co-Director Maternal and Child Health Initiative, Center for Global Health,
David Tracer, PhD – Professor of Anthropology and Health & Behavioral Sciences; Associate Dean of Research and Creative Activities.

Vision:

Establish a culture of collaboration and teamwork at the University of Colorado Anschutz Medical and Denver Campuses that enhance training in and models how to perform excellent team science. Community members from school wide leaders to senior scientists to students on both campuses will understand and support team science.

Goals:

1. Team science practiced (where desired/appropriate) by all levels of researchers (Senior PIs to Trainees).
2. Team science valued (seen as providing "value added") by all levels of researchers and administrators alike
3. Barriers to Team science are removed

I. Current Status of Curriculum Development at CU – AMC and Downtown Campus

Based on interviews with some of the key education leaders on the AMC and Downtown campus exciting initiatives are being developed to intentionally foster collaborative, inter-professional education. One such example of this approach is the REACH program, which is aimed at fostering teamwork, collaborative inter-professional practice and quality and safety through the creation of a curricular thread that is shared across schools and programs. REACH is currently focused on three core elements: The Health Mentors Program, the Clinical Transformations Program, and The Clinical Rotations Program.

In the Graduate School, of the original fourteen departmentally-based doctoral programs, all but three have become interdisciplinary. Interdisciplinary programs include one in Structural Biology and Biochemistry that encourages students to engage in collaborative projects and lab rotations with the specific aim of facilitating a team science approach to issues. The Program in Reproductive Sciences involves basic science and clinical faculty from 10 different departments and divisions that focus on various aspects of reproductive biology and pathophysiology. Within each of these interdisciplinary programs students are exposed to a variety of disciplines and are encouraged to have shared mentoring across disciplines and / or across institutions.

These programs aim to nurture and develop junior scientists with tools and exposure to different approaches to scientific issues and tools to develop their interests. ***The LITeS team felt that it was still too early in the development of these programs to consider making significant or specific recommendations for change.***

The CCTSI has also established a number of innovative programs to facilitate team science and a translational approach to research training at all levels from the Summer Undergraduate Minority Mentoring in Translational Science (SUMMIT) program to the Pre – Doctoral TL1 and Post-Doctoral KL2 programs. These programs are strong and are directed specifically at fostering clinical – translational research and a team science collaborative approach to health issues. ***The only recommendation of the LITeS team would be to try to expand the number of trainees who can be involved in these programs.***

On the Downtown Campus there are also organic efforts by individual faculty members to bring together faculty from different departments and schools to teach students on a given topic. This approach of team- teaching not only exposes students to different ways to consider issues but also establishes a relationship within the co-teachers that frequently develops into fruitful research or academic partnerships. This approach to teaching as a mechanism to develop interdisciplinary collaboration is an essential element of academic and translational research. It should be fostered, encouraged and nurtured as a catalyst to team science.

Generally, the LITeS team felt that there are a number of important and broad reaching programs on campus to expose students to multi-faceted approaches to health related problems that can foster the next generation of investigators interested in a team science approach.

II. Perceived Barriers to Team Science

Therefore, the LITeS team became focused on identifying potential barriers that might limit or stunt the potential of these newly graduating scientists to be successfully engaged in team science as they progress in their careers.

In a Needs Assessment[5] of the CCTSI members and non-members across all affiliated institutions in March 2011, the CCTSI Evaluation Core asked respondents to provide suggestions for education, training, or career development programs.

The following five themes emerged in the responses:

- **Professionalism**: Teambuilding, leadership, lab/personnel management, how to seek out job/funding opportunities, how to develop research plans
- **Research**: Institutional research procedures/regulations, how bench/clinical scientists can conduct translational/cross-disciplinary research, forming interdisciplinary teams, study design, collaborative incubator program
- **Grant Writing:** Technical writing, identification of funding sources
- **Regulatory Assistance:** Regulatory compliance, navigating COMIRB processes, safety monitoring
- **Mentorship:** Mentor training, peer-mentoring, cross-disciplinary mentoring

Specific comments include:

> *I think there is a huge need for training of investigators in basic professional skills, such as leadership, time management, running meetings and committees, and project and budget management. The CCTSI seems to provide training along these lines, but my impression is that it is mainly for more advanced faculty. Junior faculty really need those skills too!*
>
> *There is not enough support to enable the non-clinician to design their research projects so they are considered translational. Programs that fill this gap and assist faculty in basic sciences would be appreciated.*

In a follow-up survey[6] by the CCTSI Evaluation Core to explore how training and mentorship might promote team science, 19 team members from four CCTSI pilot award teams were surveyed. The individuals surveyed identified a number of important key elements that potentially limited their ability to function well as a member of a successful Scientific Team. These factors included 1) the need to

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[5] The CCTSI Needs Assessment March 2011 – not published but provided by CCTSI Evaluation Core

[6] CCTSI survey conducted by the CCTSI Evaluation Core entitled “Training and Mentorship that might Promote Team Science” – unpublished.

develop leadership skills to bring everyone together, maintain focus and facilitate a team identity; 2) the need to negotiate authorship early in the process so that expectations were appropriately set; 3) the need for mentors and institutional leaders as facilitators of team science; 4) protected research time for clinicians to join the early phase of team science endeavors; 5) increased start-up time for team science projects.

III. Focus on the Role Model

Similarly, in the literature[7], one key concern when institutions seek to encourage team science is the potential for negatively impacting the career development of the research scientist within the traditional academic structure of promotion and tenure. ***The LITeS team felt it was essential to ensure that team science, and the curricula that are being developed to promote it, would not inadvertently limit the junior scientist's potential growth or status within the academic community.*** Also, as role models are an important mechanism for further developing and supporting team scientists, ***there needed to be a clear structure by which Team Scientists could achieve success at all levels of the academic ladder across all disciplines and schools.***

Current status of promotion and tenure criteria:

Based on a review of the current promotion criteria across the CU Anschutz Medical Campus and the Downtown Campus **only** the School of Medicine in their recently revised promotion / retention criteria had language that recognizes team science but this language did not actively advocate for or strongly promote team science. It did, however, provide a methodology for addressing participation in team science.

In August 2012 the SOM faculty approved the addition of a statement modifying the official *Rules of the School of Medicine* to include the following:

> Basic, clinical, translational, educational and other forms of research are highly valued by the School of Medicine. As outlined in the Promotion Matrix, "excellence" in research may be demonstrated through peer-reviewed scientific publications, competitive grant funding, a national or international reputation, and evidence of originality and independence as an investigator. The School of Medicine recognizes the importance of inter-disciplinary science and the need for collaboration among investigators. Therefore, as recommended by the National Academy of Science, the School of Medicine defines an "independent investigator" as one who demonstrates "independence of thought" --- that is, one who has defined a problem of interest,

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[7] Rhoten, D and Parker, A. (2004). Risks and Rewards of an Interdisciplinary Research Path. Science Vol. 306, 17 December page 2046; Stokols, D., Hall, K.L., Taylor, B.K., and Moser, R.P. (2008). The science of team science: overview of the field and introduction to the supplement. American Journal of Preventive Medicine 35 (2S), S77-89

> who has chosen or developed the best strategies and approaches to address that problem and who has contributed distinct intellectual expertise.[8]

Furthermore, the School of Medicine has developed a new "Investigator's Portfolio" to assist team scientists to appropriately document their unique contributions to the projects with which they have been involved.[9]

Specifically, under Summary of funded research, team scientists are encouraged to highlight their role by detailing that "For multiple-P.I. grants and program project and center grants, be specific about how you contributed to the success of these grants."[10] Also, under Evidence of originality, creativity and independence, team scientists should:

> Use this section of the Investigator's Portfolio to clarify the contributions that you have made to multi-author publications and co-PI and co-investigator grants. Be specific about your intellectual contributions and the manner in which you defined the research objectives, led the research efforts, interpreted the results or shaped the overall research program. Additional evidence should also be provided, such as letters from the Principal Investigators or research group heads with whom you have collaborated, outlining in detail your specific contributions and the unique skills that you brought to the team. For multi-authored papers, letters from the first- or senior-authors may also provide evidence of your specific contributions. The overall objective is to convey clearly and concisely to the SOM Faculty Promotions Committee the importance, significance and broad impact of your cumulative research contributions.[11]

The LITeS team wanted to understand how involvement in team science research would impact faculty in the career evaluation process across the other schools. So the team identified the key stake holders within each school and interviewed them using a standard set of questions aimed to elicit the incentives for and barriers to team science within their school.

Responses:

- Based on the data collected, each school recognizes that team science fits within their mission and has an informal mechanism for evaluating the contribution of a team scientist.
- There was general recognition across the schools that the criteria for this evaluation could be made more transparent.
- Participation as a team scientist needed to be paired with independent research or there had to be documented leadership in team science.

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[8] New Rules of the School of Medicine can be found at: http://www.ucdenver.edu/academics/colleges/medicalschool/facultyAffairs/Documents/SOMRules2012.pdf

[9] From copy of Investigator's portfolio outline provided by Steven Lowenstein, MD
[10] From copy of Investigator's portfolio outline provided by Steven Lowenstein, MD
[11] From copy of Investigator's portfolio outline provided by Steven Lowenstein, MD

- The role of external reviewers in the promotion process could sometimes be problematic in recognizing the merit of the individual's contribution in team science.
- None of the schools give extra credit or weight for being a team scientist but the opinion was expressed that if collaborative science is better the assumption is that the resulting products of the collaboration will be stronger as outlined in the dossier.
- There was also recognition that documenting the contribution of the team scientist can be difficult

IV. Recommendations to Address Perceived Barriers to Promotion and Tenure

While each school has a mechanism for evaluating a team scientist, the LITeS team makes the following recommendations to actively promote the value of team science and to advance the culture of collaboration:

- ***Each school should explicitly address team science in the promotion and tenure criteria similar to what is now done in the School of Medicine criteria;***
- ***If schools want to go further and actively promote team science as highly valued then stronger language needs to be added to reflect that goal;***
- ***Impact of the overall team science project on the field should also carry some weight;***
- ***Assessment of productivity for team science projects should take into account the increased investment of time and planning and higher risk of failure due to operational challenges that are inherent to team science. Further, the criteria of an "independent investigator" should include demonstrated team leadership and team management.***

To assist in the Evaluation of team science, the ***LITeS team recommends development of the following:***

Tools to assist faculty to develop a clear dossier –

Recognizing that team science is almost a necessity for the conduct of innovative scientific investigation, there is a necessity to re-evaluate current criteria for the contribution of authors to multi-author publications. In this model first and last author publications will become increasingly sparse in the dossiers of faculty members collaborating as part of a team. Thus there is a need to emphasize the importance of other author roles in evaluating faculty. Rather each manuscript should be evaluated on the basis of "substantial and critical involvement" in the development of the publication. This criterion is different from the International Committee of Medical Journal Editors (ICJME) criteria. The ICJME has recommended that authorship credit should be based on "1) substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published. Authors should meet conditions 1, 2, and 3." The addition of "critical involvement" allows for a quantitative estimate of the role of the author, wherever in the list of authors the faculty member's name appears. It would allow an assessment that could read: ***The involvement of this author was essential for the successful completion of this study and the resulting manuscript.***

Tools for promotion committee to evaluate a team scientist

For faculty members considering a team science manuscript for inclusion in the portfolio being sent for review, the onus of responsibility in determining their "substantial and critical" involvement in the study resulting in the manuscript under consideration lies with the faculty member. A statement from a senior author, commenting on the role of the faculty member in the development of the study and manuscript, should accompany the citation in the CV. Team science citations in which the faculty member's contribution to the study and manuscript are considered "critical" will be accorded equal importance to that of the first or last author during the review process.

V. Modeling of Successful Team Science Endeavors

Even with all the exciting curricula changes and opportunities on campus to learn how to consider issues from a team approach, there remains a perception that individual grant funded research with lead or senior author publications is the most prestigious. People only engage in team science as a secondary option. There remains the need for a further cultural shift if team science is going to be coveted and valued equally at this institution. Changing the promotion and tenure criteria are important but alone it is not sufficient. Modeling successful team science collaborations from across the country is important but it is also essential to recognize and nurture the developing teams on campus.

Possible opportunities include:

Expand the Dean's Distinguished Lecture series to include the speaker dedicating time after the lecture to facilitate a broader discussion with the audience on the particular topic;

This lecture series frequently highlights a researcher involved in team science and attracts an inter-disciplinary audience. It would be a valuable opportunity to expand the agenda to include a segment on a topic of interest that the speaker facilitated based on their experience and perspective as a team scientist.

Highlighting local team science collaborations at Grand Rounds;

When the LITeS team was looking for role model examples of successful teams, there were very few examples identified. This suggests that either there are few faculty currently participating in team science or established venues for learning about the research work of our peers does not highlight the significance of the team science approach.

Facilitate opportunities for successful teams to discuss the challenges and strategies that make a strong team;

There are few opportunities currently on campus to learn from other researchers, who have been in successful or unsuccessful teams, to identify and possibly model how to harness individual abilities into an integrated and successful team. With the Fulginiti Pavilion, the Anschutz Medical Campus has a wonderful venue for such interactive discussions with an appropriate facilitator.

Other training and educational needs essential for a team scientist:

Leadership training and team building workshops;

The LITeS program provided essential material to enable an accomplished scientist to be successful within a team. There are necessary skill sets that are required to harness the enthusiasm and abilities of a team given that teams are not only interdisciplinary but frequently inter-generational and inter-cultural as well. These skills are important not just for the leaders of the team but also for all members of the team. Many key elements of the LITeS program could be divided and made more broadly available to the campus.

Training in mediation and crucial conversations;

Successful teams need to know how to navigate potential problems without issues and interpersonal conflict inhibiting the potential of the team. Broader opportunities to develop and augment mediation and negotiation skills are essential if participation in a team is to be a positive experience and lead to a successful career.

Establishing a role within a team;

With a growing number of large collaborations (50 to 1000 scientists) it is not feasible for each Team Scientist to be the first or last author on papers. Individual scientists need mentors but also other tools to help them establish and document a clearly defined role as an independent scientist within a large team. Knowing the expectations for promotion early and working within the team to be able to accurately document each role is essential if young Team Scientists are to achieve promotion within the current academic framework. It is possible to get lost in the middle without key tools, mentorship and support. Mentors will also need the right tools to be able to guide appropriately.

Learning to write and/ or actively contribute to a team science grant;

Similarly, the skill sets and documentation necessary to be appropriately credited for a role in a large collaborative grant is more difficult to establish compared to a single scientist with a single grant award for promotion and tenure. Specific mentorship related to development of these skills is needed.

Other Recommendations:

Building connections between clinician scientists and basic scientists to address clinically relevant issues;

The needs assessments and surveys conducted by the CCTSI Evaluation Core indicate that aligning the clinical experience of the clinical scientist with a broader interdisciplinary team is essential to the success of team science.[12] This chemistry is difficult to achieve when the clinical scientist has no or very limited protected time for research and there can be a longer planning period for a team science project to obtain funding. Making more bridging funding available to the clinical scientist to engage in translational questions will be essential.

Provide opportunities to network / small group forums;

As the LITeS teams that are focused on fiscal support and space will discuss in more detail providing opportunities for ideas to organically develop is essential. One recommendation is that the CCTSI not only fund pilot team science projects but hold inter-disciplinary town hall or small group forums around a topic to serve as an incubator to develop potential research questions and team science collaborations appropriate to apply for that pilot funding.

Infrastructure and Regulatory support to facilitate research with partners at other institutions;

Managing an interdepartmental project can be challenging but these challenges increase dramatically when considering managing an intercampus or inter-institutional project. The logistics of running a grant, tracking budgets and managing the regulatory requirements is significant. Currently, this institution does not have the administrative or regulatory infrastructure necessary to be successful. A significant investment in research infrastructure is needed.

[12] Document entitled "Major Recommendations for ways that the Institution could support/promote Team Science" unpublished and provided by CCTSI Evaluation Core

Chapter 2.

Funding Team Science

Challenge:

The committee was tasked with the objective of exploring alternative funding strategies and approaches to support team science.

Team Members:

Kathryn Beauchamp, MD – Associate Professor, School of Medicine;
Chief, Division of Neurosurgery, Denver Health medical Center.
Rob MacLaren, PharmD – Associate Professor, School of Pharmacy
Mary Reyland, PhD – Professor, School of Dental Medicine;
Director, Cancer Biology Graduate Program
Jody Tanabe, MD – Professor, School of Medicine; Section Chief, Neuroradiology.
Inge Wefes, PhD – Associate Dean, Graduate School; Associate Professor
Biochemistry and Molecular Genetics

I. Methodology

The committee met in person on seven occasions and received input from the following individuals: Christine Ahearn, Dick Johnston, Lynne Lyons, Lilly Marks, Jeff Parker, Todd Saliman, Leslie Schaefer, Laura Simon, and Richard Traystman. In addition, the most recent presentations of the State of the School of Medicine address by Dr. Krugman (12/12/2012) and the State of the Campus by Lilly Marks (10/22/2012) were reviewed.

II. Rationale

The primary reasons for developing alternative strategies for funding team science are:

1. Tenuous future funding from federal entities like the National Institutes of Health (NIH), Department of Defense (DOD), and the National Science Foundation (NSF) as a result of sequestration forcing substantial cuts to the Anschutz Medical Campus (AMC),
2. Limited capacity for the University or State of Colorado to offset these cuts, and
3. Development of research science teams that strategically optimize the likelihood of future federal funding.

Grants and research contracts represent approximately 35% ($407 million) of the AMC budget with 66% of these monies from federal agencies such as the NIH. Sequestration will reduce the NIH budget by 8.2% ($2.5 billion) and will substantially affect the AMC budget. The budget of the State of Colorado cannot offset these cuts as the budget is appropriated with the expectation that state expenses will exceed revenues by 2018 (primarily due to Medicaid expansion and utilization growth). Using the funding of higher education as an example, the state has reduced its proportion from 14% in fiscal year

2000 to 8% in 2012 to a projected 5% in 2022. Therefore, the burden of funding will directly challenge AMC, and AMC must develop new funding streams in an effort to strategically optimize team science endeavors.

III. Funding Opportunities

The committee delineated funding opportunities using the following themes:

- Reducing inefficiencies,
- Improving and promoting AMC Research image,
- Bolstering philanthropy, and
- Developing innovative funding mechanisms.

IV. Reducing Inefficiencies

The results of internal surveys conducted at AMC suggest that investigators are concerned about inefficient policies causing substantial delays in their research. Several offices have been scrutinized, including the Colorado Multiple Institutional Review Board (COMIRB), the Office of Grants and Contracts (OGC), and the Technology Transfer Office (TTO). The committee believes inefficiencies are a major issue that has cost AMC. Anecdotes exist where AMC was intentionally excluded from national studies or biomedical research programs because the local research process was perceived as "too arduous to bother with." The committee recognizes that administrators at AMC and the broader university are already aware of these inefficiencies and are actively working to alleviate these concerns. As a result, the lag times to review research protocols or grants have been substantially reduced over the past year. The committee encourages continued efforts to improve inefficiencies including amalgamating the research process across all university sites and affiliates so that subcontracts are not needed in order to include co-investigators from other institutions. Creating a database of issued grants and local investigators would be most beneficial as well.

The growth of the Bioscience Park at AMC is minimal. As the economy slowly improves, the committee believes that growth may accelerate, but it is incumbent upon AMC to position itself as a viable partner. This effort may include ensuring that tax incentives are available to biomedical companies, as well as creating technology transfer models that are flexible and can accommodate partnerships between AMC faculty and biomedical entities at all levels of the product development cycle.

V. Improving and Promoting the AMC Image

AMC and its affiliated institutions have achieved prestigious status. For example, the University of Colorado Hospital (UCH) was recently rated the number one academic hospital in the US by the University Health System Consortium. Nearly two-thirds of the top doctors rated by the magazine 5280 are School of Medicine faculty or clinical associates. The US News and World Report ranks at least three medical training programs and the pediatric nurse practitioner program in the top five nationally and the School of Pharmacy ranks third nationally for NIH funding per PhD. These accomplishments garner respect from the medical community but they require promotion for public recognition. Likewise, many AMC investigators and their research programs are known internationally for their scholarly work, but AMC is not perceived by the general public as a major research institution, but rather as one that only provides education, training, and clinical care. This is particularly true at the community and state level. Changing public perception requires increasing recognition of university-based researchers for their accomplishments to promote internal and external recognition. **The committee recommends an aggressive campaign by AMC, coordinated with its affiliate institutions, and designed to tell the success stories "from anyone to anyone by any means."** Researchers may be the focus of media, patients may blog about their care, or students may post about a class. Dissemination must come from all domains and must include administrators, faculty, staff, students, and alumni. Other efforts may include the offering of programs such as the Mini-Med School, Mini-STEM School, community outreach, promotion of a research days, or enhanced visibility through advertising apparel. Ultimately, promoting an image of research excellence in addition to exceptional education and patient care will also aid philanthropic endeavors.

VI. Bolstering Philanthropy

As mentioned above, promoting an image of research excellence will enhance philanthropic endeavors. Private support to AMC totaled $43.5 million in 2011-2012; AMC's goal is to increase this to $100 million over the next seven years. The committee believes this amount should be easily attainable and suggests that the administration consider a larger goal. Several consultants acknowledged the lack of sustained fund raising by the CU Foundation. The committee recognizes that the CU Foundation is undergoing comprehensive restructuring and believes this should help raise funds in excess of $100 million. Biomedical research priorities at the University must strategically align itself with the broader aims of the Foundation.

The committee believes two philanthropic strategies are required. First, potential large donors need to be identified and actively engaged. This should include local and international efforts. AMC must sell the fact that it is the only academic medical center in the region and should attract clientele and stakeholders from several nearby states. Most AMC buildings are without a sponsor and the committee believes the naming rights serve as an attractive offer to many large donors. Private foundations provide about $10 billion each year to research and development, and AMC must strategically align itself to partner with these organizations. Approximately 10% of AMC's research funding comes from corporate collaborations, usually by investigators independently networking with biomedical corporations. AMC should consider approaching these established partners for umbrella donations that support team science initiatives within their corporate niche.

Second, small donors need to be targeted. These initiatives may focus on current students and alumni through university events. Acknowledging donors should be done at prominent locations at AMC.. Ideas aimed at soliciting donations to "adopt an hour" of research or support specific items or programs should be considered as well.

VII. Developing Innovative Funding Mechanisms

The table below lists several ideas the committee considered to enhance research-related revenues. Some of these endeavors are already underway or are being considered as possibilities by the AMC administration: increased rates for NIH indirect cost recoveries and increased taxes (state, property, or sales). The committee would like to highlight two approaches worthy of serious consideration: biomedical research bonds or certificates of participation and the state Lottery Commission.

Certificates of participation were used to help fund the construction of AMC. Like physical space, research is a long-term investment. Certificates of participation are particularly appealing to help fund research because the investor is purchasing a share of the revenues of the research enterprise rather than expecting a return on investment based on a rate related to the risk of investment. This mode of funding is also appealing because it is free of conflicts of interest, investors may represent multiple entities, and the return will be based on innovation (e.g., a new product, service, device, therapy, or program).

The use of lottery revenues is at the discretion of each participating state. Many states allocate some funds to their general fund or various higher education initiatives. Between 2006 and 2010, the Lottery Commission of Colorado increased its revenues from roughly $470 million to over $500 million. Over these same years, the Lottery Commission allocated between $112 million to $125 million annually to various programs; about 80% of which went to the Conservation Trust Fund and Great Outdoors Colorado. In 2009, a small proportion was newly allocated to Public School Capital Construction Fund. The committee believes a precedent exists that may enable a small proportion of lottery funds to be allocated to biomedical research in Colorado.

Innovative Funding Approaches	Considerations
Research training programs targeting foreign governments	Revenues related to tuition Requires programmatic commitments
Grant writing workshops for AMC faculty	Designed to target large grants (e.g., NIH) likely from mid-career or clinical scientists
Increase ICR rates for some Federal entities but consider not doing so for other entities.	Assemble a task force to optimize ICR's
Research days with tickets	Requires programmatic commitments Possible liability issue
Increase ticket prices at university events	May require public support and administrative support
Collection boxes	Likely small revenues Requires public support and may promote wrong image
UPI collaboration	Needs UPI cooperation with minimal return
Institutional contracts	Promotes team science
Collaboration with biomedical corporations	Requires technology transfer flexibility
Increase taxes (state, property, sales)	Requires public support and may promote wrong image
Voluntary donation when filing taxes	Difficult to track May set precedent for other initiatives
Biomedical research bonds / certificate of participation	See text
Lottery commission	See text

Chapter 3.

Space and the Physical Environment

Challenge:

How could the Anschutz Medical Campus (AMC) built environment be adapted to best meet the needs of and encourage team science?

Team Members:

John L. Adgate, MSPH, PhD – Professor and Chair, Department of Environmental Health, School of Public Health.
Michelle Barron, MD – Assistant Professor of Medicine, School of Medicine; Medical Director, Infection Prevention and Control, UCH.
Dwight J. Klemm, PhD – Professor, Department of Medicine; Co-Director, Obesity Cell Biology Program, Colorado Obesity Research Initiative.
Debbi Main, PhD – Professor and Chair, Department of Health and Behavioral Sciences, School of Public Health.
Cindy O'Bryant, PharmD – Associate Professor, School of Pharmacy; Director Oncology Pharmacy Residency; Co-Director Oncology Pharmacy Translational Fellowship.
Sally E.Tarbell, PhD - Associate Professor, Department of Medicine; Chief Pediatric Psychology, Children's Hospital Colorado.
Stephanie Teal, MD, MPH – Associate Professor, Obstetrics and Gynecology, School of Medicine; Chief Section of Family Planning.

I. Methodology

We reviewed the academic literature on the impact of the built environment on team science as well as writings on collaborative work spaces within the private sector, especially innovative technology companies. We then interviewed scientists both on campus and from other institutions who are engaged in team science for their insights into how the built environment facilitates or impedes their collaborative work.

II. The Physical Environment and Team Science

One significant influence on team science that has received limited attention is the built environment, i.e., the physical design, layout, buildings, meeting rooms, lab space, outdoor and communal space. Based on empirical and anecdotal evidence from innovative technology companies such as Google, Citrix and Facebook, TED talks on spaces that foster creativity, as well as academia, we've learned that several factors influence the success of teams:

Multidisciplinary teams of investigators from the same institution are far more successful than teams composed of members from different institutions.[13,14]

Frequent face-to-face communication between team members is a key factor for success. (13, 14)

There are shared patterns in creative environments, and one of them is that "chance favors the connected mind." (Steven Johnson, TEDTalk)

Findings from the literature suggest few key physical/environmental factors that influence team effectiveness:
1. Spatial proximity of team member offices and laboratories to encourage frequent informal contact.
2. Availability of comfortable meeting areas for group discussion and brainstorming.
3. Access to distraction-free workspaces for tasks requiring concentration and/or confidentiality.
4. Physical environments that support members' efforts to regulate interpersonal privacy and accessibility to others.

III. Interviews with Team Scientists

Using a structured interview guide, we interviewed 17 local and national researchers already engaged in team science to learn more about how the physical environment could facilitate ongoing and developing team science on the Anschutz Medical Campus. We coded and analyzed interview notes to identify salient themes related to the physical environment and team science, focusing specifically on barriers and recommendations for AMC. Finally, we verified and extended our findings using team member and literature reviews to enhance their credibility and applicability. Three major findings emerged from the interviews.

[13] Cummings, J.N., and S. Keisler. 2005. Collaborative research across disciplinary and organizational boundaries. Social Studies of Science 35:703-722.

[14] Olson, G.M. and J.S. Olson. 2000. Distance matters. Human-Computer Interaction 15:139-178.3.

IV. Findings and Recommendations

1. **Funding opportunities, shared interests and need for interdisciplinary expertise were cited as key drivers for initiating team science projects.**

   a. **Key barrier(s):**
      i. School (or silo) model limits ability to find collaborators.
      ii. Current $/foot^2 metric constrains team science

   b. **Recommendations**:
      I. Organize investigators and their labs across common interests (institutes and centers, rather than departments).
      II. Allocate space based on common scientific interests rather than traditional school/departmental boundaries.
      III. Evaluate current campus model of separating space into quadrants (education, research, patient care) as a potential barrier to collaborative science. The segregation of the campus into quadrants puts artificial barriers between disciplines and between researchers and clinicians.
      IV. Improve social and technological infrastructure to help dispersed people identify potential research collaborators with shared interests.
      V. Promote more team science events to bring together investigators for presentations, discussions and "casual" collisions. (This is a term used in the technology sector to capture the importance of chance meetings to creative enterprise.)

2. **Proximity matters**: **Many informants reported that AMC'S built environment (i.e., the physical layout, buildings, meeting rooms, lab space, outdoor and indoor communal space) supports team science when research collaborators are near. The current configuration of buildings, technological capabilities, organizational structures, and distance from other campuses, however, impedes opportunities to meet (i.e., "bump into") potential collaborators from different programs/disciplines with shared interests, and to build and maintain teams locally, nationally and internationally.**

a. **Key barrier(s):**

   I. Researchers are dispersed across the campus limiting opportunities for "casual collisions."
   II. Lack of convenient parking and way-finding signage makes it difficult for collaborators and research patients to visit this campus.
   III. AMC researchers identified distance as a barrier to meeting and forming new collaborations with other researchers/programs/disciplines within the state (e.g., UC Boulder, downtown, CSU).
   IV. There is a lack of shared meeting space for clinicians and bench researchers, limiting interactions and opportunities for translational research.

b. **Recommendations to Improve Team Science at AMC:**

   I. Create an innovative "Research Commons" through re-purposing of current space or new construction. This space would be attractive to members of the University community through fulfillment of the following principles: informality, availability of intimate meeting spaces, availability of food/drink to attract members to congregate during meal or break times, location at bridging point between research, education, and patient care quadrants, easy access to intra-campus transportation.
   II. Increase the use of "hybrid" building space that encompasses interdisciplinary research teams, meeting rooms, restaurants and other places to allow for collaborative opportunities.

3. **Technology is important for collaborations (at all levels -- international, national, state-wide, inter- and intra-campus). Technology that allows for tele- and videoconferencing, secure data sharing and storage and access to buildings of campus partners (Children's, UCH) was noted as important.**

   a. **Key barrier(s):** Lack of reliable, user-friendly technology is an obstacle to effective team science on the AMC campus.

   b. **Recommendation:** Have designated core conference rooms with reliable user-friendly, state of the art technology that supports productive face-to-face meetings and collaboration with investigators elsewhere.

A Model of an Exemplary Building on the AMC Campus:

The Nighthorse Campbell Building: Researchers from different disciplines are on the same floor. Many collaborators are on campus and so can easily walk to meetings. Meeting space is an integral part of the building's design, including conference rooms for research meetings and teleconferencing and other technology in the building "that you can count on," including web meetings and videoconferencing.

Overall Recommendations

Team science can be enhanced through a combination of built, social and technological infrastructure designed to:

- Help identify others with common research interests, disciplinary skills, and interest in collaboration;
- Promote "proximity" among new or experienced team members when it's most helpful;
- Use technology to support and enhance team interactions, information and data sharing, team productivity and cohesion over time.

Action Items

Based on the above recommendations the following are fundamentals to promote team science on the AMC campus.

- Ubiquitous communications technology
- Space allocated by common research interest
- Easy access to parking and campus transit
- Creation of an Innovations Commons
- With meeting space, food and drink
- For students, staff and faculty

Chapter 4.

Toolkits

Challenge:

The original charge to our group was to consider how "toolkits" might be best applied to support and encourage Team science on the AMC and in the greater CU community. The basic first question was 'What constitutes a Team science toolkit?' since this is not broadly recognized.

Team Members:

David Bain, PhD – Associate Professor, Skaggs School of Pharmacy
Lori Crane, PhD, MPH – Associate Dean and Professor, School of Public Health
Sonia Flores, PhD – Professor, Division of Pulmonary Sciences, School of Medicine
Jori Leszczynski, DVM – Assistant Professor of Pathology, School of Medicine; University Veterinarian; Director for the Office of Laboratory Animal Resources
Anne Lynch, MD MSPH – Associate Professor of Obstetrics, Gynecology and Epidemiology, School of Medicine; Director Colorado Baby Blanket Research Program and Co-Director Child Maternal Program of the CCTSI.
Jeffrey Stansbury, PhD – Associate Dean and Professor, School of Dental Medicine

I. Methodology

Team science "toolkits" (also known as "toolboxes") have been developed by several organizations, with the toolkit developed by the National Cancer Institute being among the most widely cited (https://www.teamsciencetoolkit.cancer.gov/Public/GetStarted.aspx). A central piece of Team science toolkits is a database in which scientists share their areas of expertise and interest, as well as resources they have developed, such as measurement protocols and tools. These databases can serve as a source for the identification of collaborators and methodologies when initiating a team science endeavor. Toolkits also include recommendations and guidelines for the successful initiation and conduct of team science projects. For example, the team science guide created by the National Institutes of Health includes sections on building a research team, sharing recognition and credit, handling conflicts, and strengthening team dynamics, among other topics.

Our group discussed the merits of engaging existing toolbox designers and users, but this approach seemed overly prescriptive and would not have necessarily identified new opportunities. We came to the consensus that a high level overview of barriers to team science, based on the perspectives of faculty and academic administrators within and external to CU might be the most informative when filtered through our diverse group for potential application at CU, whether in the form of some database content or just as general policy recommendations. We developed, with the assistance of our assigned resource coaches, and refined a 12-question interview to broadly probe perceptions and experience with team science and toolkits along with open-ended questions on best practices related to team science. The semi-structured survey posed questions related to i) identifying barriers that block or complicate collaboration; ii) exposing reasons for unsuccessful collaborations; iii) intentional actions that can be taken to overcome collaborative barriers; and iv) what institutions need to provide to encourage team science projects to thrive. We individually selected and interviewed multiple faculty and administrators that cumulatively provided over twenty responses from junior faculty (2), senior faculty (6), department chairs (7) and deans/associate deans (7), with about a third of the interviewees from outside CU.

When comparing our notes, we found many commonalities but also several interesting and unique findings. There were uniformly high levels of enthusiasm expressed by those interviewed for the collaborative team science concept with plenty of warnings of potential pitfalls. However, among our group of respondents, no one had direct exposure to toolkits beyond the basic level of our Colorado Profiles or a similar faculty inventorying system, with some of those external to CU being a bit flashier but still not engendering strong support for their overall utility. Based on these responses, we consolidated the ideas expressed into global and local barriers to team science and then in combination with our group members' opinions and judgment, we developed some basic strategies to promote team science at CU. We also outlined how interpersonal relations bear on collaborative working arrangements, and finally how information intended to facilitate team science can be stored for easy access and use.

II. Barriers to Team Science

The barriers to team science that we encountered through the interview process and our own experience can be condensed to the following list:

- University infrastructure does not allow for maximal faculty interactions
- Schools and departments are organized on the basis of established research fields instead of cross-disciplinary team science
- NIH study sections are not aligned with NIH mandates to promote team science
- Current promotion and tenure requirements are based on establishing faculty independence
- Insufficient seed money to establish team science partnerships and pilot studies
- Incompatible schedules between basic scientists and clinicians

The more locally focused observations related to barriers can be summarized as follows:

- Expectations for collaboration are not spelled out up front
- Lack of a two-way relationship with giving and receiving data and results
- Disagreements on the relevant scientific question and approaches to answer the question
- Uneven contribution of resources, infrastructure or productivity
- Too many unfunded mandates (i.e., other obligations to departments, schools, and the university)

III. Strategies for Promoting Team Science

The fairly extensive list of strategies that we either heard from those we interviewed or developed among ourselves that could promote team science at CU includes:

- Environment and infrastructure: Maximize random and orchestrated "collisions" between faculty (e.g., faculty club)
- Institution: Reorganize schools and departments based on scientific affinities, problems and diseases
- NIH: Alignment of study sections with team science goals
- Promotion: Recognition of team science and corporate authorship
- Institution: Incentives for departments with team science projects (e.g., flow of ICR)
- Resources: Finances (seed funding), space, bridge funding, support staff, protected time for researchers
- Administration: Strong and centralized office of research
- Recruit and retain faculty with interpersonal skills conductive to team science

IV. What Makes an Effective Team?

The teams that are formed to effectively conduct team science, whether locally or remote, need both the appropriate interdisciplinary expertise in science, medicine, engineering, etc., and the ability to interact as individuals; thus, interpersonal requirements come into play to either foster or impede the progress of the team. The following list details the basic traits that were described as being important for effective teamwork:

- A champion of the research – a convener; creative; open and strong
- All collaborators must see the value of the research and have desire to be involved; be bought into the question and have a piece of it; "everyone needs to have a dog in the fight"
- Trust, respect, openness and sharing
- Sense of being included in decisions
- Clear expectations with everyone pulling their weight
- Intellectual compatibility
- "People do not want to work with jerks"

V. Creative Approaches to Promoting Team Science

There were quite a few interesting anecdotal stories that emerged through our exploration of this topic. One worth noting here comes from the University of Michigan where a very intentional effort was made to promote nascent team science collaborations by offering matching seed funding to newly organized groups involving at least three different academic units, not necessarily all within their institution. The unusual aspect was that all that was required to compete for the funding support was a project title and a brief explanation of why the proposed team demonstrated unique potential. The two-year funding, with required buy-in from the respective departments, was designed to help produce unique preliminary data that would translate to self-sufficient funding as is always expected in these cases. However, it was the very low barrier of entry into the competition that promoted broad base participation by faculty who were encouraged by the challenge into thinking in bigger picture, team science terms, which certainly doesn't occur in most institutions as often as we may like.

VI. Recommendations for Toolkits

Finally, in looking at broadly structured toolkits and how they relate to team science here at CU, the following features or factors were deemed important:

- A central repository (website) of all of the information specific to this campus in the office of the Vice Chancellor of Research; requires maintenance support (webmaster) and a design that allows ready accessibility. This repository could include the following:
    - Organized, current funding opportunities list
    - Easy links to all core services (system-wide)
    - Revised promotion and tenure guidelines that acknowledge collaborative efforts coupled with integrated metrics tools to assist evaluation of this aspect of faculty performance
    - ICR sharing agreement templates
    - Seminar calendars
    - Colorado Profiles with updated capabilities that allow searching for internal/external joint publications and grants (submitted as well as awarded) among our system faculty and possibly all CCTSI institutions
    - Resources for interviewing and identifying individuals that are collaborative
    - Organized announcements of seed funding opportunities[15]

[15] Bennett, LM, Gadlin, H, Levin-Finley, S. Collaboration and Team Science: A Field Guide. National Institutes of Health, August 2010, available at: https://ccrod.cancer.gov/confluence/download/attachments/47284665/TeamScience_FieldGuide.pdf?version=2&modificationDate=1285330231523 (accessed March 27, 2013).

Summary.

team science, translational research or collaborations locally and/or nationally can happen organically as individuals come together to answer important questions, develop friendships that lead to work collaborations or attend meetings or conferences concerning common interests. The physical environment, funding opportunities, toolkits, education and academic recognition can either promote an environment that is conducive to these types of collaborations or can serve to hinder their development.

Throughout this paper we have identified many ways that the University of Colorado, especially on the Anschutz Medical Campus, is serious in its commitment to team science. Having a variety of hospitals as well as research facilities on one campus in and of itself is a significant advantage when one contemplates facilitating collaboration. Furthermore with beautiful space and limited eating places, the current campus environment naturally facilitates bumping into people whether at the coffee shop or the eateries on campus. As has been outlined above, such accidental exchanges could be further facilitated by “Research Commons” areas that are intentionally-designed social spaces to foster formal and informal interactions between investigators.

The siloed nature of education has changed in recent years with a stronger focus on providing opportunities for graduate students to mix through, for example the interdisciplinary ethics course for health professionals. Also, within the Graduate School, programs are now more focused on topic areas or groupings than individual fields. There remains, however, a need to provide training resources for current researchers on how to be successful in a team science collaboration and how to be recognized under current promotion criteria as a member of a team science project.

There is also an opportunity to provide additional incentives to encourage team science through the use of funding initiatives based on bolstering philanthropy and developing innovative funding mechanisms internally and in collaboration with the state.

Despite being on one campus, it can be difficult to connect with other people who are working on similar projects or have similar interests to you. A toolkit is a virtual mechanism to further promote collaboration. It could be a virtual resource and network site that expands the CCTSI Profiles network by also serving as a “hub” for resources and opportunities on campus as well as regionally and nationally that relate to team science.

Even more importantly, this LITeS project has shown that a varied group of busy scientists with no common interest other than a commitment to science can come together as an integrated group to address the issues posed. This desire to cooperate and work together is a strong resource that reflects a broader willingness among faculty and staff on campus to work towards a common goal. Some small changes as outlined in this paper could further channel the energy of this important resource to better address numerous health challenges by effective team science collaborations.