Canadian Academy of Health Sciences
Académie canadienne des sciences de la santé

ACADEMIC RECOGNITION OF TEAM SCIENCE:

HOW TO OPTIMIZE THE CANADIAN ACADEMIC SYSTEM

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THE CANADIAN ACADEMY OF HEALTH SCIENCES

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THE CANADIAN ACADEMY OF HEALTH SCIENCES

The Canadian Academy of Health Sciences (CAHS) recognizes Canadians of great achievement in the academic health sciences. Founded in 2004, CAHS now has over 600 Fellows and appoints new Fellows on an annual basis. The organization is managed by a voluntary Board of Directors and a Board Executive. The Academy brings together Canada's top-ranked health and biomedical scientists and scholars from all disciplines across our nation's universities and its healthcare and research institutes to make a positive impact on the urgent health concerns of Canadians. These Fellows evaluate Canada's most complex health challenges and recommend strategic, actionable solutions. Since 2006, CAHS has successfully engaged the sponsorship of a wide variety of public and private organizations representing patients and families, professionals, health system leaders, policy-makers, and service and private industry providers. It has co-invested in rigorous, independent assessments that address key health issues with outcomes that have shaped its strategic policy and initiatives. CAHS mobilizes the best scientific minds to provide independent and timely assessments that inform policy and practice addressing critical health challenges affecting Canadians. CAHS helps put change into action for a healthier Canada.

THE EXPERT PANEL ON ACADEMIC RECOGNITION OF TEAM SCIENCE IN CANADA

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MESSAGE FROM THE CHAIR

The Expert Panel is pleased to submit its final report. Though the importance of its subject may not yet be fully appreciated, this report addresses matters that are crucial if Canada is to realize the benefits of team science. The true measure of its value will depend on the follow-up to our recommendations.

The Panel is indebted to many people at Canada's universities and funding agencies who provided us with information critical to our work. We are indebted as well to our peer reviewers and to our editor. We must single out the Council of Canadian Academies for special mention. Without the leadership of Eric Meslin, President and CEO, and his excellent team (Tijs Creutzberg, Rebecca Chapman, Andrea Hopkins, Joanne Linnay, and Samantha Rae Ayoub), this report would not have been possible. We thank them from and with our hearts.

Peter MacKinnon, O.C.
Chair, Expert Panel on Academic Recognition of Team Science in Canada

MESSAGE FROM THE CAHS PRESIDENT

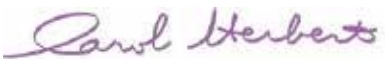
On behalf of the Canadian Academy of Health Sciences (CAHS), I am pleased to present this report on the **Academic Recognition of Team Science**. The assessment was initially proposed by the Canadian Cancer Research Alliance, which also served as one of the sponsors. The other sponsors include Alberta Innovates – Health Solutions, the Canadian Institutes for Health Research, Fonds de recherche du Québec – Santé, the Michael Smith Foundation for Health Research, and the Nova Scotia Health Research Foundation. One of the expert panel members, Dr. Holly J. Falk-Krzesinski, was sponsored by her employer, Elsevier, which has provided her services to similar panels in the United States and the United Kingdom. To all of you, we wish to express our gratitude both for the funding as well as for your patience. We are also grateful to the Council of Canadian Academies, which assisted with research and project management.

CAHS wishes to extend our thanks to the Chair of the Expert Panel, Peter MacKinnon, former President of the University of Saskatchewan and Interim President of Athabasca University, and to panel members Drs. Stephen Bornstein, Sarah Bowen, Holly J. Falk-Krzesinski, Sara Israels, Joanne Keselman, Roderick R. McInnes, Carol L. Richards, D. Lorne Tyrrell, and Peter Walker.

Appreciation is due also to Dr. Dale Dauphinee, McGill University, who served as Peer Review Monitor, and to the members of the CAHS Standing Committee on Assessments, especially Dr. Tom Feasby. They provided guidance and assistance in all aspects of this report from the initial proposal through to fundraising and report completion. Dr. John Cairns (Past-President) also provided advice and leadership for this project.

Every CAHS assessment requires the financial sponsorship of visionary organizations. This assessment was supported by several organizations that generously contributed anywhere from $5,000 to $50,000. CAHS is profoundly grateful to each of these sponsoring organizations. They are acknowledged above and in the introductory pages of this report. The CAHS leadership brings this report to the attention of the Canadian academic community, granting agencies, and major scientific award committees to ensure that contemporary scientific endeavours requiring participation from a variety of experts will recognize the work of all members of such teams and encourage team science approaches.

Sincerely,



Carol P. Herbert, MD, CCFP, FCFP, FCAHS
President, Canadian Academy of Health Sciences

REPORT REVIEW

This report was reviewed in draft form by the individuals listed below — a group of reviewers selected by the Canadian Academy of Health Sciences (CAHS) for their diverse perspectives and areas of expertise. The reviewers assessed the objectivity and quality of the report. Their submissions — which will remain confidential — were considered in full by the Panel, and many of their suggestions were incorporated into the report. They were not asked to endorse the conclusions, nor did they see the final draft of the report before its release. Responsibility for the final content of this report rests entirely with the Expert Panel on Academic Recognition of Team Science in Canada.

CAHS wishes to thank the following individuals for their review of this report:

Alison M.J. Buchan, FCAHS, Professor, Department of Physiology, Faculty of Medicine, University of Toronto (Toronto, ON)

Rama C. Nair, Professor, Epidemiology, Public Health and Preventative Medicine and Vice Dean, Professional Affairs, University of Ottawa (Ottawa, ON)

Anne Ridley, Professor of Cell Biology, King's College London (London, United Kingdom)

Barbara G. Vickrey, Professor and Chair, Department of Neurology, Icahn School of Medicine at Mount Sinai (New York, NY)

Lori J. West, FCAHS, Professor of Pediatrics, Surgery and Immunology and Director, Alberta Transplant Institute (Edmonton, AB)

On behalf of CAHS, the report review procedure was monitored by **W. Dale Dauphinee, FCAHS,** Senior Scholar, Foundation for Advancement of International Medical Education, and Adjunct Professor, McGill University. The role of the report review monitor is to ensure that the Panel gives full and fair consideration to the submissions of the report reviewers. The Board of CAHS authorizes public release of a report only after the report review monitor confirms that CAHS's report review requirements have been satisfied. CAHS thanks Dr. Dauphinee for his diligent contribution as report review monitor.

EXECUTIVE SUMMARY

Research questions and methodologies have become more complex in recent decades. As a result, successful health science research relies more and more on collaboration among experts across disciplines, institutions, or countries, all working together in research teams. While team science yields many benefits for scientific discovery, it is not without risk for individual team members. Concerns about appropriate recognition for personal contributions and — by extension — career advancement can discourage strong researchers from collaborating in team science projects. As summarized in Chapter 2, the problem lies in how to fairly evaluate the research records of applicants (for advancement, promotion, tenure, or funding) who have devoted much of their activities to team science. This can particularly affect specialists (e.g., biostatisticians, communicators, bioethicists) whose work is often critical to the success of projects led by others. Overall, academic institutions, funding agencies, and research award programs in Canada have been slow to adapt assessment/evaluation processes to recognize the contributions of individual investigators to team science.

The factors that hamper the fair evaluation of individual work performed in a team are numerous. They can exist in institutional structures, in the structure of review committees, and within the actual assessment/evaluation process itself as set forth by universities and funders. This report therefore examines these factors through three lenses: culture and behaviour, review committees, and assessment/evaluation (Figure 1). Promising practices (Chapter 3) and recommendations (Chapter 4) are also presented through these lenses.

CHARGE TO THE PANEL

The Canadian Academy of Health Sciences (CAHS) convened an expert panel (the Panel) to examine how institutions in Canada's research system evaluate and recognize the contributions of individuals for work done within research teams, and to identify promising practices to improve such evaluation and recognition. The Panel comprised 10 experts from Canada and the United States with backgrounds in health research,

FIGURE 1 THREE LENSES FOR EXAMINING CHALLENGES RELATED TO RECOGNITION AND REWARD OF INDIVIDUAL MERIT IN TEAM SCIENCE

collaborative research, university administration, and funding agency operations. Specifically, CAHS tasked the Panel to prepare a report that would provide:

- *an inventory of best academic recognition practices that recognize the role of an individual in a team of investigators either in Canada or in other countries;*
- *recommendations that can assist academic promotion, tenure, and merit committees to develop their own guidelines to evaluate the role of individuals within a larger research team;*
- *discussion of the role of promotion and tenure processes in serving the goals of fostering the health of Canadians and health system innovation; and*
- *discussion about possible means that national research award selection committees might use in determining recognition of individuals and teams of individuals for consideration.*

APPROACH

Since this report's definition of *team science* encompasses single-discipline, multiple-discipline, cross-disciplinary, and cross-sectoral teams (Section 1.3.1), the Panel reviewed evidence related to participatory (action) research, engaged scholarship, integrated knowledge translation, and Mode 2 research. To supplement a limited evidence base on university and funding agency recognition practices, the Panel administered a survey to Canadian universities and funding agencies (Section 1.3.3). The Panel also drew from the experiences of its members as research administrators, researchers, and reviewers. See Chapter 1 for more information about the Panel's methodology and survey.

Few of the promising practices identified in this report have been formally assessed for effectiveness, and several are simply examples of what could be done. The Panel acknowledges that there remain significant gaps in available evidence. These practices do, however, demonstrate a need for organizations to reassess criteria for advancement, promotion, tenure, or funding, and to experiment with new practices that involve not just universities and funders but also researchers. Chapter 3 discusses promising practices related to culture and behaviour, review committees, and assessment/evaluation.

RECOMMENDATIONS

The Panel is hopeful that its recommendations will be considered and put into practice by universities, research institutions, and funding agencies. As recommendations are tested in real-world settings, it is important that organizations conduct rigorous and appropriate evaluation of any changes made, given the limited evidence base for promising practices. Such evaluation is necessary in relation to both the *implementation* and *impacts* of any process modifications. Leadership must also be prepared to identify and promote strategies for sharing the results of these changes throughout the academic and research funding systems for the encouragement and benefit of all.

Below are the Panel's 12 practical recommendations, directed at universities, funders, and researchers. These are expanded on in Chapter 4.

Recommendations to Adapt Culture and Behaviour to Team Science

1. Promote a broader concept of scholarship and a more inclusive understanding of the complexity of team science.
2. Acknowledge the critical contributions of "skills specialists" to team science and establish career paths for specialists to facilitate their advancement.
3. Recognize team research by providing the support required for the additional infrastructure essential to team-building and the development of successful collaboration.
4. Expand the funding timeframe for large interdisciplinary teams and for teams that must build collaborations with other sectors.

5. Allow the funding for team grants to be allocated to multiple institutions.

6. Mentor young researchers on team science opportunities.

Recommendations to Help Review Committees Measure Team Science Contributions

7. Ensure that advancement, promotion, and tenure (APT) and funding criteria include explicit recognition of contributions to team science and collaborative activities.

8. Compose review committees that can knowledgeably and fairly assess team science contributions.

9. Train reviewers in the evaluation of individual contributions to research teams.

Recommendations to Improve the Assessment/Evaluation of Team Science Contributions

10. Ensure that the evaluation of team science reflects current knowledge about metrics for faculty evaluation.

11. Adapt application forms and templates to reflect the diversity of research contributions to team science projects.

12. Use databases that aggregate researcher publication output for more accurate attribution.

Towards Implementation

Only strong leadership among Canadian universities, funding agencies, and researchers — and at the highest levels — will allow Canada full participation in the global team science environment. The Panel recommends that Universities Canada's Standing Advisory Committee on Research, the National Vice-Presidents Academic Council (NATVAC), and our Tri-Agency and other funding organizations redraft their policies and/or criteria to better recognize team science contributions. The Panel also recommends that the Tri-Agency Presidents and the executive of NATVAC convene a cross-sectoral leadership forum to carve a pathway to implementing the above recommendations at all levels. The Panel further encourages major health science bodies in Canada, such as CAHS and CIHR, to highlight this report's recommendations and promising practices at upcoming conferences or annual general meetings. This will generate the leadership and momentum needed for Canada to adapt to a more international, interdisciplinary, and complex research ecosystem.

CONTENTS

1 INTRODUCTION

Research questions and methodologies have become more complex in recent decades. As a result, successful health science research relies more and more on collaboration among experts across disciplines, institutions, or countries, all working together in research teams. Indeed, the increasingly cross-disciplinary nature of health science research, and the growing complexity of scientific knowledge and techniques, are making it more difficult for the lone researcher to produce a novel discovery (Esparza & Yamada, 2007; Jones, 2009; Arbesman, 2010). The fact that innovative solutions are now more likely to emerge from cross-disciplinary perspectives and expertise is also driving the trend towards team-based science (Wuchty *et al.*, 2007). Publication statistics underscore this growing trend. Over the last several years, there has been a rise in the average number of authors per publication and in the proportion of publications authored by researchers representing multiple disciplines and international collaborations (Wuchty *et al.*, 2007; Jones *et al.*, 2008). In Canada, the importance of research done in teams, or *team science*, has not gone unnoticed. Several funders, such as the Canadian Institutes of Health Research (CIHR), the Networks of Centres of Excellence of Canada (NCE), Genome Canada, and the Canadian Institute for Advanced Research (CIFAR), have developed new opportunities to support such collaborative work.

Yet despite a growing appreciation of the importance of collaboration and Canada's strong history of collaborative research, there is legitimate concern in the health science research community about the lack of recognition for team science in the academic reward system. In particular, concerns have been raised about the way an individual researcher's efforts are evaluated in the context of a research team. Put simply, academic employers are being called on to adapt faculty evaluation processes to ensure that they reward the work they wish to encourage (Taylor, 2015).

These same challenges extend to the evaluation of funding applications or award nominations. Funding agencies and award programs often use the same criteria that academic institutions use to assess a researcher's qualifications and track record. It is important to ensure that academic institutions, funding agencies, and research award programs take a similar approach to assessing merit, one that includes appropriate recognition for the contributions of individual investigators to team science.

To bring a much-needed Canadian perspective to these issues, the Canadian Academy of Health Sciences (CAHS) convened an expert panel (the Panel) to examine how institutions in Canada's research system evaluate and recognize the contributions of individual researchers for work done as members of research teams, and to identify best practices to improve such evaluation and recognition.

1.1 CHARGE TO THE PANEL

Specifically, CAHS tasked the Panel to prepare a report that would provide:

- *an inventory of best academic recognition practices that recognize the role of an individual in a team of investigators either in Canada or in other countries;*
- *recommendations that can assist academic promotion, tenure, and merit committees to develop their own guidelines to evaluate the role of individuals within a larger research team;*
- *discussion of the role of promotion and tenure processes in serving the goals of fostering the health of Canadians and health system innovation; and*

- *discussion about possible means that national research award selection committees might use in determining recognition of individuals and teams of individuals for consideration.*

The Panel comprised 10 experts from Canada and the United States with backgrounds in health research, collaborative research, university administration, and funding agency operations. The assessment process involved three in-person panel meetings and several teleconferences over the course of 2015, 2016, and 2017 to identify and review relevant evidence, and to reach a consensus on findings and recommendations. Funding for this assessment was provided by CIHR as well as Alberta Innovates – Health Solutions, the Canadian Cancer Research Alliance (Canadian Partnership Against Cancer), Fonds de recherche du Québec – Santé (FRQS), the Michael Smith Foundation for Health Research, and the Nova Scotia Health Research Foundation.

1.2 SCOPE AND LIMITATIONS

Given the recent publication of reports on team science by the U.S. National Research Council (2015) and the U.K. Academy of Medical Sciences (2016) (see Section 1.3.2), the Panel chose to focus on one aspect of team science: the assessment/evaluation of contributions by individuals engaged in team science for the purposes of academic advancement, awards, or funding. The Panel therefore reviewed the evidence related to how institutions in the Canadian research system — mainly universities and funders — can best assess individual contributions within a team science project.

The Panel considered how team science can be supported generally and did so within the context of (1) academic merit and promotion and (2) the awarding of grants, in recognition of the overlap between these distinct but related areas. The published literature on academic tenure and promotion practices is growing, especially on the subject of interdisciplinary research and team science (Klein & Falk-Krzesinski, 2017). It is, however, quite limited in the Canadian context, although the Panel does identify some trends and promising practices in Chapter 3. To supplement the evidence base, the Panel administered a survey (see Section 1.3.3) and drew from the experiences of its members as research administrators, researchers, and reviewers. Although the funders' survey focused on health sciences, the Panel recognizes that its findings and recommendations have applicability in many areas of research where science is being carried out in teams.

While the Panel agrees that team science leaders in Canada could benefit from formal training to help them create effective teams of collaborators, manage and mentor participants, and improve research outcomes, the training of team science leaders is beyond the scope of this report.

1.3 METHODOLOGY

1.3.1 Defining *Team Science*

The Panel's first step was establishing a definition of *team science* for its work. Published definitions vary depending on a report's purpose and emphasis. *Team science* has been defined variously as:

- ***Number of participating researchers:*** "Research conducted by more than one individual in an interdependent fashion, including research conducted by small teams [(at least 2, but <10 individuals)] and larger groups [(> 10 individuals)]" (NRC, 2015).
- ***Collaboration of more than one research group:*** "Any team-based research involving two or more research groups [...] that aims to produce an academic publication or other research output" (AMS, 2016).
- ***Collaboration across disciplines:*** The promotion of collaborative and cross-disciplinary approaches to the analysis of research questions (Stokols *et al.*, 2008) or the combination of "specialized expertise, theoretical approaches, and research methods across disciplinary boundaries" (Börner *et al.*, 2010).

To examine team science recognition and reward in the Canadian context, the Panel took elements from each of these definitions and, for the purposes of this report, defined *team science* as:

- *Research that involves significant work by more than one contributor as principal investigator(s), co-investigators, or collaborators, and where the work may be either in a single discipline, in more than one discipline and/or more than one sector.*[1]

The Panel's definition makes it clear that team science may be undertaken by a group of researchers working in the same field, but that it often crosses disciplines and/or spans multiple sectors (e.g., industry, community, knowledge-user). *Interdisciplinary research* is defined as that which "integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge" (Institute of Medicine, 2004). Similarly, *cross-sectoral research* tackles research questions by integrating the knowledge, insight, and experience of researchers in academia with those in other sectors (e.g., community, industry). Many forms of *participatory research* are found in the health sciences. Collaborations may be created among researchers and knowledge-users (e.g., policy-makers, health system managers, clinicians) or among researchers and the intended beneficiaries of the research (e.g., patients, community groups) (Cargo & Mercer, 2008).

1.3.2 Review of the Literature

The Panel chose to take a broad approach and considered a variety of sources, including peer-reviewed publications, government reports and reviews, and "grey" literature.[2] Much of the literature examined came from the emerging field referred to as the *science of team science*, which studies factors that enhance or impede the success of team-based research, as well as team attributes that influence productivity, innovation, and knowledge translation (KT) (Stokols *et al.*, 2008). Since this report's definition of *team science* encompasses single-discipline, multiple-discipline, cross-disciplinary, and cross-sectoral teams, the Panel did not limit its review of the literature to publications about the science of team science. It also included evidence from related research traditions, such as participatory (action) research, engaged scholarship, integrated knowledge translation, and Mode 2 research, among others. Literature on these various approaches was useful and relevant for examining the recognition of team science contributions.

The Panel also relied on two recent international reports to inform discussion: one from the U.S. National Research Council (U.S. NRC) and one from the U.K. Academy of Medical Sciences (AMS). Although their focus differs from that of the Panel, each report includes some relevant material related to the recognition of individuals participating in team science. In the report from the U.S. NRC (2015), the authors focused on the science of team science — the interdisciplinary study of the features that facilitate or impede the success of team-based research. Among other topics, the U.S. NRC report examines how team success can be challenged by individual/team and institutional/organizational dynamics, and how universities and disciplinary societies are traditionally structured to acknowledge individual research contributions rather than team efforts. Impediments include physical and organizational structures that may hinder interdisciplinary initiatives and the evaluation of individual and team contributions to scholarship (including promotion and tenure review) (NRC, 2015). Similarly, the report from the AMS (2016) offers recommendations for researchers, institutions, funders, and publishers to help address barriers to team science, including challenges in documenting research contributions, standards for academic recognition and career advancement, and models of funding that could enhance participation in collaborative research. Importantly, the AMS study points to the lack of recognition of individual contribution as a deterrent to participation in team science.

1 The traditional biomedical research unit (single principal investigator-led laboratory or research group) is considered by the Panel to represent a single contributing entity (sometimes referred to in this report as *individual research*) and does not here represent collaborative research or team science.

2 *Grey literature* refers to various types of documents produced by government, academia, industry, and organizations that are not formally published.

1.3.3 Survey

To better understand the Canadian landscape of recognition practices related to team science, the Panel undertook a survey to explore academic advancement, promotion, and tenure (APT) processes at universities, and evaluation processes at funding agencies. The survey was sent by email to 101 Canadian universities and colleges, including all medical schools and members of the U15. It was also sent to the 43 national and provincial funding organizations that were members of the Forum of Health Research Funders in the beginning of 2016, as well as other key funders such as CIFAR. In the case of universities, the survey was sent to provosts, vice presidents academic and research (or equivalent), deans, associate deans, and some department heads; in the case of funding agencies, it was sent primarily to presidents and vice presidents. Responses were received from 35 universities — including 15 of Canada's largest research universities — and from 28 funding agencies.

The questions used in the university portion of the survey were modelled on those used for the survey described in Falk-Krzesinski (2013). The questions were then modified slightly for the funding agency component (see Appendix for survey questions). The open-ended questions allowed for a wide variation in responses. For example, university responses ranged from a simple "no" on the question of whether institutions have policies, to informative responses on the APT processes of a particular department or university, to observations on how team science is viewed overall. As a result, survey responses did not lend themselves to quantitative analyses; instead, they were treated in the same manner as a call for evidence, whereby all submissions were read in full and common themes were identified. Each entry was then analyzed in light of these themes and observations.

This analysis revealed a significant limitation of the survey: there seemed to be some confusion regarding the term *team science* itself, and the Panel's definition was not always interpreted by respondents as intended by the survey authors (see Section 1.3.1). For example, some funders responded that they do not fund team science, when it has been established that they do, in fact, have team grants. Based on this, the Panel concluded that some respondents did not use terminology the way the survey did and may therefore have provided incomplete or inappropriate responses. A second notable limitation of the survey was that it might not have been representative, since not all funders or universities responded. Given these limitations, the survey results should not be considered definitive or comprehensive, but rather one source of evidence for this report.

1.4 BACKGROUND ON CURRENT APT AND FUNDING PROCESSES

Before exploring the degree to which individual contributions to team science are recognized in Canada, it is important to understand current APT and funding award processes. Although considerable variation exists across institutions in both the criteria and processes that govern decisions on APT and funding in the health sciences (see Chapter 2), the Panel found some common elements and standard approaches.

1.4.1 Universities: APT Processes

APT policies define the academic reward system. In general, candidates seeking tenure or promotion prepare dossiers that detail their contributions to teaching, research and scholarship, and service. Review committees, established to assess these contributions, use a formal set of APT criteria and a well-defined process. Although criteria for tenure consideration vary among universities, the process typically takes place after five to six years in the academic ranks, with promotion through the ranks normally following thereafter.[3]

Practices also vary with respect to the extent of support provided to candidates preparing for the APT process, and to the review committees themselves. Some institutions conduct workshops for candidates to

3 The Panel acknowledges that tenure is not available for some health science researchers, such as physicians, who are instead rewarded with promotion.

help them prepare their dossiers and understand the process, and some offer training sessions for review committee members to ensure the efficacy and consistency of the process. In other institutions, unit heads (e.g., department heads, deans, directors) are supposed to provide this guidance and oversight, and ideally conduct annual pre-tenure assessments to give individuals feedback on their academic progress with respect to APT criteria.

While the composition and mandate of review committees differ across institutions, the candidate's discipline/department peers usually comprise the majority of members, with the balance representing cognate areas. Unit heads also play an important role in the decision-making process, but the nature of that role varies. For example, unit heads may be members or chairs of review committees, or they may provide recommendations independent from those of the committee. In the Panel's experience, review committees often solicit external peer reviews to inform their deliberations when assessing a candidate's work. Finally, committee recommendations are usually advisory, providing an assessment to a senior academic officer of the university (e.g., the provost or equivalent) and/or a university governing body.

APT criteria and processes are established in a variety of ways, but normally with significant input from colleagues within the unit itself. For institutions where academic and research staff are unionized, APT criteria and processes are often referenced in the collective agreement. These provisions, however, tend to be general in nature, with the specifics left to be formally determined at the unit level.

1.4.2 Funders: Evaluation and Award Processes

In Canada, health research is funded by a variety of organizations, some of which focus exclusively on health science (e.g., CIHR, Nova Scotia Health Research Foundation) while others include health science as part of a broader portfolio (e.g., Natural Sciences and Engineering Research Council of Canada or NSERC). Funders include the three federal granting councils (CIHR, NSERC, Social Sciences and Humanities Research Council or SSHRC) and other significant national-level funders, such as the Canada First Research Excellence Fund and CIFAR. Other funders include provincial health research granting agencies, such as Alberta Innovates – Health Solutions and FRQS. Health charities such as the Canadian Diabetes Association and the Heart and Stroke Foundation of Canada, as well as an assortment of private and family foundations, are also part of this structure.

Most of these organizations include grants for multiple researchers in their portfolios, but a few primarily — or exclusively — fund individuals through graduate and post-graduate fellowships and salary support programs for faculty members (generally known as career awards). In some cases, the competitions for these grants are open to both individual researchers and to teams, as is the case with CIHR's Open Operating Grants Programs. In many cases, however, only teams of researchers are eligible to apply for funding. This is true, for example, of CIHR's Partnerships for Health System Improvement, CIFAR's interdisciplinary research programs, and the Tri-Agency's Networks of Centres of Excellence Program. Even in the case of organizations whose funding portfolios emphasize, or are limited to, the funding of groups of researchers, and even when (as with CIHR) these programs are called *team grants*, the term *team science* is rarely used.

1.5 ORGANIZATION OF REPORT

Chapter 2 begins with a discussion of the importance of team science in health research and a summary of the challenges in recognizing an individual's contribution to team science efforts. The challenges are examined through three key lenses that are used throughout the report (see Figure 2.1). Chapter 3 examines recently established and emerging practices that may support improved recognition of individual contributions to team science and seeks to overcome some of the challenges identified in Chapter 2. Finally, in Chapter 4, the report concludes with a list of the Panel's recommendations and action items for moving forward. Throughout the report, the Panel strives to distinguish between challenges and best practices for academic institutions versus funding agencies.

2 CURRENT CONTEXT AND CHALLENGES

This chapter reviews evidence on the value of team science in the sphere of health research. The purpose of this review is to highlight challenges facing both universities and research funders in the evaluation of individual merit within a team science context. Despite growing institutional support for team science in Canada, the practices and processes in place for reviewing applications — be they for promotion and tenure or for funding — remain focused on the individual researcher and have yet to be adapted for researchers working collaboratively in teams.

2.1 IMPORTANCE OF TEAM SCIENCE IN HEALTH RESEARCH

The shift from the individual to the team model in scientific discovery has been happening for decades (Leahey, 2016). The many and varied challenges of complex health-related issues, such as climate change, health equity, and epidemics of chronic diseases, cannot be tackled by individual-based approaches to research (Leahey, 2016). Put simply, many important health issues cannot be addressed by a single discipline or by researchers working in isolation. Several pose unprecedented challenges for the Canadian health system, such as the increasing cost of healthcare delivery, the changing needs of an aging population and of those with more complex illnesses, and structural inequities affecting various segments of the population (i.e., Indigenous Peoples, immigrants and refugees, people with disabilities, and people living below the poverty line).

Large teams have significant impacts on new knowledge and innovation (e.g., Human Genome Project, development of antiretroviral therapies), as a number of studies have concluded (Wuchty *et al.*, 2007; Arbesman, 2010). Teams typically generate more highly cited work (a proxy for high impact) than individually authored papers. In the sciences and engineering, for example, "team-authored papers received 1.7 times as many citations as [individually] authored papers in 1955, but 2.1 times the citations by 2000" (Wuchty *et al.*, 2007). This upward trend seems to be continuing. Wuchty *et al.* (2007) found that team-authored papers (those having more than one author) are now six times more likely than individually authored papers to have received 1,000 citations or more; citation distribution is asymmetrical across disciplines, however, and this statistic may not be as high among health science publications. Compared to individually authored papers, team-authored papers are also more likely to have an optimal combination of conventionality and novelty (a proxy for creativity); papers of this type are cited twice as often as papers lacking either conventionality or novelty (Uzzi *et al.*, 2013).

Funding awarded to research teams also produces better outcomes than funding awarded to individual grantees. According to Hall *et al.* (2012), a study comparing team science initiatives with traditional investigator-initiated grants funded by the U.S. National Cancer Institute demonstrated greater success for the research teams in terms of bibliometric indicators of productivity, collaboration, and impact. These indicators included "number of publications, number of coauthors per publication, and journal impact factors associated with these publications" (Hall *et al.*, 2012). Indeed, when evaluated over the decade following initial funding, team grants have been shown to result in more publications per year and higher cumulative publication rates, outpacing individual investigator publication productivity by year four, despite some teams' initial lag in publication rate (Hall *et al.*, 2012).

Diversity of expertise and perspective also contributes to innovation (Stokols *et al.*, 2008). Some of the important roles in team science projects may be performed outside the academic field and yield a number of benefits. For instance, the growing use of participatory approaches — that is, involving stakeholders from different sectors in research on health services and policy — has shown positive results. Research is more likely to be acted on if potential users are involved in its design in meaningful ways (Landry *et al.*, 2003), and research is also found to be more relevant and of higher quality when all pertinent perspectives are included (Bowen *et al.*, 2016).

One review of participatory research literature identified several potential benefits of promoting culturally and linguistically appropriate research. Such an approach can "enhance recruitment capacity; generate professional capacity and competence in stakeholder groups; increase the sustainability of project goals beyond funded time frames and during gaps in external funding; and create system changes and new unanticipated projects and activities" (Grant *et al.*, 2015). Moreover, Cottrell *et al.* (2014) found that stakeholder engagement in systematic reviews helped with the "identifying and prioritizing of topics for research; providing pragmatic feedback on the research protocol; aiding in recruitment of research participants; helping researchers understand the research subject's perspective; ensuring that findings are interpreted with the end-user in mind and that final products are readable and accessible; and facilitating wider dissemination and uptake of research findings."

The inclusion of policy-makers, managers, practitioners, and patients in teams may be especially important in health research, as the engagement of these groups has been correlated with greater research relevance and with its likelihood of being used (Wooding *et al.*, 2014). Reported benefits of patient engagement include increased study enrolment rates, improved dissemination (i.e., more meaningful and understandable reporting), and more assistance for researchers in obtaining funding, designing study protocols, and selecting relevant outcomes (Domecq *et al.*, 2014). On the practitioner side, Boaz *et al.* (2015) have identified several mechanisms by which the engagement of clinicians and healthcare organizations in research may lead to improved healthcare performance. On the other hand, as shown in Section 2.2, including a range of stakeholders also complicates the research process and creates challenges for defining individual contributions.

Like participatory approaches, inter-institutional and international research collaborations are also becoming more common. Jones *et al.* (2008) demonstrate that collaborations between institutions, particularly top-tier universities, are more likely to have greater impact (i.e., more citations) than in-house collaborations, even those within a top-tier institution. International collaborations can generate additional benefits, including the creation of teams with increased capacity, regional expertise and investment, and the best researchers regardless of geographic location (The Royal Society, 2011). The growth in international collaborations is evident in bibliometric indicators. In 1996, 25% of scientific papers were published by authors from more than one country, rising to 35% (of a much larger total) in 2008 (Smith, 2011). Additionally, publications stemming from international collaborations were more highly cited, with Smith (2011) noting a correlation between the number of citations and the total number of collaborating countries.

Another potential advantage of interdisciplinary and cross-sectoral research teams can be found in the communication and application of research. KT specialists can help ensure that generated knowledge is communicated effectively to various audiences. Giving potential knowledge-users meaningful roles on research teams (known as *integrated knowledge translation*) also helps promote more effective translation of research into practice. These knowledge-users can identify opportunities for knowledge dissemination throughout the research process; help tailor effective messages; and provide guidance on how best to integrate the new knowledge with current practice. Canada, for its part, has a good record of team science projects supported by major funders and resulting in significant impacts (Box 2.1).

Box 2.1: Team Science in Health Research: Canadian Success Stories

Canadian Pharmacogenomics Network for Drug Safety (CPNDS): Adverse drug reactions (ADRs) in childhood cancer treatments are common. For example, anthracycline, frequently used in childhood cancer treatments, can lead to anthracycline cardiotoxicity in more than half of treated children (Smith *et al.*, 2010). ADRs predispose childhood cancer survivors to serious health outcomes in later life. The prediction and prevention of ADRs through pharmacogenomics has tremendous potential for improving treatment outcomes. Founded in 2005 under the name Genotype-Specific Approaches to Therapy in Childhood (GATC) and funded by CIHR, Genome Canada, and CFI, CPNDS is a nationwide team seeking genomics-based solutions to this problem (CPNDS, 2017a, 2017b). The CPNDS team is composed of academic and clinical experts in functional pharmacogenomics, human genetics and genomics, pediatric clinical pharmacology, and pediatric oncology, as well as pharmacists and clinical pharmacologists at children's hospitals across Canada. This interdisciplinary team enrolled pediatric cancer patients from across Canada (and globally through collaboration), clinically characterized patients, identified ADRs, collected biospecimens, and conducted large-scale pharmacogenomic case-control studies. Genomic variation associated with ADR susceptibility was validated through replication and functional/mechanistic assessment with discoveries leveraged into predictive genetic tests. A pilot pharmacogenomic-testing program, funded by Genome BC, was implemented at BC Children's Hospital for all patients undergoing anthracycline treatments (Genome BC, 2017). CPNDS takes a bedside-to-bench-to-bedside approach that encompasses the discovery, validation, and application of pharmacogenomics. This is an excellent example of team science that benefits Canadians. Funding to expand this program throughout Canada is currently being sought.

Canadian Stroke Network (CNS): The CNS has engaged with and supported a range of team science efforts that have improved healthcare in Canada. For instance, prior to 1996, stroke patients admitted to hospital received intravenous fluid and bed rest. In 2002, six years after clot-dissolving drugs were approved, well under 10% of stroke patients in Canada received this highly effective treatment (CSN, 2011a). In response, the CNS partnered with the Heart and Stroke Foundation to develop the Canadian Stroke Strategy (CSN & HSF, 2010). The two organizations worked directly with provincial governments to assist them in adopting "an integrated approach to stroke prevention, treatment, and rehabilitation" (CSN, 2011b). The strategy led to many improvements in stroke care, such as increasing the use of clot-dissolving drugs to 42% in stroke centres in Ontario, which is near the optimum rate (Hakim, n.d.). The new approach has decreased morbidity and mortality associated with strokes in Canada (CSN, 2011a).

Cardiovascular Health Awareness Program (CHAP): The CNS-supported CHAP program brought together medical, population health, and biostatistics researchers, healthcare practitioners, and community organizations and volunteers to try to reduce the risk of stroke for seniors in several Ontario communities (Kaczorowski *et al.*, 2011). The CHAP program took place over 10 weeks and combined education sessions with cardiovascular risk assessment (including blood pressure monitoring that was, with permission, shared with participants' family physicians and pharmacists). This effective program led to 3.02 fewer annual hospitalizations for cardiovascular diseases per 1,000 seniors (Kaczorowski *et al.*, 2011).

2.2 RECOGNIZING INDIVIDUAL PARTICIPATION IN TEAM SCIENCE: THE CHALLENGE

While team science yields many benefits for scientific discovery, it is not without risk for individual team members. The competing interests of the team and the individual may be at odds, and the individual's participation in team science can be accompanied by uncertainties about recognition and reward. One of the greatest disincentives for individual researchers, particularly those in the early stages of their careers, is concern about appropriate personal recognition for contributions made to a team's publications and grant applications (Sellers *et al.*, 2006; Bennett *et al.*, 2010; Kong & Segre, 2010; AMS, 2016), and how this may impede career advancement. Essentially, the problem lies in how to fairly evaluate the research records of APT and funding applicants who have devoted a considerable fraction of their research activities to team science. Researchers, applying either as principal applicants or as co-applicants, and whose CVs are dominated by team science activities (on projects often led by others) run the risk of their contributions being undervalued. This problem can particularly affect specialists, such as biostatisticians, communicators, or bioethicists, whose work is often critical to the success of projects led by others but who rarely get the

FIGURE 2.1 THREE LENSES FOR EXAMINING CHALLENGES RELATED TO RECOGNITION AND REWARD OF INDIVIDUAL MERIT IN TEAM SCIENCE

opportunity to be a principal investigator (PI). The same lack of fairness might also affect researchers who have spent much of their time leading large teams without receiving appropriate credit for those teams' publications, since review committees may, unless instructed to do otherwise, undervalue the importance of the leadership and management skills and other contributions required for these roles.

The factors that hamper the fair evaluation of individual work performed in a team are numerous. They can exist in institutional structures, in the structure of review committees, and within the actual evaluation process itself as set forth by universities and funders. To provide analytical clarity on these factors, the Panel chose to examine them through three lenses: culture and behaviour, review committees, and assessment/evaluation (Figure 2.1).

2.2.1 Culture and Behaviour

In the Panel's view, there appears to be some consensus that the culture of academic institutions tends to place higher value on individual efforts. Prevailing institutional cultures can be slow to adapt long-standing processes in response to emerging research trends. While institutions may stress the importance of team science in their strategic plans, outdated attitudes and practices may persist in some departments, obscuring individual efforts within team projects. The Panel has noted that culture and behaviour have three dimensions: universities are slow to adapt policies; the recognition of individuals working in teams may not be considered to be a problem; and institutions vary in the recognition of individual contributions to team projects.

Universities Are Slow to Adapt Policies and Processes

Historically, universities in Canada and elsewhere have been structured to promote and recognize individual, investigator-driven research rather than support collaboration and interdisciplinary/cross-sectoral research. The common APT evaluation framework categorizes academic contributions as teaching, service, and research but does not explicitly recognize team science or provide criteria against which to assess an individual's contributions to team projects. The "research" designation itself is a potential barrier to appropriate recognition and reward, as often only "discovery" research is valued, leaving many essential team science roles (e.g., team-building, developing partnerships across sectors) either unrecognized or evaluated in the traditionally less prestigious category of "service."

University policies and processes may simply be slow to adapt to non-traditional types of research, which is not unique to team science. For example, researchers have found that, although community-engaged scholarship (one type of team science) has been commonplace in Canada for several decades, APT processes often consider such activity in the "realm of public service, voluntarism and community outreach," as opposed to the "realm of research"; therefore, it receives less institutional support (Barreno *et al.*, 2013). This poses problems for researchers (particularly for early career researchers (Zucker, 2012)) engaged in, or wanting to engage in, non-traditional research (e.g., interdisciplinary or cross-sectoral research) since it may not contribute to academic career advancement (Pfirman *et al.*, 2007; Feder & Madara, 2008; Klein, 2010; AMS, 2016).

The Recognition of Individuals Working in Teams Is Not Considered to Be a Problem in Canada

The Panel's survey of universities provides some indication that most universities do not believe there is a problem with respect to APT evaluation of individual efforts in team science. In fact, only about a quarter of respondents stated that the term *collaboration* appears in their APT documents, and none acknowledged the use of the term *team science*. *Collaboration* in current APT documents is primarily related to discussions about conflicts of interest or how to evaluate the degree or nature of an applicant's work within a collaboration. Indeed, often the criteria merely require that an applicant provide a percentage to indicate their contribution to a publication or grant. A few respondents simply indicated that collaborations are expected or are seen as evidence of good scholarship, but no additional detail was provided.

Similarly, the recognition of individual contributions to team science research does not appear to be a hot-button issue for the Canadian funders that responded to the survey. None of the respondents reported giving serious consideration to the way team science is evaluated in Canada, though a few did acknowledge that some initial discussion had taken place.

In contrast, a survey of 58 U.S. institutions (Falk-Krzesinski, 2013) found a much higher degree of recognition of team science language in policies and guidelines compared to institutions in Canada (perhaps because the definition itself is more fluid in Canada; see Section 1.3.1). The survey revealed that, of the 42 responding U.S. institutions, only 10 did not include any such language. Of the 32 that did include relevant language, three themes emerged: recognition of team science, criteria for evaluating team science, and processes for evaluating team science. Most of the institutions' policies contained some criteria for evaluating participation in interdisciplinary research and/or team science, and included definitions and/or described demonstrations of contributions to interdisciplinary and/or collaborative work.

Institutions Vary in Their Recognition of Team Science Contributions

The importance of department-level evaluation of team science contributions was highlighted by almost three-quarters of university respondents to the Panel's survey, either in direct survey responses or in those universities' APT documents. Overall, survey results indicate that, among universities with significant research programs, there is a general view that team science should be considered and evaluated at the department level because of the differences among disciplines. However, some respondents did identify specific challenges, such as departmental variation, the inherently complicated nature of team science, and fear of failure. As one survey respondent explained:

> "Success has many children while failure is an orphan." Professors self-identify as collaborators in successful (i.e., funded) projects, but there is generally little way of identifying what that really means. It is especially complicated where very large grants and complex clinical trials are concerned.

Although identified only a handful of times, it is likely that these challenges affect most, if not all, universities in Canada. Some respondents identified certain disciplines as being ahead of others in terms of

encouraging collaboration, and suggested that the absence of a university-wide policy may enable departments to discourage collaborations (directly or inadvertently) if they so choose. As another respondent explained, "practices vary from department to department regarding how they address these issues. [...] We have received recommendation letters from committees that praise teamwork and make positive comments about collaborative and joint publications, and then others who criticize lack of sole authorship." Yet another respondent suggested that, while a one-size-fits-all policy for all disciplines would not be effective, "it may be helpful to have a policy directing each department or discipline to have a clear explanation of how scholarly activity within collaborations can be evaluated, and this explanation should be included with each candidate's case where their dossier relies on such scholarly activity."

2.2.2 Review Committees and Processes

Review committees are at the centre of processes for evaluating both APT and grant applications. Their members are tasked with reviewing applicants and assessing the quality of academic contributions both collectively and as individuals. In the Panel's experience, the composition of these committees, together with the training their members receive in evaluating team science applications, determine the ability of a committee to successfully evaluate individual merit in team science projects. The Panel believes that committees lacking appropriate diversity of expertise are not well positioned to assess highly multidisciplinary projects involving different roles within a team, such as practitioners and KT specialists.

The Composition of Review Committees Is Not Always Diverse

Many university respondents to the survey stated that peer committees are the preferred method of ensuring that disciplinary differences are considered in the assessment/evaluation of faculty members for APT. Unfortunately, the survey did not explicitly ask about the composition of these committees. Based on the experience of the Panel, however, these committees tend to be limited to those in the traditional academic/research fields and are often predominantly made up of experts from similar disciplines (e.g., from the same faculty or department).

Research shows that attention also needs to be paid to various forms of potential bias that can intrude on deliberations and evaluations. For example, a 2002 study of CIHR review committees showed that members of committees dealing with fundamental science highlight the track record and productivity of the principal applicant, while committees for health services research focus on research design, methods, and statistics (Thorngate *et al.*, 2002).

Reviewers Generally Receive Little Guidance Specific to Team Science

In general, the Panel found that little formal training or guidance is offered to APT or funding review committees in Canada when it comes to evaluating applicants, including those who engage in team science. There is rarely any direction even on which criteria to use.

Among funders, most survey respondents offering team grants indicated that they specifically advise review committees to examine the credentials of all applicants and in some cases provide copies of these instructions. Not surprisingly, the criteria tend to emphasize the qualifications and performance records of the principal applicants as well as their leadership capabilities. Several respondents indicated that, despite instructions to the contrary, their reviewers usually focus heavily on the qualifications of the principal applicant(s) and may thus underestimate the importance of the qualifications of the other investigators on grant proposals. Many, but not all, of the organizations that fund teams (either within programs explicitly designated for teams or to which both individuals and groups may apply) specifically instruct reviewers to consider the composition of the proposed team, the value added by the collaboration, and whether the team is the right one for the proposed project.

According to the Panel's survey, only a few organizations explicitly direct review committees to consider co-author status on publications. Strong emphasis is placed on first authors, senior (corresponding) authors, or single authors. None of the respondents advise reviewers to consider not just publications but also grants secured by applicants, either as principal applicants or as members of a team. Several of the organizations that urge reviewers to consider co-authored publications acknowledge that these reviewers, especially in some disciplines, may actually not comply with these instructions. Only two organizations instruct reviewers to examine the co-authorship production of individual applicants for personnel and training awards as a way of assessing their aptitude for future collaborative research. One organization offers the same advice to committees reviewing the CVs of principal and co-applicants to its Partnership Grants for teams. More narrowly, only four organizations urge reviewers to examine the co-publication records of applicants for evidence of prior participation in collaborations.

Funders were also asked whether they provide reviewers with specific training for reviewing multi-authored applications. The response was overwhelmingly negative. The survey found that none of these organizations, even the largest ones, appear to have formal training programs for reviewers. Many expect experienced committee chairs to instruct members, while others conduct preliminary conference calls to discuss procedures and, sometimes, to conduct calibration exercises. Many respondents pointed to the guidance materials, scoring guidelines, and grading scales that they distribute to reviewers, noting that instructions and criteria for reviewing grant programs are tailored to that program type.

2.2.3 Assessment/Evaluation

Universities and funding agencies generally use different assessment/evaluation factors and metrics, and often do not take into account the properties that make team science unique. Existing processes developed for more traditional (often single-discipline) research may not adequately evaluate researchers who engage in team science. For instance, participants may play many roles within team science research groups, and different types of outputs may result; these are hard to quantify with traditional metrics. Large teams present the added complication of evaluating attributions — that is, ensuring all participants receive their fair share of credit for the work (i.e., not too little or too much credit) (Shapiro *et al.*, 1994).[4] The assessment/evaluation and recognition of individual efforts to team science projects are, in the Panel's experience, often complicated by the diversity of team roles, challenges with attribution, and a range of possible contributions.

The Range and Variety of Team Science Roles Are Not Widely Acknowledged

Successful team science sometimes relies on the participation of researchers outside of the classical primary investigator role. Teams need content experts, but may also require specialists such as statisticians, bioinformaticians, communicators, and technical experts. These specialists may be members of more than one team but, in the experience of the Panel, are unlikely to be the PI, team leader, or first author on publications. Many of these roles do not align with traditional expectations of discovery research, so these unrecognized contributions may place researchers at a disadvantage in promotion and tenure (Smith *et al.*, 2012). In short, non-PI roles and activities critical to a collaborating team may not be adequately acknowledged by the conventions of author attribution (discussed below), grant reviews, or academic performance evaluations, including tenure and promotion criteria (Curtin, 2008; Klein, 2010; Falk-Krzesinski *et al.*, 2011; Petersen *et al.*, 2011). Some would suggest that roles that do not receive authorship status (e.g., communicating findings to a specific audience) should be considered within the broader framework of appropriate attribution (Scientific Integrity Committee of Swiss Academies of Arts and Sciences *et al.*, 2015).

4 The Panel acknowledges, of course, the irony that the traditional referencing system used in this report does not always highlight the contributions of every author to the cited studies. See Shapiro *et al.*(1994) for an analysis of attribution challenges with respect to multi-authored biomedical research papers.

Author Attribution Can Be a Challenge for Team Members

For many researchers in health science, authorship position can be critical to career advancement, which still relies heavily on evaluations focused on first and last authorship on publications and on lead PI status on grants. While this is reasonable for small research groups, in large teams, author positions of consequence become more difficult to secure, especially for skills specialists or other experts in non-traditional roles. The risk of obscured credit and the threat this poses both to the academic incentive system and to reputation make authorship (and thereby attribution) an important consideration for researchers (Lissoni & Montobbio, 2015). There remain concerns about both the ambiguity of individual contributions and misattributions (which increase as the number of authors increases (Lissoni & Montobbio, 2015)).

Undeserved credit is reported to be widespread (Scientific Integrity Committee of Swiss Academies of Arts and Sciences *et al.*, 2015). In some cases, senior scientists may be listed as authors without having contributed to either the publication or the research on which it was based (e.g., guest publications). In other cases, junior colleagues may ghostwrite an article for which more senior team members get credit. Current systems favour more senior researchers, and more eminent co-authors have been found to receive disproportionately more credit than less eminent co-authors — the so-called *Matthew Effect* (Merton, 1968, 1988). Differences in disciplinary norms for using author order to assign credit can cause additional complications for interdisciplinary teams and may impede team integration. Furthermore, the common practice of awarding funding to the nominated principal applicant on behalf of the team means that only one named researcher benefits from the financial metric, no matter how much researchers in other institutions may have collaborated. No common authorship or attribution system exists at this time.

There are other factors beyond authorship position that may impact how much credit researchers receive for their work. For instance, when a paper is retracted, the citation penalty on eminent co-authors is small, while less eminent co-authors experience large citation declines, especially in those cases where the retracted paper includes an eminent co-author (Jin *et al.*, 2014). Gender has also been found to affect the credit co-authors receive for team publications. In the field of economics, for example, where authors are generally listed alphabetically, it has been shown that men are tenured at approximately the same rate whether they publish as individual author or as a co-author (Sarsons, 2017). This is not the case for women, however, who are less likely to receive tenure (Sarsons, 2017).

Common Metrics Have Significant Limitations When Used for Evaluating Individual Efforts in a Team Science Context

Standard metrics often do not measure knowledge integration, a critical component of successful interdisciplinary research (Wagner *et al.*, 2011). All research metrics have limitations and there is documented concern about the appropriateness of some commonly used metrics (e.g., h-index, journal impact factor) for faculty evaluation (DORA, 2012; Brembs *et al.*, 2013; Herrmann-Lingen *et al.*, 2014; Wilsdon *et al.*, 2015). This is especially true when the limitations are not acknowledged, when a lone metric is proposed for evaluation, or when metrics are used to the exclusion of qualitative indicators. The problem is further exacerbated when metrics or their algorithms are not transparent (van Noorden, 2014).

For many types of research performed in teams (e.g., participatory research), alternative forms of communication (e.g., policy papers, policy briefings) may result in higher readership, greater public scrutiny, and greater likelihood of action than publication in a peer-reviewed journal. Yet the limited palette of publication metrics currently in use does not recognize the many and varied outputs of scientific research (DORA, 2012) (Box 3.2). This can pose a challenge for academics working in teams, since producing alternative communication tools increases workload if findings must also be published in a peer-reviewed journal.

Box 2.2: The Official Languages Challenge in Canada

In addition to those outlined above, there are other factors that can exacerbate the challenges associated with evaluating individual efforts in team science projects. The most notable Canada-specific challenge relates to the fact that, while Canada has two official languages (French and English), in practice English is more commonly used. French-speaking researchers often choose to write funding applications in English due to considerations such as limited reviewer pools; this can create a linguistic disadvantage for some candidates. Language issues are not unique to the assessment/evaluation of team science research, however, and affect the evaluation of grant and APT applications in general.

2.3 CONCLUDING REMARKS

In the area of health sciences, evidence indicates that team science research is generally of higher impact than individually produced research and is required to tackle many of the complex health questions facing Canada today. Indeed, team science is vital for Canada's productivity, innovation, international competitiveness, and its delivery of high-value healthcare. Successful team science relies on the participation of researchers outside of the classical primary investigator role and may include specialists, communicators, and/or the users and beneficiaries of health research outputs (e.g., policy-makers, health leaders, physicians, and patients). This wide scope of inclusion has benefits for many health research projects.

There are, however, challenges associated with proper attribution in team science, resulting in some individuals receiving too much or too little credit. The diversity of team roles, challenges with attribution, and range of possible contributions complicate the recognition of individual efforts in team science projects. The risk of loss of credit makes authorship an important consideration for researchers. In the view of the Panel, the underlying culture and behaviour of universities and many funding agencies also contribute to the risks for individuals participating in team research. Symptoms of this culture are the processes that currently govern advancement at universities and the evaluation of grant applications, most notably the makeup of review committees and the instruction and guidance they are given. If all committee members arrive at the table with the same perspective (e.g., they are from the same discipline), they may not have the background needed to evaluate applications outside their area of expertise. Furthermore, if review committees are not given the tools they need to properly recognize and evaluate team efforts (e.g., training, scoring rubrics), they may fall back on traditional methods and metrics. This hinders the evaluation of team science in APT and funding processes, as such projects may produce a range of contributions beyond peer-reviewed publications. In fact, in some cases, the publication of team science outputs in alternative forms of communication (e.g., policy papers) may result in higher readership, greater public scrutiny, and greater likelihood of action. While assessment/evaluation of team projects that does not translate into traditional metrics is more challenging, ensuring these projects are valued and properly considered will give participating researchers appropriate recognition for their work.

3

RECOGNIZING INDIVIDUAL CONTRIBUTIONS TO TEAM SCIENCE: PROMISING PRACTICES

This chapter identifies practices and initiatives that have or (in the Panel's view) could address the challenges of recognizing individual contributions to team science identified in Chapter 2. These practices, drawn from the relevant literature and documentation, relate to the three dimensions introduced in Chapter 2: culture and behaviour, review committees, and assessment/evaluation. In presenting these promising practices, the Panel acknowledges that there remain significant gaps in available evidence. Few practices have been formally assessed for effectiveness, and several of those identified are simply examples of what could be done. They do, however, demonstrate a need for organizations to reassess APT and funding criteria and to experiment with new assessment practices that involve not just universities and funders but also researchers themselves.

3.1 CULTURE AND BEHAVIOUR

As discussed in Chapter 2, universities and funders have been slow to adapt their evaluation processes to the realities of team science; they have not fully acknowledged that the assessment of individual merit within team science projects is problematic; and there is significant institutional variability in how this assessment proceeds. In the Panel's view, the following practices are promising because they have the potential to recast the system of incentives and support for faculty members who undertake (or are considering undertaking) team science.

Explicit Promotion of Team Science

There is a history of team science in Canada, one that enables the development and promotion of collaborative work among health researchers. For over 20 years, health science teams in Canada have relied on routinely collected population health data to improve healthcare delivery and the function of health systems; to influence policy; and to generate impactful health science. There are many examples of team science research being encouraged and supported by CIHR. CIHR's Partnerships for Health System Improvement (PHSI) program, for instance, supports applied research that will be "useful to health system managers and/or policy makers" (CIHR, 2014). The integrated KT program emphasizes the importance of building teams with a range of skills; these teams often must include experts from multiple disciplines and/or sectors, as well as knowledge-users and/or decision-makers, in the research process. Another CIHR example is the Strategy for Patient-Oriented Research (SPOR), which focuses on research that "engages patients as partners" in the research process in order to improve the quality and accessibility of healthcare (CIHR, 2016b). Research is done by interdisciplinary teams working with cross-sectoral partners (e.g., policy-makers, clinicians) to ensure relevant learning is applied in practice. As a final example, CIHR's Open Operating Grant Program accepts applications that include multiple principal applicants (CIHR, 2016a). Furthermore, knowledge-users may be a nominated principal applicant provided there is another principal applicant who is an independent researcher.

The Panel has seen many Canadian universities identify collaborative research as a goal in their strategic plans and policies. In order to transcend traditional disciplinary departmentalization, many universities have established interdisciplinary research institutes and programs. In some cases, this has resulted in the creation of shared facilities for teaching and research, which gather experts from many disciplines in order to facilitate new collaborations. For example, Western University now identifies "leadership through interdisciplinary research" as one of the five core principles guiding their research mandate (Western University, 2016). The university also continues to support its Brain and Mind Institute and National Centre for Audiology; the former includes researchers from a range of disciplines (e.g., music, medicine, business) who are "advancing understanding of cognitive neuroscience," while the latter is both interdisciplinary (e.g., audiology, computer science) and engaged in cross-sectoral partnerships with government and industry (Western University, 2016).

A growing number of universities worldwide are taking steps to promote team science. For instance, in a review of APT policies from over 30 NIH-funded Clinical and Translational Science Awards (CTSA) institutions (Falk-Krzesinski, 2013), over half "highlighted the significance and prevalence of collaborative and/or cross-disciplinary scholarship in advancing science, and the need to consider such scholarship in [APT] decision-making." Select policies noted the "significance and prevalence of Team Science in advancing science; the recognition of the need to consider Team Science in [APT]; [...] encouragement for faculty to pursue Team Science; [and] the inclusion of Team Science in [the] definition of scholarship/excellence." One such policy at Case Western Reserve University stated the following in 2006:

> While the evaluation of research accomplishment has traditionally focused on the faculty member's individual achievements, including first and senior authorships and funding as principal investigator, the present and future of science will place increasing emphasis on interdisciplinary research team science. Where relevant, therefore, a faculty member's contributions to interdisciplinary research and team science shall also be considered. (Falk-Krzesinski, 2013)

Other examples can be found in the United Kingdom. For instance, the U.K. Networks in Industrial Biotechnology and Bioenergy are 13 collaborative networks that "foster collaborations between academia, industry, policy makers and NGOs" in order to develop biological resources for a range of uses (e.g., biopharmaceuticals, energy) (Networks in Industrial Biotechnology & Bioenergy, 2017). As of October 2016, the networks collectively represented more than 2,600 academic members and had engaged with almost 750 companies. A further example is the Usher Institute of Population Health Sciences and Informatics at the University of Edinburgh Medical School, which brings together experts from multiple science, health science, and social science disciplines (e.g., public health, epidemiology, statistics, sociology) in order to conduct "transformative research, education, and knowledge exchange" related to healthcare (Usher Institute of Population Health Sciences and Informatics, 2017). The Usher Institute publishes on topics such as the risk factors for disease, communication methods in primary care, and Google trends related to health topics, to name a few (University of Edinburgh, 2017).

Funders, for their part, have the potential to change institutional culture by providing frameworks that encourage the development of multi-institutional research and team science. A well-established example, FRQS, has been supporting health-focused research groups and networks since 1994. These networks bring together researchers from multiple disciplines and across sectors — including universities, healthcare facilities, and industry — to address research priorities. This structure has fostered a province-wide culture of health research collaboration and has made Quebec researchers competitive beyond the province (FRQS, 2017). Alberta Innovates – Health Solutions is another strong example of a provincial funding network that supports collaborative health science innovation and an impactful culture of knowledge sharing.

Commitment to Scholarship Instead of Research

Another promising practice is adapting policies and processes to recognize individual contributions to team science, and by extension encourage researchers to participate in collaborative research. Practitioners of various types of team science have argued that reframing *research* as *scholarship* facilitates validation of the non-traditional contributions and research roles that are often part of team science (CAHS, 2005; Hofmeyer *et al.*, 2007; Pfirman *et al.*, 2010; Saltmarsh *et al.*, 2014). Perhaps the most recognized scholarship model emerged from the field of engaged scholarship in a 1990 Carnegie Foundation report, authored by Ernest Boyer (Boyer, 1996). The report concludes that the definition of scholarship should be broadened to include four separate but overlapping areas of scholarly activity: "the scholarship of discovery, the scholarship of integration, the scholarship of application, and the scholarship of teaching" (Boyer, 1990).

Some Canadian universities have responded to this call. For example, in 2006, the University of Manitoba's Faculty of Medicine adopted Boyer's model to recognize the diversity of scholarly activity among its academic staff (as illustrated by the supplement to their most recent guidelines for promotion and tenure (University of Manitoba, n.d.)). In practice, a broader definition of *research/scholarship* would benefit most researchers, as many of the challenges of current APT evaluation are relevant beyond team science (CAHS, 2005).

Institutional Reform

Evidence suggests there is a need for institutional change that goes beyond promoting team science if team science is indeed to be fostered. Jeschke *et al.* (2016), for example, point to a need for re-evaluating departmental structures and policies and implementing professional development and mentorship programs that support collaborative research. A recent example of comprehensive structural change that promotes team science occurred at the Division of Blood Diseases and Resources in the U.S. National Heart, Lung, and Blood Institute. The institute was reorganized from a disease-focused structural model to one that promotes the creation of cross-disciplinary teams and partnerships within and beyond the institute (Brzakovic & Cozzens, 2014; Hoots *et al.*, 2015; Hoots, 2016).

3.2 REVIEW COMMITTEES AND PROCESSES

As discussed in Chapter 2, review committees can impede the fair evaluation of team science when its members lack the breadth of knowledge necessary to review applications, and when they have been given little guidance on how best to evaluate individuals involved in team science projects, be it for promotion or for grant purposes. The following practices and initiatives have the potential to address these challenges.

Diversifying Review Committee Membership

Reviews of team science proposals require specific considerations frequently absent in the adjudication of single-investigator proposals. Experience that goes beyond single-discipline content expertise is often required. When a review committee examines team science proposals that comprise researchers from different disciplines, the committee's membership should reflect the knowledge and skill sets of the researchers whose proposal is being reviewed (NRC, 2015). Doing so may require the inclusion of committee members from outside the university (and possibly academia) and from various knowledge communities, who can provide essential skills (Jordan *et al.*, 2011; Gelmon *et al.*, 2013). In many cases, it may be most appropriate to set up interdisciplinary review committees, already a common practice and one of the approaches cited by the European Science Foundation (ESF) as improving the quality of peer reviews (Box 3.1). In addition, the active participation and engagement of knowledge-users or beneficiaries provide critical skills when reviewing health services research proposals.

Developing Guidelines

Both the National Science Foundation (NSF) and the ESF highlighted the importance of education and guidance for review committee members. Falk-Krzesinski (2013)'s review of APT policies from over 30 NIH-funded CTSA institutions found that close to half of the institutions

Box 3.1: Use of Interdisciplinary Review Committees in Europe

The European Science Foundation (ESF) surveyed 30 research-funding organizations from 23 European countries about organizational best practices in peer review. (The survey was related to interdisciplinary[5] research proposals, and therefore only relevant for one type of team science.) The ESF survey asked how organizations dealt with interdisciplinary proposals. Eighty percent of respondents reported that they received interdisciplinary proposals all the time (23%) or regularly (57%). Most funders asked applicants to identify their proposals as interdisciplinary, but they also relied on staff and reviewers to identify such proposals. Funders supported the evaluation process of interdisciplinary applications in a variety of ways. The most common (70%) was identification of interdisciplinary reviewers. The second most common approach (54%) was to ask committees familiar with the discipline in question to review the proposal. Forty-three percent of funders reported setting up ad hoc interdisciplinary review committees and 33% reported setting up a standing interdisciplinary review committee. Organizations with specific calls for interdisciplinary proposals relied principally on the use of interdisciplinary reviewers (82%), interdisciplinary review committees (82%), and specific criteria for interdisciplinary proposals (73%).

The ESF found that the creation of ad hoc interdisciplinary review committees populated with interdisciplinary reviewers, coupled with the development of specific criteria for the assessment of these proposals, was effective in improving the quality of the reviews. Notably, the creation of an external interdisciplinary reviewing committee was highly effective.

(ESF, 2011)

5 *Interdisciplinary research* refers to multi-, inter-, and trans-disciplinary research. Interdisciplinary research proposals clearly require expertise from different broad disciplinary domains.

(16 of 33) provided varying levels of information about the process of evaluating team science, such as guidelines for faculty on how to prepare dossiers that demonstrate the significance of their contributions to science teams; models of CVs, candidate statements, and letters from collaborators; explicit guidelines to committee members on how to review the dossier materials; and general guidelines on the importance of reviewing these sources of evidence for contributions to team science.

According to respondents to the Panel's survey, funders in Canada often do provide written materials to guide reviewers. As these materials are generally designed with the characteristics of each specific competition in mind, there is an opportunity to tailor guidelines to ensure team science is evaluated appropriately. Changes to guidelines and processes need to be clearly communicated to review committees so they have the tools needed to consistently apply the chosen criteria. In some cases, having different resources and/or training available for different types of reviewers (e.g., from different disciplines and sectors) may be appropriate. Additionally, instructing APT committee members about concepts and principles related to the various expressions of team science, and the limitations and pitfalls of commonly used metrics, may — in the Panel's view — encourage reviewers to adopt new approaches to evaluation.

3.3 ASSESSMENT/EVALUATION

As discussed in Chapter 2, many roles essential to team science are not fully acknowledged in standard metrics, authorship attribution is often difficult, and standard metrics can have significant limitations when relied on for evaluating team science projects and related contributions. Concerns about the misuse of metrics are not unique to team science and have led to the development of principles for ensuring review committees are not basing evaluations on quantitative indicators alone (Box 3.2). Several institutions are pioneering new approaches, with no single approach having yet emerged as a best practice.

Box 3.2: The Leiden Manifesto

Concerns over the misuse of metrics in research evaluation led to the creation of the Leiden Manifesto for research metrics, published in *Nature* in 2015. The Manifesto proposes 10 principles intended to address problems brought about by "evaluation [being] led by the data rather than by judgement." The authors of the Manifesto posit that the principles would allow "researchers to hold evaluators to account" but also support evaluators in holding "indicators to account." While these principles aim to solve problems related to research evaluation in general, many are particularly relevant to the challenges of evaluating individual efforts within team research. For instance, the principles recognize the importance of locally relevant research, which encourages projects that include local stakeholders outside academia. They also suggest measuring performance against the goals of the project, which would help ensure there is recognition of outputs beyond articles in peer-reviewed journals.

(Hicks *et al.*, 2015)

Broadening the Criteria for Evaluating Team Science

Institutions have expressed interest in developing new and broader criteria for assessment processes that take into account not just team science contributions but all research contributions — whether they be patents, policy papers, evaluation reports, specialized tools, or information systems (Gusic *et al.*, 2014). For team science, the goal is to recognize and reward individual contributions in a way that encourages researchers to participate in team research (Beebe, 2016).

In a U.S. study of universities with NIH-funded CTSA Program Hubs, the majority of institutions (27 of 33) included varying levels of criteria for evaluating team science, such as criteria for evaluating participation in team science; definitions and/or described demonstrations of contributions to team-based work; and expectations and requirements in terms of authorship, publications, and grants. Specifically, policies included "demonstration of contributions; demonstration of unique/original/independent contributions; discussion of authorship/credit; guidelines for 'counting' collaborative work; demonstration of leadership in collaborative work; [and] demonstration of impact of collaborative work" (Falk-Krzesinski, 2013; NRC, 2015).

The Mayo Clinic has developed specific team-science-focused criteria for appointment and promotion (Box 3.3), adding them to more traditional metrics of scholarship. These criteria adopt a portfolio approach to evaluating faculty members, in a way that recognizes citizenship, teaching, mentoring, and fiscal responsibility (Beebe, 2016). Team science participation is now one of seven indicators of high-quality research: participation in extramural meetings/presentations; extramural service in peer review; awards and recognitions; innovation/invention/translation; extramural funding; publications; and team science. The Mayo Clinic's indicator related to team science requires that "there is individual traceability of the unique contributions made by the candidate and [that] those contributions were essential to the success of the research endeavor as a whole" (Beebe, 2016). Submitted evidence for APT consideration at the Mayo Clinic:

- clearly acknowledges the distinct, essential contributions made by the candidate, including authorship or collaboration;
- may be traditional grants and publication expectations, where one is able to clearly articulate the importance of the role (e.g., seminal contribution), identify distinct intellectual contributions to the advancement of the project, or emphasize the candidate's role in funding and/or publication using a hierarchy of contributions (e.g., major, minor, supportive), where major contributions are expected; and
- may also be based on less traditional research metrics, such as major changes to the practice, technical materials, or committee roles.

Among funders, another promising development is the inclusion of more than one PI in application processes, allowing team science researchers to receive more credit. For example, while it is necessary to have a designated PI for CIHR team grant applications, it is possible to name multiple PIs

Box 3.3: The Mayo Clinic's Criteria for Team Science Roles

The Mayo Clinic has developed team-science criteria based on the appointment levels of staff. At the Associate Professor level, the criterion is: "Potential for success in developing new or independently engaging in team science initiatives as an essential collaborator or author." At the Professor level, it is: "Evidence of sustained team science; key contributions across multiple multidisciplinary initiatives that span a broad array of teams."

The criteria further distinguish between *essential collaborator* and *principal investigator*: "An essential collaborator is a person engaged in a study with a title other than Principal Investigator or Co-Principal Investigator [who] provided substantial and essential contributions to the design and execution of a grant, research protocol or other scholarly activity." They also define *essential author* as opposed to a *lead* or *senior author*: "An essential author is an author who is not a first or senior author but who provided substantial and important methodologic contributions such as study concept, design, generation, analysis, interpretation of data to the publication and was a major contributor to the writing of the paper."

(Beebe, 2016)

who are responsible for different aspects of the grant, as well as collaborators and clinical associates. The NIH created a multiple-PI model for a large number of its funding mechanisms over a decade ago (NIH, 2011b). The multiple-PI model supplements the traditional single-PI model, allowing applicants and their institution(s) to identify more than one PI on a single grant application. As explained by NIH (2011b), "the goal is to encourage collaboration among equals when that is the most appropriate way to address a scientific problem." NIH (2011a) also explains:

> The [multi-PI] option presents an important opportunity for investigators seeking support for projects or activities that require a team science approach. This option is targeted specifically to those projects that do not fit the [single PI model], and therefore is intended to supplement and not replace the traditional single [PI model]. The overarching goal is to maximize the potential of team science efforts in order to be responsive to the challenges and opportunities of the 21st century.

Recognizing Leadership and Collaboration

From what the Panel has observed, several policies now recognize leadership as a criterion in the evaluation of team science applications. Some funders are developing applications that include sections specifically dealing with management and leadership, which puts the onus on teams to demonstrate a collaborative ability to reach intended outcomes. The NSF suggests that teams develop a formal charter or agreement that describes the roles and responsibilities of each member and the organizational and leadership structure of the team (NSF, 2017).

When the NIH implemented the multiple-PI option, it simultaneously expanded its core proposal review criterion for multiple-PI grant applications: "If the project is collaborative or [multi-PI], do the investigators have complementary and integrated expertise; are their leadership approach, governance and organizational structure appropriate for the project?" (NIH, 2014a). More recently, a number of grant-funding opportunity announcements include specific and detailed guidance on the review and evaluation of leadership in team science proposals. Below are examples of questions from the guidelines of three different NIH programs:

- "Will this team of investigators contribute unique skills to the overall [Network]? Are the [PI(s)] and support personnel adequately trained and qualified for participating and managing multi-institutional collaborations? [...] Are there adequate plans for effective interaction and coordination with the other Network units, the Steering Committee, and the NCI?" (NIH, 2014a).

Box 3.4: Leadership and Teamwork in CIFAR's Application Review

The process for selecting new CIFAR teams is involved and can take over a year, starting with a call for letters of intent (LOIs). The LOIs are submitted by a core group of researchers (usually fewer than half a dozen), who briefly describe the goals of their project, show how their project addresses a question of importance to the world, and demonstrate the need for a global network of outstanding researchers to tackle the challenge. The criteria for selection explicitly include the requirement for a team approach (all successful networks have been interdisciplinary). CIFAR frequently funds workshops for the development of proposed research programs, and these workshops include Canadian and international scholars. The LOIs are then evaluated by panels of highly esteemed international and interdisciplinary researchers. Successful proposals become research programs.

Once a program starts, researchers are selected to complement the initial group of applicants. In addition to individual research excellence, which is a requirement for all members of a given program, the selection criteria measure how a researcher adds strength to the team, brings in different skills and viewpoints, and demonstrates an ability to collaborate. Thus, while individual excellence is a necessary requisite, it is not sufficient. Potential new members are usually invited to one or more regular program meetings so existing members can judge how well nominees fit in with the group. One to three program meetings are held yearly, as sustained interaction among members is a critical feature of CIFAR programs, one that clearly promotes team science.

- "Is the range of expertise of the investigator team sufficient to facilitate the conduct of high-impact research related to the cancer screening process? Are representatives of key disciplines appropriately represented in the team? What is the experience of the participating investigators in large-scale collaborative research in community healthcare settings?" (NIH, 2016).
- "How well do the proposed interactions and collaborations between the Center [PI(s)], Project Leads, and other key personnel unite the components and advance the science of the Center? How well does the proposed Center support and nurture a team science environment that can lead to important advances in cancer research through physical sciences perspectives and approaches?" (NIH, 2014b).

CIFAR also provides an example of supporting team science collaboration. The CIFAR model, which has been applied to a diverse range of research questions, offers long-term support for an international, interdisciplinary team of leading researchers focused on a specific area of global importance. CIFAR funding provides full support for two to three in-person program meetings per year for each research team, where ideas can be openly discussed and refined. It also offers a small, unrestricted research grant each year to most program members. As Box 3.4 highlights, CIFAR places high importance on an individual's demonstrated ability to collaborate when putting together teams for multidisciplinary programs.

Recognizing Non-Traditional Roles

The consideration of non-traditional roles in the APT process may also have a positive impact on the recognition of team science efforts. One method that may support the identification of non-traditional roles is the CRediT contributorship project taxonomy, which identifies a schema of 14 different roles (each with 3 levels) of contributions to publication (Brand *et al.*, 2015; CASRAI, 2017). The schema recognizes team roles related to conceptualization, software, visualization, review and editing, and project administration, among others, and clarifies whether these roles were lead or supporting in a given project (Box 3.5).

Box 3.5: CRediT Contributorship Project Taxonomy: How a Paper Is Cited

TERM	DEFINITION
Conceptualization	Ideas; formulation or evolution of overarching research goals and aims
Methodology	Development or design of methodology; creation of models
Software	Programming, software development; designing computer programs; implementation of the computer code and supporting algorithms; testing of existing code components
Validation	Verification, whether as a part of the activity or separate, of the overall replication/ reproducibility of results/experiments and other research outputs
Formal Analysis	Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data
Investigation	Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection
Resources	Provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools
Data Curation	Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later reuse
Writing – Original Draft	Preparation, creation and/or presentation of the published work, specifically writing the initial draft (including substantive translation)
Writing – Review & Editing	Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision — including pre- or postpublication stages
Visualization	Preparation, creation and/or presentation of the published work, specifically visualization/ data presentation
Supervision	Oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team
Project Administration	Management and coordination responsibility for the research activity planning and execution
Funding Acquisition	Acquisition of the financial support for the project leading to this publication

Taken from: Brand *et al.*, 2015

The following examples show (1) attributions for a recent *Cell Press* paper and (2) a version revised to include the CRediT taxonomy (example from CellPress, n.d.):

1. Original: S.C.P. and S.Y.W. conceived and performed experiments, wrote the manuscript, and secured funding. M.E., A.N.V., and N.A.V. performed experiments. M.E.V. and C.K.B. provided reagents. A.B., N.L.W., and A.A.D. provided expertise and feedback.

2. Revised: Conceptualization, S.C.P. and S.Y.W.; Methodology, A.B., S.C.P., and S.Y.W.; Investigation, M.E., A.N.V., N.A.V., S.C.P., and S.Y.W.; Writing – Original Draft, S.C.P. and S.Y.W.; Writing – Review & Editing, S.C.P. and S.Y.W.; Funding Acquisition, S.C.P. and S.Y.W.; Resources, M.E.V. and C.K.B.; Supervision, A.B., N.L.W., and A.A.D.

The CRediT taxonomy has been adopted by the Consortia Advancing Standards in Research Administration (CASRAI), an international non-profit membership initiative led by research institutions and their partners. These partners include the Wellcome Trust, Open Researcher and Contributor ID (or ORCID, a non-proprietary alphanumeric code that provides unique identifiers to academic authors and contributors), and about a dozen publishers to date. An initial assessment of the CRediT taxonomy by researchers at Université de Montréal and elsewhere showed that first and last authors usually contribute to more tasks than middle authors (Larivière & Desrochers, 2016). It is still unclear, however, whether each contribution within the CRediT schema is properly recognized or whether bias still exists towards certain positions in the reference list.

Another emerging contributorship schema is one used by OpenVIVO, an application that "enables the discovery of researchers across institutions" (OpenVIVO, 2017). The OpenVIVO schema includes almost 60 separate and more detailed roles than those listed in the CRediT schema, including those related to data creation and sharing, educational material development, and funding acquisition for a project. The OpenVIVO contributorship taxonomy is intended to apply to published works, preprints, and other scholarly output.

Both the OpenVIVO and CRediT taxonomies are appropriate for basic life sciences and biomedical research. They both, however, lack clinical research, health services, and community engagement roles, and are thus incomplete in terms of recognizing the full slate of roles in team science across health, life, and biomedical science research. Furthermore, how assessors will interpret the contribution of the different roles within these two taxonomies has not yet been fully evaluated. Nonetheless, these taxonomies — or other agreed-upon standards for authorship and attribution — support individual researchers by acknowledging their contributions in a format that can be recognized by APT committees and funders. The AMS and Science Europe's Scientific Committee for the Life, Environmental and Geo Sciences have each recently made similar recommendations to researchers, publishers, and funders about identifying individual contributions to team science (AMS, 2016; Science Europe, 2016).

Developing a Range of Quantifiable Metrics: Traditional and Altmetrics

There exists a range of research metrics at multiple levels for faculty evaluation (e.g., researcher/author, article, journal, institutional ranking). These rely on both traditional bibliometrics and emerging altmetrics (Priem *et al.*, 2010; Bornmann, 2014), each with its own uses and limitations. Because output production and citation patterns vary significantly across disciplines and sub-disciplines (Wilsdon *et al.*, 2015), not all metrics are appropriate for all fields and nor is it always possible to compare researchers across disciplines. Outputs of scientific research are diverse and they all deserve to be recognized. These include "research articles reporting new knowledge, data, reagents, and software; intellectual property; and highly trained young scientists" (DORA, 2012).

The San Francisco Declaration on Research Assessment (DORA) states that researcher evaluation should rely on the use of quantitative, metric-based input alongside qualitative, expert, opinion-based input (DORA, 2012). DORA's general recommendation is that journal-level metrics should not be used "as a surrogate measure of quality of individual research articles, to assess an individual scientist's contributions, or in hiring, promotion, or funding decisions" (DORA, 2012). DORA recommends instead that institutions and funders use explicit criteria in decision-making and measure the importance of a paper's scientific content rather than rely on its publication metrics or the reputation of the journal in which it was published. DORA also

recommends that research assessment be based in part on "the value and impact of all research outputs (including datasets and software) in addition to research publications, and [the consideration of] a broad range of impact measures including qualitative indicators of research impact, such as influence on policy and practice." As of March 2017, DORA had over 800 organizational and 12,500 individual signatories (DORA, n.d.).

In the foreword to a recent U.K. report, "The Metric Tide: Report of the Independent Review of the Role of Metrics in Research Assessment and Management," Chair James Wilsdon wrote:

> Yet we only have to look around us, at the blunt use of metrics such as journal impact factors, h-indices and grant income targets to be reminded of the pitfalls. Some of the most precious qualities of academic culture resist simple quantification, and individual indicators can struggle to do justice to the richness and plurality of our research. [...] Metrics hold real power: they are constitutive of values, identities and livelihoods. How to exercise that power to positive ends is the focus of this report. (Wilsdon *et al.*, 2015)

The report identifies 20 specific recommendations for further work and action by stakeholders across the U.K. research system. In the Panel's estimation, these recommendations offer a starting point for the development of appropriate metrics for the Canadian system. Some of these recommendations relate to the use of "responsible metrics," discussed further in Box 3.6.

To prevent bias and to discourage undesirable behaviour, the quantitative metrics aspect of evaluation should not rely on a single metric, and selected metrics should be transparent and reproducible (Wilsdon *et al.*, 2015). There is growing awareness of this problem (Box 3.2) and team science researchers are developing new evaluation metrics for team science processes and outcomes (Börner *et al.*, 2010; Falk-Krzesinski *et al.*, 2010, 2011) while new and more specific collaboration metrics are being used by data providers to complement traditional individual output metrics. For instance, Elsevier's SciVal institutional research performance solution includes metrics related to the degree of institutional collaboration on publications (for which there are four categories: *single authorship, institutional collaboration, national collaboration,* and *international collaboration*) and the identification of collaborations with the private sector (i.e., *academic-corporate collaboration metric*) (Colledge & Verlinde, 2014).

Box 3.6: Dimensions of Responsible Metrics

Responsible metrics [is proposed] as a way of framing appropriate uses of quantitative indicators in the governance, management and assessment of research.

Responsible metrics can be understood in terms of the following dimensions:

- **Robustness:** basing metrics on the best possible data in terms of accuracy and scope;
- **Humility:** recognising that quantitative evaluation should support — but not supplant — qualitative, expert assessment;
- **Transparency:** keeping data collection and analytical processes open and transparent, so that those being evaluated can test and verify the results;
- **Diversity:** accounting for variation by field, and using a range of indicators to reflect and support a plurality of research and researcher career paths across the system;
- **Reflexivity:** recognising and anticipating the systemic and potential effects of indicators, and updating them in response.

Taken from Wilsdon *et al.*, 2015

Beyond a range of possible research outputs, there are also many impacts these outputs may have besides citations in peer-reviewed journals. This is true now more than ever thanks to the internet and social media. Metrics used to evaluate research must reflect the evolution of output dissemination and impact (e.g., Twitter's reach). One response to the demonstrated limitations of commonly used journal metrics has been the promotion of *altmetrics*, "an approach to uncovering previously invisible traces of scholarly impact by observing activity in online tools and systems" (Priem, 2014). As summarized by Wilsdon *et al.* (2015), "from the mid-1990s, as advances in information technology created new ways for researchers to network, write and publish, interest grew in novel indicators better suited to electronic communication and to capturing impacts of different kinds." The 2010 Altmetrics Manifesto recognizes that the internet and social media are changing how information is disseminated, that this has advantages for reaching diverse audiences, and that the definition of *impact* and the metrics used to measure it must be broadened (Priem *et al.*, 2010).

Many potential publication/dissemination/impact metrics have been suggested. These include "web citations in digitised scholarly documents (e.g. eprints, books, science blogs, or clinical guidelines) and [as mentioned above] *altmetrics* derived from social media (e.g. social bookmarks, comments, ratings, and tweets)" (Wilsdon *et al.*, 2015). Wilsdon *et al.* (2015) acknowledge altmetrics' limitations and risks (particularly gaming, bias, and quality control), but these limitations and risks also apply to traditional citation metrics. There will always remain a need to explore the qualitative data behind quantitative metrics (Konkiel *et al.*, 2016). Furthermore, quantitative metrics, no matter how carefully chosen, cannot replace narrative reporting (Wilsdon *et al.*, 2015).

Some undervalued contributions may apply equally to individual and team researchers. For example, Cantor and Gero (2015a) propose an R-index to quantify the contributions of academics undertaking the important work of peer review. As explained by the authors in a summary post:

> The R-index aims to track scientists' efforts as reviewers, accounting not only for the quantity of reviewed manuscripts, but also the length of the manuscripts as a proxy for effort, impact factor (IF) of the journal as a proxy for standing in the field, and, perhaps most importantly, a quality score based on the editor's feedback on the punctuality, utility and impact of the reviews themselves. The quality control built into R-index allows editors to quantify how useful the review was to the decision to publish, but also on how constructive the commentary was for the authors, and what should be the most basic of all courtesies, if it was returned on time.
>
> (Cantor & Gero, 2015b)

The Role of Researchers and the Standardization of Data Collection

While many initiatives for responding to the team science assessment challenge fall to universities and funders, researchers themselves also play an important role in ensuring that their team science contributions are properly recognized. Research identifiers are one way to ensure that contributions are recognized and attributions are accurate. These identifiers rely on digital databases that link unique, persistent researcher identifiers with their research output (e.g., ORCID ID) (Haak *et al.*, 2012), improving attribution accuracy by allowing multiple authors to link to a single publication to identify their contribution.

The potential of ORCID was recognized by the AMS (2016), which recommended that:

- "Researchers should obtain an ORCID ID and link it to all their research activities."
- "Publishers should ensure that publications include ORCID IDs for any associated inputs and outputs."
- "As publishers do for publications, data and software repositories should also link to ORCID" and
- "Funders should develop and use publically accessible grant information databases, wherein each record is linked to ORCID."

The scope of existing digital registries is continually improving but does not yet capture all research disciplines with equivalent thoroughness. These registries do, however, represent an opportunity to develop a universally available standardized format for representing each researcher's activities and output, one that would be useful to funders and APT committees (Frische, 2012).

3.4 CONCLUDING REMARKS

The Panel found that, while no widely accepted approach for evaluating team science contributions and applications has yet emerged, there are nonetheless several promising practices that can be embraced by universities, funders, and even researchers. A multifaceted commitment to experimenting with promising practices (such as those identified in this chapter) is needed at the level of organizations, review committees, and applications for funding and APT.

4

CONCLUSIONS AND RECOMMENDATIONS

Team science is vital to Canada's research efforts, as many advances and innovations in all types of science now require a team-based approach. This is also true for health research, which is increasingly complex and multidisciplinary. Overall, Canada has been very successful in team-based research. It is clear, however, that properly recognizing individual contributions to teams requires academic and research institutions and funders to rethink how these contributions are assessed. Organizations must explicitly recognize contributions both to team science and to individual investigator-driven research. Both are valuable forms of scholarship for faculty members in Canada, and both are required to advance health science research. The Panel's 12 recommendations below reflect this reality and suggest ways to better acknowledge the contributions of individuals to research teams. Much is at stake, both for individual researchers themselves and for our national capacity to embrace the indispensable domain of team science.

Assessment for promotion and tenure at Canadian academic institutions generally has not changed much in recent years. Tenure and promotion are assessed in terms of an individual's contribution in three domains: research, teaching, and service. The research domain is crucial in candidate evaluations, with research often conceptualized narrowly to emphasize single-investigator, university-based research. Contributions to teams and various forms of collaborative research are often categorized as *service* rather than *research*. There is often a significant gap between an institution's stated support for team science and its actual practice. There is also widespread concern among researchers that the current evaluation system does not recognize or value the diversity of skills and contributions required for participatory research such as team science. As a result, assessment efforts by APT committees tend to fall back on traditional metrics and approaches that are often unsuitable for assessing team efforts. For many researchers, these practices can be significant disincentives to their participation in team science.

Barriers and disincentives similar to those presented above also apply to many Canadian funding agencies and programs. Review committees rarely receive much formal training before members begin their work, especially around assessment criteria for evaluating team applications or team-based contributions on applicant CVs. Review committees often lack representation from the appropriate range of disciplines required to assess the contributions of researchers to team science. Moreover, many reviewers are unfamiliar with multidisciplinary research, or research conducted in partnership with various health system sectors and the diverse nature of the contributions required for its success.

The Panel strongly believes that we cannot be satisfied with merely adjusting existing team science policies or with other incremental changes. Change is required not only in the policies of our universities and funding agencies but in the institutional cultures in which they operate. Nor will changes made at a few universities and funders suffice. **If Canadian health research is to avoid being left behind, a nationwide demonstrated commitment to the following**

recommendations is needed from universities, funders, APT committees, and award selection committees. Without such leadership, the recommendations are unlikely to be implemented, and researchers' contributions to team science will continue to be undervalued and inadequately measured. These recommendations will facilitate the appropriate recognition of individual contributions to teams and help promote the full participation of Canada in global team science.

In keeping with the structure of Chapters 2 and 3, the recommendations are aligned with the three key lenses through which the Panel examined team science: culture and behaviour, review committees, and assessment/evaluation. Each recommendation is flagged for its relevant actor(s): universities, funders, and/or researchers themselves.

4.1 RECOMMENDATIONS TO ADAPT CULTURE AND BEHAVIOUR TO TEAM SCIENCE

Recommendation 1

Promote a broader concept of scholarship and a more inclusive understanding of the complexity of team science.

A broader conception of scholarship will help ensure that the diverse skills and contributions necessary for team science are recognized by both university APT committees and funding agencies. As noted in Chapter 3, one approach is to use Boyer's more complex typology of categories of academic work (*discovery, integration, application,* and *teaching*) to replace the current typology used by most Canadian universities (*research, teaching,* and *service*). An expanded conception of scholarship must also recognize that there are many different forms of team science — including partnerships between investigators from academic institutions and those from other sectors — and that team science may be described as *engaged scholarship, participatory research* or *integrated knowledge translation* in the Canadian context.

Recommendation 2

Acknowledge the critical contributions of "skills specialists" to team science and establish career paths for specialists to facilitate their advancement.

Universities and research institutes must identify career paths for researchers whose primary research activities are as skills specialists in research teams, rather than as PIs and first authors. The essential contributions of skills specialists to team science must be recognized so these researchers' roles, value, and impact are fairly acknowledged, which in turn facilitates career advancement. These pathways need not differ in status and recognition from those of more traditional researchers. Funders must ensure that, in assessing grants, the critical contribution of researchers with special skills, including statisticians, ethicists, and those with, for example, skills in building and leading teams are adjudicated fairly in light of their essential contributions to team-based research.

Recommendation 3

Recognize team research by providing the support required for the additional infrastructure essential to team-building and the development of successful collaboration.

Funding for the additional infrastructure essential to team-building and the development of successful collaborations (e.g., travel, meetings, planning, coordination, budget management) must be a budgetary component of all grants for research teams.

Recommendation 4

Expand the funding timeframe for large interdisciplinary teams and for teams that must build collaborations with other sectors.

Funding timeframes must be adequate for large teams. They must take into consideration the time needed to build and nurture a research team, and to publish research from that team's multiple contributing authors.

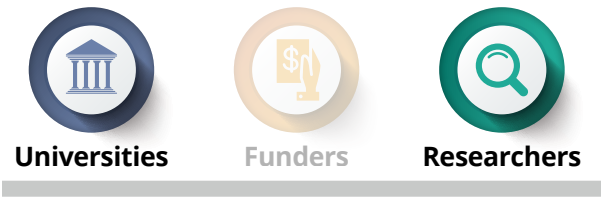
Recommendation 5

Allow the funding for team grants to be allocated to multiple institutions.

When a research team is multi-institutional, granting agencies must be willing to fund several participating institutions rather than allocate all funds to the PI's institution (requiring its finance office to arrange the sharing of funds with other institutions). Sharing funding among team members' institutions will allow a fairer allocation of support for the indirect costs associated with the research. It will also reduce the burdens on the lead investigator(s) and their finance office when it comes to distributing, managing, and reporting on the funds.

Recommendation 6

Mentor young researchers on team science opportunities.



Many young researchers in the health sciences do not have a clear view of potential research careers beyond the role of PI. Canadian universities must expose all health science trainees to the full range of careers available in research, including being a regular contributor to one or more research teams. Roles in research teams will be attractive to trainees and junior faculty only when universities and funders explicitly and fairly recognize the value of team science contributions.

4.2 RECOMMENDATIONS TO HELP REVIEW COMMITTEES MEASURE TEAM SCIENCE CONTRIBUTIONS

Recommendation 7

Ensure that APT and funding criteria include explicit recognition of contributions to team science and collaborative activities.

Universities and funding agencies must have appropriate criteria in place for evaluating team science. The emphasis should be on criteria that recognize individual contributions to team projects. Rules and procedures should be revised to ensure that appropriate attention is paid to candidates' team-based activities, including their roles as co-authors, co-applicants, or specialists on team projects, as well as their contributions as leaders of team applications and programs of research. Accordingly, review committees should develop language in their guidelines that acknowledges collaborative scholarship and that addresses its value to the field. The guidelines should be explicit about the value of contributions by individuals to team scholarship and should provide candidates with advice on how to frame these contributions in their applications. Finally, review committees should conduct training and calibration exercises for their members to ensure they are fully attentive to the scholarly contributions of co-investigators on team grants, co-authors of publications, and organizers and leaders of research teams (i.e., even if the leaders' contributions do not result in authorships on every team publication).

Recommendation 8

Compose review committees that can knowledgeably and fairly assess team science contributions.

Review committees for APT and funding applications require a membership that can understand the nature of team science and that can fairly evaluate (past or proposed) team science contributions. Review committees should include members from a range of fields and sectors appropriate to the applications being reviewed, especially when multidisciplinary in nature. Funding agencies overseeing competitions that involve research teams should include peer reviewers with experience in team science and an appreciation for its requirements — such peer reviewers could also strengthen university APT committees. Funders especially should recognize that a fair evaluation of team science applications involves not just the proposed contributions of a team's leader(s) but those of individual team researchers as well. Their committees should also consider the requirements of team integration and communication.

Recommendation 9

Train reviewers in the evaluation of individual contributions to research teams.

When evaluating the CVs of applicants and co-applicants, university APT committees and funding agencies at both the national and provincial levels should conduct training and calibration exercises for their reviewers, to ensure that they are fully attentive to the scholarly contributions of co-investigators on team grants, co-authors of publications, and organizers and leaders of research teams (i.e., even if the leaders' contributions do not result in authorships on every team publication).

4.3 RECOMMENDATIONS TO IMPROVE THE ASSESSMENT/ EVALUATION OF TEAM SCIENCE CONTRIBUTIONS

Recommendation 10

Ensure that the evaluation of team science reflects current knowledge about metrics for faculty evaluation.

There is concern that the metrics presently used in both faculty evaluation and funding competitions are not well suited to the evaluation of researchers who work in teams. Moreover, evidence has established the limitations of using these standard metrics in many situations and fields of study. There is a need to use multiple metrics rather than any single metric in evaluating researchers engaged in team science.

Recommendation 11

Adapt application forms and templates to reflect the diversity of research contributions to team science projects.

Funders are well positioned in the research system to promote the use of a wider range of evidence for team science proposals. Several funders have already taken the lead in updating application forms to require information on leadership, team structure, and roles. University APT applications should also be updated so that candidates can better distinguish their team science contributions for review committees.

Recommendation 12

Use databases that aggregate researcher publication output for more accurate attribution.

Health science researchers who use databases such as ORCID to link their names to collaborative publications make their achievements more visible for APT committees and funding agencies. Such databases enable all members of a science team to link to their collaborative publication so they can highlight their contributions. Universities and granting agencies should make ORCID IDs a requirement for candidates, and researchers themselves should regularly flag their contributions in such databases.

4.4 TOWARDS IMPLEMENTATION

Overcoming the challenges described in this report and implementing promising practices requires leadership among Canadian universities, funding agencies, and researchers. Only strong leadership across the country and at the highest level can equip Canada to fully participate in the global team science environment. The Panel recommends that the Tri-Agency Presidents and the executive of the National Vice-Presidents Academic Council convene a cross-sectoral leadership forum to guide and oversee the implementation of the above recommendations at all levels. The Panel further encourages major health science bodies in Canada, such as CAHS and CIHR, to highlight this report's recommendations and promising practices at upcoming conferences or annual general meetings. This will generate the leadership and momentum needed for Canada to adapt to a more international, interdisciplinary, and complex research ecosystem.

The Panel is hopeful that its recommendations will be considered and put into practice by universities, research institutions, and funding agencies. As recommendations are tested in real-world settings, it is important that organizations conduct rigorous and appropriate evaluation of any changes made, given the limited evidence base for promising practices. Such evaluation is necessary in relation to both the implementation and impacts of any process modifications. Leadership must also be prepared to identify and promote strategies for sharing the results of these changes throughout the academic and research funding systems for the encouragement and benefit of all.

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APPENDIX

SURVEY QUESTIONS

Universities

A. Does your institution's current APT policies or guidelines include any specific language regarding collaborations/collaborative activity, multi/interdisciplinary research and scholarship, and/or team science, either with other academic disciplines or with potential knowledge-users or interested/affected parties? If yes, please:

1. share the sections containing relevant language from those documents,

2. indicate whether or not your APT committees have received training in the implementation of these policies or guidelines (and what that might be?), and

B. Please provide information and feedback regarding actual practices, as well as your experiences with these issues, even in the absence of any formal policies.

Funding Agencies

A. How do your peer-review panels evaluate CVs that include co-PI, co-investigator, collaborator, and co-author roles?

B. How do your grants panels evaluate proposals from teams vs. individual applicants?

C. Do you provide your review panels with any training that involves these issues?

Please provide information and feedback regarding *actual* practices, as well as your experiences with these issues, even in the absence of any formal policies.

LIST OF ACRONYMS USED IN THE REPORT

ADR	Adverse drug reaction
AMS	Academy of Medical Sciences
APT	Advancement, promotion, and tenure
CAHS	Canadian Academy of Health Sciences
CFI	Canadian Foundation for Innovation
CIFAR	Canadian Institute for Advanced Research
CIHR	Canadian Institutes of Health Research
CPNDS	Canadian Pharmacogenomics Network for Drug Safety
CTSA	Clinical and Translational Science Award
DORA	San Francisco Declaration on Research Assessment
ESF	European Science Foundation
FRQS	Fonds de recherche du Québec – Santé
KT	Knowledge translation
LOI	Letter of intent
NATVAC	National Vice-Presidents Academic Council
NIH	National Institutes of Health
NSF	National Science Foundation
NSERC	Natural Sciences and Engineering Research Council of Canada
ORCID	Open Researcher and Contributor ID
PI	Principal investigator
U.S. NRC	U.S. National Research Council

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