The importance of diversity and outreach in geroscience research: Insights from the Annual Biomedical Research Conference for Minority Students

Mitchell B. Lee · Dibyadeep Datta · Cristal M. Hill · Alessandro Bitto

Received: 9 April 2020 / Accepted: 16 April 2020 / Published online: 3 May 2020
© American Aging Association 2020

Abstract US academic science lacks racial, ethnic, sex, gender, disability, and socioeconomic diversity. Addressing this problem is essential to drive scientific progress but is confounded by broad misunderstandings regarding diverse groups. Increasing representation in science is particularly relevant in geroscience, where our research to maximize healthy human lifespan must also address existing racial and socioeconomic health disparities. The American Aging Association (AGE) is committed to addressing these issues as part of its larger mission to advance and promote geroscience research. Over the last three years, AGE has sponsored an exhibition booth staffed by trainee leaders to promote our society and research at the Annual Biomedical Research Conference for Minority Students (ABRCMS), an ideal venue to interact with diverse students from across the country. Through our interactions with students, advocates, and representatives from other institutions and societies, we have learned a great deal about how to engage and promote the success of diverse students in the sciences. Here, we share these insights that are

helping shape our own outreach efforts. In addition to interacting with ABRCMS attendees, we also learned a great deal about how societies like AGE can partner with other organizations to advance our shared goals and the importance of reaching students early in their academic journey to promote their success. Finally, we consider how to grow our outreach efforts beyond ABRCMS to reach those in disadvantaged areas and support students navigating academic science.

Keywords American Aging Association · ABRCMS · Geroscience · Diversity · Outreach

Introduction

US academic science lacks racial, ethnic, sex, gender, disability, and socioeconomic diversity (Allen-Ramdiel and Campbell 2014; Valantine and Collins 2015; Asai and Bauerle 2016). As of 2018, 14.1% of life science doctorate degrees were awarded to underrepresented minority (URM) students, defined here as African American, Hispanic or Latinx, and Native American including Native Alaskan individuals (NSF 2019b). While unrepresentative of the US population, this is nearly twice the percent of life science doctorate degrees awarded to URM trainees in 1998 (NSF 2019b). During this time, all groups except Native Americans, Hawaiians, and Pacific Islanders experienced increases in representation (Booksh and Madsen 2018; Kerr et al. 2018; NSF 2019a, b). In terms of academic employment,

M. B. Lee (✉) · A. Bitto
Department of Pathology, University of Washington, Seattle, WA
98195-7705, USA
e-mail: mlee33@uw.edu

D. Datta
Department of Neuroscience, Yale University, New Haven, CT,
USA

C. M. Hill
Department of Neurosignaling, Pennington Biomedical Research
Center, Baton Rouge, LA, USA

women and URM populations remain proportionally underrepresented, and those employed make less than their male and non-URM counterparts (Micheltore and Sassler 2016; NSF 2019b). Continuing to grow representation of these groups in science is critical, but only a first step toward broadly increasing diversity and inclusion in science.

Misunderstanding and discrimination experienced by diverse groups are multifaceted and encompass a broad spectrum. For example, analyses of gender diversity and participation in science are obscured by misunderstandings regarding the concept of gender itself and how it differs from biological sex (biological sex can often be determined anatomically or physiologically whereas gender is the highly individualized expression of a person's sexuality) (Torgimson and Minson 2005; Greider et al. 2019). While nuanced, this distinction is important. The consequences of persistent societal misunderstanding, stigma, and prejudice on gender non-conforming individuals and sexual minorities is challenging to study but believed by most experts to be part of the explanation for elevated rates of mental disorders and suicide in these groups (Haas et al. 2011; Center 2018). Individuals with disabilities, another frequently overlooked group when considering diversity, experience sociological and often physical barriers that prevent their full participation in academic science, even 30 years after passage of the Americans with Disabilities Act (Booksh and Madsen 2018; Williams and Hagood 2019). Less information is available on the basis of socioeconomic status alone, but far fewer individuals from low socioeconomic conditions are expected to attain advanced degrees and, contrary to many other groups, this is getting worse with time (NCES 2014). Advancing socioeconomic diversity is made more difficult by a limited understanding of socioeconomic factors that create barriers for educational achievement and how those factors are assessed (NCES 2012). Family income and parent educational status are routinely used to assess socioeconomic status. Other barriers commonly found in low-income and rural areas, like low access to STEM and Advanced Placement courses as well as low retention of high-quality teachers throughout K-12 education, create what are now being described as STEM deserts (Kasey et al. 2012; Sawchuk 2017). Barriers to academic achievement and advancement are amplified for intersectional individuals, who represent more than one of these groups. For instance, the idea of a “double bind” for women of color, who must navigate both race-

and sex-based marginalization throughout STEM fields, is long known and complex, yet still poorly understood and appreciated (Malcom et al. 1975; Ong et al. 2011; Charleston et al. 2014; Ireland et al. 2018).

Scientific progress is slowed when we fail to include those with diverse backgrounds. Numerous examples of diversity driving creativity, innovation, and complex problem solving are found in business (McLeod et al. 1996; Higgs et al. 2005; Hewlett et al. 2013). Computational modeling of functionally diverse groups shows improvements in solving complex problems, as well as promoting novel solution discovery, relative to functionally homogeneous groups (Hong and Page 2004). In science, research impact (measured by citation) increases when research groups are diverse (Campbell et al. 2013). In addition to broadening group diversity, science benefits critically from expanding the diversity of research questions asked and hypotheses generated. Broadening participation in science has expanded the questions that are asked in biomedical research. For instance, with a greater share of women participating in research, greater attention began to be paid to sex differences in health outcomes and treatments (Rosser 2002; Mazure and Jones 2015; Ashpole et al. 2017; Chaudhari et al. 2020). Different backgrounds create different values and ways of engaging problems. These inform our goals, interests, and promote self-confidence, which is critical to drive further innovation and discovery. In science, where “follow your passion” is a mantra commonly spoken to trainees, it should not be a surprise that individuals from broader backgrounds engage with broader research.

While generally important in science, increasing diversity is of particular relevance in geroscience for multiple reasons. (1) Human longevity in the USA stratifies on the basis of race, sex, and socioeconomic status (Singh and Jemal 2017; Lee and Kaerberlein 2018). These differences are driven, at least in part, by differential survival with regard to age-associated diseases, like cancer, heart disease, stroke, and diabetes (Modan and Wagener 1992; Safford et al. 2012; Spanakis and Golden 2013; Horvath et al. 2016; Subedi et al. 2019). For humans to live the longest and healthiest lives possible, these health disparities must be addressed. (2) Healthspan extending interventions identified by geroscientists could help mitigate these existing health disparities. Multiple lines of evidence show that lifespan extending interventions preferentially benefit shorter-lived subpopulations in model systems (Rikke et al. 2010; Schleit et al. 2013; Wilson et al. 2018).

Treatments with this kind of preferential response can be thought of as “equitable interventions” (Lee and Kaeberlein 2018). In our efforts to identify successful healthspan interventions for human use, an important question to ask is whether these interventions are equally effective across groups with different survival rates (Chaudhari et al. 2020). Decreased health disparities driven by equitable healthspan interventions may emerge as another important longevity dividend (Olshansky et al. 2006; Creevy et al. 2016; Lee and Kaeberlein 2018). (3) Death and the worry of chronic, age-associated disease robbing us of our health are universally feared, for ourselves and for those we love. Geroscience unites us all by addressing a universal concern. As a corollary of 3, (4) we have the unique opportunity to inform, engage, and inspire the public through scientific outreach. The goal of geroscience is to identify ways to live the longest, healthiest life possible. We have an obligation to share our insights into the nature of aging and age-associated disease with as many as possible, and including individuals from diverse backgrounds is an indispensable part of this endeavor. In this way, we can serve as ambassadors to science and help grow a diverse pool of researchers and medical professionals that mirror the diversity of the US population. These individuals can help increase access to, and awareness of, insights made by geroscience.

How can we address the structural inequalities that prevent participation in science? The pragmatic concerns we described so far are important, but we should broaden outreach and include as many as possible in the scientific endeavor simply because people should not be deprived the opportunity to participate. We do not need to seek a benefit in order to advocate for greater inclusion of underrepresented and disadvantaged groups. It is wrong that these disparities exist, wherever and whenever they manifest. However, this is a harm that we can actively address. By fostering scientific interactions and supporting young, diverse scientists, we have an opportunity to change the lives of marginalized people. Committing to these goals can help overcome socioeconomic, systematic, societal, cultural, and international barriers and be a force for advancement in science and society.

The American Aging Association’s commitment to diversity and outreach

As a professional society, the American Aging Association (AGE) is dedicated to promoting aging and

geroscience research with the goals of increasing healthy lifespan and slowing the rate of aging, educating the public on the importance of maintaining healthy lifestyles as we age and means of doing so, and fostering the scientific and career development of trainees in this field of research. As a vital part of this commitment, AGE is dedicated to broadening diversity within geroscience. A major investment by AGE is growing these values from the ground up in their recently formed trainee chapter, which is composed of trainee leaders committed to broadening diversity, equity, inclusion, and outreach. Among the initiatives led by the AGE trainee chapter is participation as exhibitors in the Annual Biomedical Research Conference for Minority Students (ABRCMS). More than just a conference, ABRCMS is a community of diverse community college, undergraduate, postbaccalaureate, and graduate students that meet annually to hear from scientific leaders, showcase their research, and hone professional development skills. For many attendees, ABRCMS is their first scientific conference. Students at ABRCMS are highly motivated, energized, and represent the top talent of their generation. Over 5250 people attended ABRCMS 2019, held in Anaheim, CA, on November 13–16. A major focus of ABRCMS is connecting students to graduate programs, professional societies, public and private grant funding institutions, and other private and non-profit research entities. Over 400 different programs and organizations gathered at ABRCMS in 2019 to network with the 2875 students in attendance. The goals of AGE at ABRCMS are to promote research in the biology of aging and geroscience to attendees, encourage students to attend and present their research at the annual AGE national meeting, identify trainees interested in joining AGE, and communicate opportunities to lead the AGE trainee chapter by serving on committees that provide resources for AGE trainees and direct our outreach efforts.

Insights from ABRCMS

Since 2017, AGE has sponsored an exhibition booth at ABRCMS organized by AGE trainee leaders. By interacting with students, non-student attendees, and representatives from professional societies and other institutions, we have learned a great deal about opportunities to advance the scientific development of underrepresented students. The insights we gained from

attending ABRCMS are steering our outreach and inclusion efforts within AGE and apply to professional societies and institutions generally.

ABRCMS is ideal for geroscience outreach

A major highlight of ABRCMS is introducing attendees to geroscience and the biology of aging. The healthspan concept, geroscience, and even biological investigations into the mechanisms that drive aging are new and still largely unknown to most (Sierra and Kohanski 2017; Kaerberlein 2018). A common occurrence at ABRCMS is watching attendees momentarily pause their walk down the exhibition aisle when they come to AGE's booth and mouth the words "American Aging Association" with a surprised and sometimes incredulous look. These curious individuals often make their way to the booth to understand what the American Aging Association is and what it does. Another gratifying experience is relating trainee research to geroscience and biology of aging concepts. The majority of students that attend ABRCMS are performing research in labs or have conducted summer research through funded programs. Often, those studying heart disease, diabetes, cancer, or neurodegeneration have not connected their research to geroscience. Even more surprising to students is when their basic science research intersects with studies in aging. For instance, a student performing research into CO₂ exposure and *Caenorhabditis elegans* was excited to learn about work in hypoxia and the concept of hormesis as a mechanism to promote extended lifespan (Adachi et al. 1998; Mehta et al. 2009; Leiser et al. 2013; Leiser et al. 2015). So much research can be interpreted through the lens of geroscience and the biology of aging. We sparked the interest of all students and trainees we interacted with when we could make these connections. Showing how seemingly disparate areas of study are unified under our science is a powerful way to generate interest in our work and empower trainee researchers to connect their work to aging.

Outreach at ABRCMS is not limited to students. Directors of university programs and graduate curricula attend ABRCMS to identify new opportunities for diverse students at their institutions. A large number of faculty attend ABRCMS and visit the AGE booth to learn more about our society, the biology of aging, and opportunities we have available for their students. This year in Anaheim, we introduced two immunology faculty from different universities to AGE and geroscience

research, both of whom signed up to receive more information about our upcoming national meeting for themselves and their students. Reaching faculty at ABRCMS is a particular benefit because many that attend are from the Support of Competitive Research (SCORE) schools, Historically Black Colleges and Universities (HBCUs), Hispanic-Serving Institutions (HSIs), Tribal Colleges and Universities (TCUs), community colleges, and other institutes that serve large populations of first-generation and URM students. This makes ABRCMS a highly effective venue to broadly reach underrepresented groups and forge new relationships with other advocates while promoting our science.

Grow connections with other societies, institutions, and advocates

To give ABRCMS attendees a broader understanding of geroscience and the biology of aging, we partnered with graduate programs, major research initiatives, and centers of excellence in the biology of aging. We asked for promotional materials from these groups to display at the AGE booth. These collaborations allowed us to show attendees the geographic and conceptual breadth of biology of aging nationwide. Discussing and providing information on new research initiatives, like the Dog Aging Project (DAP), with attendees proved to be a powerful way to engage and excite while simultaneously advancing the goals of DAP. This is true for the graduate programs and the UW Nathan Shock Center of excellence in the basic biology of aging that partnered with AGE at ABRCMS as well. At future conferences, we plan to expand these partnerships to include more graduate programs and hope to attract other institutes, organizations, and potentially other societies interested in partnering with AGE. Growing these partnerships will allow us to educate attendees about leading graduate programs in the biology of aging, promote AGE and AGE-affiliated scientists, and serve as a gateway to introduce people to important work in geroscience.

At ABRCMS, we met many enthusiastic advocates for students among fellow exhibitors and attendees. As a society just beginning its association with ABRCMS, AGE exhibitors benefitted tremendously by talking to other society representatives. We learned about the goals of these societies and how they measured success relative to those goals. We also learned ways that exhibitors incentivize greater engagement by curating specific programs suited to the needs of individuals from diverse

backgrounds. Most importantly, we developed an appreciation for the enthusiasm of those involved with ABRCMS. Student advocates are prominent and eager to develop new connections and collaborations with interested organizations. For instance, we met a passionate high school instructor from IA that was very excited to discuss opportunities to develop biology of aging-related science projects for his classes. These types of outreach collaborations can open up new venues for AGE and its members to spread their science to underserved communities and inspire the next generation of scientific leaders.

Create opportunities for undergraduates

At each advancing stage of academia from undergraduate to graduate school, postdoctoral studies, and to tenure track positions, we lose talented diverse individuals. To reduce this attrition, we need to reach students early in their academic development and nurture their success. A common question asked by ABRCMS attendees is whether AGE sponsors a research experience for undergraduates (REU) program. AGE currently does not. However, by bringing this to our attention, we can think about ways that we can offer these opportunities. Interacting with representatives from other professional societies, we recognize two general factors that prevent establishing such programs, i.e., grant funding to support students and labs willing to host them. Identifying grant mechanisms and investigators willing to invest their time in developing grants for REUs is a long-term project. Identifying host labs is much easier to organize, and as a professional society with scientific members across the USA, AGE is in a unique position to facilitate matchmaking between interested students and willing host labs. Creating a system where undergraduates interested in aging can be introduced to local and regional labs that specialize in aging research is well within the purview of AGE. These opportunities are especially important for students at small universities and rural community colleges that have access to few or no labs with ongoing research.

In addition to REUs, professional societies can create other opportunities to facilitate advanced undergraduate development. Many professional societies at ABRCMS focused on recruiting undergraduate students. This was done by offering reduced or free memberships to these students. Identifying advanced undergraduate students and including them in societies like AGE fosters their

professional development and creates important networking opportunities. This can be particularly beneficial for undergraduates considering graduate school and investigators looking to bring on graduate students in the near future. Further, it is reasonable to assume that many undergraduate members of AGE will continue their membership as trainees once they transition to graduate school. To promote this, we must provide valuable experiences for members at all levels. Offering reduced cost memberships, undergraduate-specific travel awards, and creating a space for graduate school-bound students to interact with potential advisors are all important ways that AGE and other societies can grow their membership from the ground up.

Looking forward

While ABRCMS provides a great venue to reach URM trainees, it is not enough to accomplish our goal of growing diversity within geroscience. In the AGE trainee chapter, we consider ABRCMS as the beginning of our efforts, not their culmination. So, how best do we continue?

Developing sustained outreach between AGE, AGE-affiliated labs, and institutions that serve underrepresented students is a key goal as we move forward. We seek to establish interactions with SCORE institutions, HBCUs, community colleges, HSIs, and TCUs. For outreach into rural areas and other places which considered STEM deserts, interacting with younger students at secondary schools can create opportunities for these students to meet and learn from scientists. It is rare that people in disadvantaged areas meet a scientist in their lives or even understand where scientific research takes place. Through our diversity, equity, inclusion, and outreach (DEIO) committee, we hope to recruit AGE members across the country interested in conducting outreach and developing educational experiences for underrepresented students. Through our connections made at ABRCMS and existing relationships among trainee chapter members, we can reach into underserved communities and grow these opportunities. Engagement with diverse communities is a primary goal of the DEIO committee and a continuing source of investment by AGE.

Outreach can take many forms. In addition to visiting institutions to promote our science and creating opportunities for these students to perform research, we can

engage in creative and cost-effective ways to reach these populations. One option is to increase digital outreach. Utilizing technology to grow and spread scientific awareness can be achieved through multiple ways. Developing website content meant to broadly educate and promote an understanding of geroscience can be added to society webpages. Educational modules that are free to access and teach fundamental concepts in the biology of aging and geroscience are a potential launch point for interested individuals. Creating an index of AGE member lab webpages with searchable keywords could create a venue for advanced exploration of geroscience topics. To maximize the impact of these resources, we must also promote their existence to those who would benefit. Engaging social media is a key venue to promote these resources and another platform to perform broad outreach. Science twitter, or #SciTwitter, is a good example of how social media can be utilized to create a community that broadly shares their research and experiences in science. Growing awareness of groups within these platforms can provide a resource for teachers, instructors, and interested individuals to establish connections with world-leading scientific researchers and their trainees.

A larger and critically important project to engage in the digital realm is educating the public on how to identify quality sources of information. Disinformation abounds online. It finds a home and spreads in an information vacuum. As scientific experts, we are able and obligated to combat scientific disinformation. Creating resources to educate the public on how to identify quality sources of scientific information is not simply a matter of performing scientific outreach but may in fact prove critical to maintaining public trust in the scientific endeavor. As the majority of scientists depend on federal funding through the NIH for their research, maintaining the public trust in science is not simply an ideal, but a matter of survival.

Lastly, our efforts to grow diversity in science must be combined with ensuring that underrepresented individuals are fully included and welcomed into scientific culture. Succinctly stated “[d]iversity without inclusion is an empty gesture” (Asai 2019). Inclusion takes many forms and is different for each person, but there are some general principles that we can all consider. Introducing new trainees and students to everyone in the lab and fostering opportunities for people to connect, interacting directly with trainees and helping grow trainee mentor networks, and maintaining a lab culture that

promotes mental health and wellness are all ways to help students from broad backgrounds find a home in science. Normalizing and even celebrating non-traditional pathways to science is an important way for those coming from smaller schools or community colleges to feel like full community members. It is not true that all successful scientists enter the most prestigious colleges directly from high school. In fact, science is likely better because this is not the case. Science benefits from the varied experiences of scientists. For those in science who are the sole representatives of their background, we must develop empathy toward their unique position. These individuals are pioneers for their communities, and we must recognize their personal sacrifice, courage, and persistence to have made it to academic science. Supporting these diverse pioneers is critical to make meaningful changes in representation in science.

Acknowledgments We would like to thank Matt Kaerberlein, Michael Kiflezghi, Arianna Gomez, and Daniel Promislow for the careful and critical review of the manuscript. We thank our partner programs for advertising with AGE at ABRCMS: USC Leonard Davis School of Gerontology, Johns Hopkins Division of Geriatric Medicine and Gerontology, University of Washington Nathan Shock Center of Excellence in the Basic Biology of Aging, and The Dog Aging Project. We thank the University of Washington Nathan Shock Center for sponsoring MBL travel to ABRCMS.

Funding information MBL is supported by the NIH Alzheimer’s Disease Training Program (T32 AG052354). DD is supported by the Alzheimer’s Association Research Fellowship (AARF-17-533294) and the American Federation for Aging Research Diamond Postdoctoral Fellowship. CMH is supported by the NIH-NIDDK Ruth L. Kirschstein NRSA (F32 DK115137).

References

- Adachi H, Fujiwara Y, Ishii N. Effects of oxygen on protein carbonyl and aging in *Caenorhabditis elegans* mutants with long (age-1) and short (mev-1) life spans. *J Gerontol A Biol Sci Med Sci*. 1998;53:B240–4.
- Allen-Ramial S-AA, Campbell AG. Reimagining the pipeline: advancing STEM diversity, persistence, and success. *BioScience*. 2014;64:612–8.
- Asai D. To learn inclusion skills, make it personal. *Nature*. 2019;565:537.
- Asai DJ, Bauerle C. From HHMI: Doubling Down on Diversity. *CBE Life Sci Educ*. 2016;15:fe6.
- Ashpole NM, Logan S, Yabluchanskiy A, Mitschelen MC, Yan H, Farley JA, et al. IGF-1 has sexually dimorphic, pleiotropic, and time-dependent effects on healthspan, pathology, and lifespan. *Geroscience*. 2017;39:129–45.

- Booksh KS, Madsen LD. Academic pipeline for scientists with disabilities. *MRS Bull.* 2018;43:625–32.
- Campbell LG, Mehtani S, Dozier ME, Rinehart J. Gender-heterogeneous working groups produce higher quality science. *PLoS One.* 2013;8:e79147.
- Center NLHE. Suicide risk and prevention for LGBTQ people, Fenway Institute; 2018.
- Charleston L, Adserias RP, Lang NM, Jackson JF. Intersectionality and STEM: the role of race and gender in the academic pursuits of African American women in STEM. *J Progress Policy Pract.* 2014;2:273–93.
- Chaudhari K, Reynolds CD, Yang SH. Metformin and cognition from the perspectives of sex, age, and disease. *Geroscience.* 2020;42:97–116.
- Creevy KE, Austad SN, Hoffman JM, O'Neill DG, Promislow DEL. The companion dog as a model for the longevity dividend. *Cold Spring Harb Perspect Med.* 2016;6:a026633.
- Greider CW, Sheltzer JM, Cantalupo NC, Copeland WB, Dasgupta N, Hopkins N, et al. Increasing gender diversity in the STEM research workforce. *Science.* 2019;366:692–5.
- Haas AP, Eliason M, Mays VM, Mathy RM, Cochran SD, D'Augelli AR, et al. Suicide and suicide risk in lesbian, gay, bisexual, and transgender populations: review and recommendations. *J Homosex.* 2011;58:10–51.
- Hewlett S, Marshall M, Sherbin L. How diversity can drive innovation, in *Harvard Business Review*. Boston: Harvard Business Publishing; 2013.
- Higgs M, Plewnia U, Ploch J. Influence of team composition and task complexity on team performance. *Team Perform Manag.* 2005;11:227–50.
- Hong L, Page SE. Groups of diverse problem solvers can outperform groups of high-ability problem solvers. *Proc Natl Acad Sci U S A.* 2004;101:16385–9.
- Horvath S, Gurven M, Levine ME, Trumble BC, Kaplan H, Allayee H, et al. An epigenetic clock analysis of race/ethnicity, sex, and coronary heart disease. *Genome Biol.* 2016;17:171.
- Ireland DT, Freeman KE, Winston-Proctor CE, DeLaine KD, McDonald Lowe S, Woodson KM. (Un)hidden figures: a synthesis of research examining the intersectional experiences of black women and girls in STEM education. *Rev Res Educ.* 2018;42:226–54.
- Kaerberlein M. How healthy is the healthspan concept? *Geroscience.* 2018;40:361–4.
- Kasey PSG, Omolola AA, Gabriela CW. Teachers' perceptions of rural STEM teaching: implications for rural teacher retention. *Rural Educ.* 2012;33:9–22.
- Kerr JQ, Hess DJ, Smith CM, Hadfield MG. Recognizing and reducing barriers to science and math education and STEM careers for native Hawaiians and Pacific Islanders. *CBE Life Sci Educ.* 2018;17:4.
- Lee MB, Kaerberlein M. Translational geroscience: from invertebrate models to companion animal and human interventions. *Transl Med Aging.* 2018;2:15–29.
- Leiser SF, Fletcher M, Begun A, Kaerberlein M. Life-span extension from hypoxia in *Caenorhabditis elegans* requires both HIF-1 and DAF-16 and is antagonized by SKN-1. *J Gerontol A Biol Sci Med Sci.* 2013;68:1135–44.
- Leiser SF, Miller H, Rossner R, Fletcher M, Leonard A, Primitivo M, et al. Cell nonautonomous activation of flavin-containing monooxygenase promotes longevity and health span. *Science.* 2015;350:1375–8.
- Malcom SM, Hall PQ, Brown JW. The double bind: the price of being a minority woman in science. Washington DC: American Association for the Advancement of Science; 1975.
- Mazure CM, Jones DP. Twenty years and still counting: including women as participants and studying sex and gender in biomedical research. *BMC Womens Health.* 2015;15:94.
- McLeod PL, Lobel SA, Cox TH. Ethnic diversity and creativity in small groups. *Small Group Res.* 1996;27:248–64.
- Mehta R, Steinkraus KA, Sutphin GL, Ramos FJ, Shamieh LS, Huh A, et al. Proteasomal regulation of the hypoxic response modulates aging in *C. elegans*. *Science.* 2009;324:1196–8.
- Michelsmore K, Sassler S. Explaining the gender wage gap in STEM: does field sex composition matter? *Russell Sage Found J Soc Sci.* 2016;2:194–215.
- Modan B, Wagener DK. Some epidemiological aspects of stroke: mortality/morbidity trends, age, sex, race, socioeconomic status. *Stroke.* 1992;23:1230–6.
- NCES, 2012 Improving the measurement of socioeconomic status for the National Assessment of Educational Progress: a Theoretical Foundation, edited by U. D. o. Education.
- NCES, 2014 Education longitudinal study of 2002, pp. in *Digest of Education Statistics*, edited by U. D. o. education, National Center for education statistics.
- NSF, 2019a Doctorate recipients from U.S. Universities: 2018, In *National Center for Science and Engineering Statistics*, Alexandria, VA.
- NSF, 2019b Women, minorities, and persons with disabilities in science and engineering: 2019, in *Special Report NSF 19–304*. National Center for Science and Engineering Statistics, Alexandria, VA.
- Olshansky SJ, Perry D, Miller RA, Butler RN. In pursuit of the longevity dividend. *Scientist.* 2006;20:28–36.
- Ong M, Wright C, Espinosa L, Orfield G. Inside the double bind: a synthesis of empirical research on undergraduate and graduate women of color in science, technology, engineering, and mathematics. *Harv Educ Rev.* 2011;81:172–209.
- Rikke BA, Liao CY, McQueen MB, Nelson JF, Johnson TE. Genetic dissection of dietary restriction in mice supports the metabolic efficiency model of life extension. *Exp Gerontol.* 2010;45:691–701.
- Rosser SV. An overview of women's health in the U.S. since the mid-1960 s. *Hist Technol.* 2002;18:355–69.
- Safford MM, Brown TM, Muntner PM, Durant RW, Glasser S, Halanych JH, et al. Association of race and sex with risk of incident acute coronary heart disease events. *JAMA.* 2012;308:1768–74.
- Sawchuk, S., 2017 'STEM Deserts' in the poorest schools: how can we fix them? in *Curriculum Matters*, Education Week.
- Schleit J, Johnson SC, Bennett CF, Simko M, Trongtham N, Castanza A, et al. Molecular mechanisms underlying genotype-dependent responses to dietary restriction. *Aging Cell.* 2013;12:1050–61.
- Sierra F, Kohanski R. Geroscience and the trans-NIH Geroscience Interest Group, GSIG. *Geroscience.* 2017;39:1–5.
- Singh GK, Jemal A. Socioeconomic and racial/ethnic disparities in cancer mortality, incidence, and survival in the United States, 1950–2014: over six decades of changing patterns and widening inequalities. *J Environ Public Health* 2017;2819372.

- Spanakis EK, Golden SH. Race/ethnic difference in diabetes and diabetic complications. *Curr Diab Rep*. 2013;13:814–23.
- Subedi P, Nembrini S, An Q, Zhu Y, Peng H, Yeh F, et al. Telomere length and cancer mortality in American Indians: the strong heart study. *Geroscience*. 2019;41:351–61.
- Torgrierson BN, Minson CT. Sex and gender: what is the difference? *J Appl Physiol*. 2005;99:785–7.
- Valantine HA, Collins FS. National Institutes of Health addresses the science of diversity. *Proc Natl Acad Sci*. 2015;112:12240–2.
- Williams T, Hagood A. Disability, the silent D in diversity. *Libr Trends*. 2019;67:487–96.
- Wilson KA, Nelson CS, Beck JN, Brem RB, Kapahi P. Genome-wide analysis reveals distinct genetic mechanisms of diet-dependent lifespan and healthspan in *D. melanogaster*. *bioRxiv*. 2018.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.