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ARTICLE
PROJECT DiViNe: DIVERSE VOICES IN NEUROSCIENCE
Profiles of Rita Levi-Montalcini, Ricardo Miledi, Simon LeVay, Erich Jarvis, and Steve Ramirez

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In this paper we share the first five of what we hope will be many profiles of neuroscientists from historically underrepresented or marginalized groups. This initial collection of profiles, meant to stake out the general territory for future offerings, takes as its subjects a fairly broad range of individuals from Nobel laureates to early career scientists and educators. The goal of this project is to facilitate the dissemination of materials neuroscience educators can use to highlight the scientific contributions and personal stories of scientists from historically marginalized groups, and has been developed more extensively in the Editorial that accompanies this collection (Frenzel and Harrington, 2021). We believe that by sharing these stories, and highlighting the diversity of those who have and will continue to contribute to the field of neuroscience, we can help to foster a more inclusive discipline for our undergraduate students. Each of these profiles is a testament to the respect these contributors hold for their subjects. We hope that others might see this new feature as an opportunity to share the admiration they have for those who have impacted them as colleagues, mentors, and role models

Key Words: diversity, equity, and inclusion in STEM, inclusive pedagogy, scientific biography, neuroscientist

RITA LEVI-MONTALCINI

Contributor: Judith M. Ogilvie
Topics: neural development, nerve growth factor, neural signaling
Primary Resources: Levi-Montalcini and Booker, 1960a; Levi-Montalcini and Booker, 1960b

Description: These two papers are central to the Nobel Prize winning work of Rita Levi-Montalcini. Levi-Montalcini, together with Stanley Cohen, received the 1986 Nobel Prize in Physiology or Medicine "for their discoveries of growth factors" (Nobel Prize Outreach, 2022). In these papers, the authors describe the discovery that mouse sarcoma tumors release a substance that induces growth and differentiation of sympathetic neurons, which was subsequently isolated and named nerve growth factor. The introductory paragraphs of the first of these two papers provide a summary of the experiments that preceded this work and clearly lay out three unanswered questions that follow. Levi-Montalcini and Booker begin by demonstrating that the growth-promoting effects previously reported *in vitro* in chick, mice, and rats are also produced in sensory and sympathetic ganglia from human fetuses (Levi-Montalcini and Booker, 1960a). The primary focus of the first paper is on the *in vivo* extension of this work, demonstrating that injections of the purified substance in newborn and adult mice have dramatic growth promoting effects on the sympathetic ganglia, resulting in an increase in both the number and size of the neurons. In the second paper, Levi-Montalcini and Booker demonstrate that inhibition of the nerve growth factor leads to destruction of the sympathetic ganglia in several mammalian species (Levi-Montalcini and Booker, 1960a, 1960b). Together the articles provide gain-of-function and loss-of-function evidence that nerve growth factor is both necessary and sufficient for development and maintenance of the sympathetic ganglia. A third paper by Stanley Cohen, with whom Levi-Montalcini shared the Nobel Prize, is included in the same volume (Cohen, 1960). His work, summarized in these two papers, describes the biochemical isolation of the substance and the production of the antibody.

Value: In a manner typical of classic papers but less common today, the inquiry-based nature of science is emphasized rather than hypothesis-driven experiments. A study that began with experiments on mouse tumors led to a fundamental and far-reaching discovery on the mechanisms underlying the development of the nervous system. Serendipity played a key role, as illustrated in the authors' description of their plan to use snake venom as a source of proteolytic enzymes only to find that the venom contained the very same growth-inducing effect they were investigating. The leap from snake venom to the mouse salivary gland was the result of keen insights.

Instructors may wish to include the third paper by Cohen (1960), although this paper is not necessary for understanding the work of Levi-Montalcini. Classic biochemical protein isolation techniques are described in detail, although these techniques have largely been replaced in modern biochemistry labs. This may be enlightening for students with a biochemistry background, but may be more challenging for others.

Biographical Information: Rita Levi-Montalcini had a remarkable life story (Levi-Montalcini, 1988). She and her twin sister were born on 22 April 1909 in Turin, Italy, the youngest of four children raised in an intellectual Jewish family. Although her father expected his daughters to pursue a traditional role of marriage and family, she persuaded him to allow her to pursue a professional career in medicine with her cousin, Eugenia Sacerdote de Lustig (Cowan, 2001). Since math and science were considered unnecessary for a girl's education, a private tutor was hired to prepare them for medical school. They were among four women students in a class of 500 men at University of Turin Medical School (Deutsch, 2010).

After completing her medical degree and unsure whether to pursue a career in research or medicine, Levi-Montalcini chose to continue her training, specializing in neurology and neuroanatomy under Giuseppe Levi, the foremost Italian histologist of the time (unless otherwise specified, the source for this biographical information was the website, www.nobelprize.org). Half a world away, Victor Hamburger's reputation as a leading developmental biologist was solidified by his work establishing the chick embryo *in ovo* as a model organism, and by his subsequent discoveries (Ribatti, 2016). He used this system to analyze the relationship between the wing bud and spinal neurons during development. Aware of Levi's reputation, he sent a reprint of his studies to Levi who shared it with Levi-Montalcini. This paper was to have a profound and lasting effect on her future career (Cowan, 2001).

In 1938 Levi-Montalcini's academic work came to a halt when Mussolini issued the "*Manifesto for the Defense of the Race.*" The manifesto meant that Jews could no longer be employed at state institutions, including schools and universities, nor could they practice medicine. For a brief period in 1939, she continued her training in Brussels, but as the threat to Jews spread across the continent, she returned home to Turin. Determined to continue her research and now intrigued by Hamburger's results, she established a small lab in her bedroom using fertilized eggs purchased from a local farmer. She worked there with Levi until 1941 when the Allied bombardment of Turin forced her family to retreat to their country cottage. There she again set up a small lab, continuing her research until the German invasion of Italy in 1943. Her family went into hiding in Florence until Italy was liberated in 1944.

After the war, she resumed her position at the University of Turin and published the work that she had done in her makeshift laboratory during the war. This work built on ideas from Hamburger's 1934 paper and caught his attention. Now chair of the Department of Zoology at Washington University in St. Louis, Hamburger invited Levi-Montalcini to visit his lab in 1947 (Cowan, 2001). What was intended to be a one year stay, became a long and fruitful collaboration that extended many decades. Recognizing the need for expertise in biochemistry to understand the mechanism underlying their anatomical observations, in 1952 Hamburger recruited Stanley Cohen to the Zoology Department where their groundbreaking work on nerve growth factor was completed (Cowan, 2001). Levi-Montalcini was promoted to associate professor of Zoology in 1951 and full professor in 1958. In 1969 she established a second laboratory in Rome, dividing her time between Italy and St. Louis. She retired from Washington University in 1977 to become the director of the Institute of Cell Biology of the Italian National Council of Research, where she continued to work as a guest professor well after her retirement in 1979.

In 1986, Levi-Montalcini was awarded the Nobel Prize in Physiology or Medicine with Stanley Cohen for "for their discoveries of growth factors." The omission of Victor Hamburger from the Nobel Prize award led to a rift between these collaborators that sometimes overshadowed the important contributions of each of these scientists (Cowan, 2001; Ribatti, 2016). Coming from a background where she was expected to limit her aspirations to that of a wife and mother, Levi-Montalcini chose to do neither and instead overcame many obstacles to become one of the most important neuroscientists of her generation. Rita Levi-Montalcini died on December 30, 2012 at the age of 103, becoming the longest-lived Nobel Laureate.

Audience: These papers would be appropriate for mid-level to advanced undergraduate courses including introductory neuroscience or developmental biology courses or more specialized courses in developmental neuroscience, neurochemistry, neuropharmacology, or related subjects.

Additional Teaching Resources: Two years after receiving the Nobel Prize Levi-Montalcini published an autobiography (1988) which was reviewed by Hollyday the following year (1989). As with all other Nobel laureates, the information available concerning Levi-Montalcini on the www.nobelprize.org website is excellent and freely accessible. Additional online information is available through the digital collection at Washington University in St. Louis (http://beckerexhibits.wustl.edu/mowihsp/bios/levi_montalcini.htm). As mentioned earlier, some instructors might include the paper by Cohen (1960) when discussing the two papers identified as primary resources in this profile. Finally, those interested in exploring the exclusion of Viktor Hamburger from the Nobel Prize should consult the interesting papers of Cowan (2001) and Ribatti (2016).

RICARDO MILEDI

Contributor: Kristen E. Frenzel
Topics: neurophysiology, synaptic release
Primary Resources: Katz and Miledi, 1967; Miledi, 1973

Description: The calcium hypothesis of neurotransmission is a central dogma in the field of neurophysiology. In these papers Ricardo Miledi and his frequent collaborator Bernard Katz systematically walk through the possibilities for ionic control of neurotransmitter release and definitively demonstrate Ca^{2+} as the critical ion. These two papers address the necessity and sufficiency of Ca^{2+} for neurotransmitter release, as measured by postsynaptic potentials at the squid giant synapse. The one-two punch of these papers nails the calcium hypothesis to the door and fuels this line of inquiry for years to come.

The purpose of the 1967 paper was to describe in detail experiments that reveal the nature of the presynaptic depolarization needed to generate a postsynaptic response, but in the absence of the all-or-nothing event of an action potential. The data in this paper had been previously published in several papers throughout 1965 and 1966 but this paper synthesizes these data, providing a complete set of detailed experiments that reveal the ionic nature of neurotransmission. These experiments utilized tetrodotoxin and tetraethylammonium to effectively block the voltage-gated channels critical for action potential generation, and elegantly reveal the necessity of Ca^{2+} influx for generating a postsynaptic potential.

In the first set of experiments, Katz and Miledi used tetrodotoxin to block voltage-gated sodium channels and simultaneously inject current to depolarize the presynaptic membrane. Specifically, the data from Figure 4 of the paper described and the statement on page 415 suggest that the cause of neurotransmitter release is not the influx of sodium ions that occurs during an action potential but another event stimulated by presynaptic depolarization. The data from Figures 10 and 11 address the hypothesis that the efflux of potassium through voltage-gated channels is the necessary event, yet the data effectively demonstrate that blocking both influx of sodium (with tetrodotoxin) and efflux of potassium (with tetraethylammonium) does not diminish the postsynaptic response after presynaptic depolarization. These data definitively ruled out the need for sodium and potassium as ions necessary for neurotransmitter release and were foundational in the hypothesis put forth as “the calcium hypothesis,” simply stated as depolarization → calcium influx → quantal neurotransmitter release.

The introduction to the 1973 paper concisely synthesizes the overwhelming evidence to date for the necessity of Ca^{2+} in neurotransmission. The direct test for the sufficiency of calcium in neurotransmission is injection of calcium into the presynaptic terminal in the absence of an action potential and measuring a postsynaptic response. However, this experiment is technically not possible at the frog neuromuscular junction because the presynaptic terminal is too small to accommodate the injection and recording electrodes. In the giant synapse of squid, Miledi needed to overcome a technical issue: the response to the release of a few quanta at the giant synapse (i.e., the miniature excitatory postsynaptic potential) was generally too small to be detected. Overcoming this technical hurdle by using very small squid allowed Miledi to proceed with the experiments that tested the sufficiency of calcium in neurotransmission. Direct injection of Ca^{2+} ions into the presynaptic terminal in the presence and the absence of Ca^{2+} in the extracellular solution (Figures 2 and 3) provide concrete support for the calcium hypothesis laid out almost a decade previous.

Value: Neurophysiology textbooks sometimes utilize the exact data from these two papers or modified versions of these figures and students might find it informative to read the original text to understand the context of the experiments and the logical arguments built by the authors in support of the calcium hypothesis. As well, the pros and cons of the two primary synaptic model systems, the frog neuromuscular junction and the squid giant synapse, are elegantly described in the 1967 Katz and Miledi paper. The techniques described are straightforward neurophysiology techniques that are accessible for mid-level undergraduate students to understand, and reinforce the concepts of membrane potential and equilibrium potential. As well, the concepts of necessity and sufficiency for a biological process are easily understood based on experiments in these two papers. Together, these two papers can be used to walk through the ionic nature of neurotransmitter release and to push students to check their biases with regard to data. Students tend to come into an introductory neuroscience or neurobiology course with the basic idea that action potentials trigger neurotransmitter release. However, these data require the students to check their biases about the need for influx of Na+/efflux of K+ per se in neurotransmitter release. The experimental setups in both papers can be used to introduce, or solidify, understanding about electrophysiological techniques that are still used today, and to reinforce skills in interpreting data figures and drawing conclusions. After working through specific figures in the 1967 paper, students can be challenged to consider what experiments would test the sufficiency of calcium in neurotransmitter release, and many of them come up with the exact experiments performed by Miledi in 1973. Recognition that undergraduate students can also design an experiment similar to the one published in Miledi, 1973 helps them identify as scientists.

These studies did not involve the use of voltage clamp, but subsequent experiments by Rodolfo Llinas, in which the presynaptic membrane was clamped at the desired potentials, substantiated the findings of Katz and Miledi (1982). It is also worth pointing out that the work by Katz and Miledi predates the evidence for the fluid mosaic model of the lipid bilayer, as well as our modern-day models of ion channel structure. Discussions of this work can lead naturally to the question of “what is the calcium sensor for release?” and discussion of SNARE proteins that mediate vesicle release.

Biographical information: Ricardo Miledi was one of seven children and was born in Mexico City in 1927 (Jeng, 2002). When taking the broad view of the research career of Ricardo Miledi it is clear that: a) science has no borders, b) networking opened doors, and c) persistence is often key to success. He attended medical school in Mexico but decided that his interests in how and why the body worked in normal conditions and in disease states would be more interesting than directly treating the patient’s symptoms. He parlayed this interest into a research fellowship (as a way to satisfy the social service component of his medical training) in the lab of Arturo Rosenblueth. Working with Rosenblueth in 1954, Miledi had a serendipitous meeting with two renowned scientists, Albert Grass and Stephen Kuffler, from the Marine Biological Laboratory (MBL) in Woods Hole, MA. At this point in his life, he was a married 27-year old man who was working in a lab as a research fellow and his research career had not yet started. He jumped at the opportunity to spend the summer of 1955 at the MBL. There, he began his study of synapses in the common squid and began to see the importance of calcium in synaptic transmission, particularly when he would forget to add calcium to his solutions. Miledi found his way to Canberra, Australia to work with John Eccles, and through this relationship met his future collaborator and Nobel Laureate

Bernard Katz. Katz would offer him a position in the Department of Biophysics at University College London (UCL) where he worked on acetylcholine receptors at the frog neuromuscular junction, laying important groundwork for subsequent experimentation in understanding postsynaptic neurotransmitter receptor biology. In the early 1960s, he circled back around to his interest in Ca^{2+} and synaptic release and revisited the squid giant synapse as the model system for investigation of the fundamental nature of Ca^{2+} in synaptic vesicle release. His work with squid while at UCL was not without its challenges. Obtaining live squid suitable for research in England was not possible, despite trips to the marine center in Plymouth to collect squid. Again, a serendipitous discussion with a colleague in London turned him towards centering his research in squid at an aquarium in Naples, Italy. His fruitful work in Naples provided the data for the seminal work in the mid-1960s and into the 1970s to test “the calcium hypothesis”.

Later, Miledi’s work moved away from a study of calcium-mediated neurotransmitter release to structural and functional analysis of proteins involved in synaptic communication. He pioneered the use of frog oocytes for heterologous expression of neurotransmitter receptors and channels, extensively publishing detailed analyses of these proteins and their role in normal and disease states until his death at age 90 in 2017.

Audience: These papers would be appropriate for mid-level to advanced undergraduate courses including introductory neuroscience, neurobiology or neurophysiology course.

Additional Teaching Resources: Much of the detail about Miledi and his life comes from the outstanding review by Jeng (2002) who had the opportunity to interview Miledi for a Timeline article in *Nature Reviews Neuroscience*. These papers can be used to highlight the trajectory of a Mexican undergraduate STEM student to a renowned scientist, and his research story highlights the global nature of scientific inquiry.

Those looking for a broader overview, perhaps to help students synthesize the importance of this work, especially those earlier in their academic careers, might make use of Llinas (1982). Although brief, some information and useful links are available on his Wikipedia page (https://en.wikipedia.org/wiki/Ricardo_Miledi). A memoriam written by colleagues at UC Irvine can also be found online (https://senate.universityofcalifornia.edu/in-memoriam/files/ricardo-miledi.html).

SIMON LEVAY

Contributor: William (Bill) Grisham
Topics: hormones and behavior, sexual differentiation, sex differences in brain and behavior
Primary Resource: LeVay, 1991

Description: LeVay’s 1991 paper compared the size of a hypothalamic nucleus (INAH 3) in homosexual men to its size in heterosexual men and women. Not only was the sex difference between heterosexual men and women replicated, but also the size of this nucleus was reduced in homosexual men relative to heterosexual men and was not found to be different from women. The scientific side of this research has been addressed previously and can be found elsewhere (Harrington et al., 2015).

Value: The study of neuroanatomical sex differences changed radically during the latter half of the 20th century. The dogma went from denying that they existed at all to noting their presence first at a microscopic scale and then macroscopically in birds and rodents, and finally to demonstrating their existence in humans. This paper’s bold contribution was to explore differences in brains between homosexual and heterosexual individuals. This paper would be of value in any course touching on the topic of sexual differentiation or sex differences in behavior. Students often miss how studies in animals (e.g., rodents/birds) have any possible connection with themselves or other people. Students also seem to believe that science and public policy are completely divorced and are often surprised about the interplay between science and socio-political policy. Indeed, LeVay’s paper was an element that helped shift the zeitgeist, the spirit of the times, in science and policy that ultimately changed attitudes, norms, and laws in our society.

Biographical information: Simon LeVay worked on vision and collaborated with David Hubel and Torsten Wiesel, who eventually won a Nobel prize. LeVay should probably be more famous for that work than he is (see Hubel, Wiesel, and Levay, 1977, for example.) Other aspects of his research led Francis Crick (of DNA fame) and his long-time collaborator Christof Koch (presently President of the Allen Institute for Brain Science) to decide that the claustrum is the seat of consciousness (Crick and Koch, 2005). Interestingly, he’s not terribly famous for that either.

Rather, LeVay is most famous for a two-page article that he published after his partner’s death from AIDS. It was LeVay’s swan song to bench science, which he never left in his scientific career. In that issue of *Science*, he described the size of a nucleus in the hypothalamus in gay men, straight men, and women (LeVay, 1991). Not only did he replicate the sex difference previously reported from a UCLA lab (men > women; Allen, Hines, and Gorski, 1989), he showed that the size of this nucleus in gay men is on average about half the size it is in heterosexual men, and not statistically different from its size in women.

In the current zeitgeist, it may seem odd—indeed queer—but LeVay’s paper received criticisms from diverse sources, including feminist (Spanier, 1995) and religious (Reichebach and Anderson, 1995) scholars. Most objections to the science were already refuted in LeVay’s beautifully written discussion in which he notes the limitations and other possible interpretations (see also my observations in Harrington et al., 2015). While it may be safe to say that his work helped shift the socio-political outlook on gay rights, LeVay’s approach has been critiqued by some members of the LGBTQ+ community, mostly because he did not address sexual variability and fluidity but treated gay versus straight as a binary variable (Ward, 2015). Also, a biological difference was seen by some as behavioral destiny (Spanier, 1995; Bailey et al., 2016).

This brief biography hardly does justice to LeVay's personal life. Readers should access his website for his autobiography, which is littered with tongue-in-cheek British humor — think Monty Python but with a lot more class (http://www.simonlevay.com/). Despite his alleged retirement after the famous study, he became very active in the gay community; published several books, including a novel; and established a gay school, the Institute of Gay and Lesbian Education. He gave a great talk to UCLA undergraduates, arriving on his bicycle after riding over from West Hollywood—a tiny hop for this avid cyclist. If you can get him to visit, he gives one of the best talks that I have ever heard.

Audience: This source has been used in teaching labs on sex differences in spinal cord nuclei (Grisham et al., 2003) and the birdsong system (Grisham et al. 2011). A colleague uses LeVay's textbook, "Discovering Human Sexuality" (LeVay et al., 2015) in his "Psychobiology of Sexual Behavior" course. The colleague also includes material about LeVay's (1991) paper in his course. Both of these are upper division courses, but these materials could be adapted to lower division courses as well.

Additional Teaching Resources: In addition to LeVay's 1991 paper, instructors might make use of his textbook on human sexuality (LeVay et al., 2015).

ERICH JARVIS

Contributor: William (Bill) Grisham
Topics: Birdsong, neural basis of vocalization, brain evolution, neuroethology, comparative neuroanatomy
Primary Resources: Pfenning et al., 2014; Jarvis, 2019; Arriaga and Jarvis, 2013

Description: Jarvis's research has focused on the parallels in neural circuits of vocalization, particularly learned vocalization. Unlike most neuroscience researchers, he has not only stretched his research across species, but also expanded his research across orders and even classes of animals. Further, his research extends across the whole gamut of neuroscience--from molecules to circuits to behavior. The articles listed above encapsulate Jarvis's research. The first article is a tour-de-force showing how DNA data can be utilized to reconstruct the evolution of birds. Some orders show song behavior whereas others do not (e.g. ostriches, ducks, and others). Most singers clearly learn their song whereas closely related orders may not. This work also highlights how the singers and non-singers diverged in evolution. The second article is a review of Jarvis's work, which spans the molecular to the behavioral. This work notes the similarities in vocalization circuits in both birds and mammals and discusses how convergent evolutionary forces took advantage of extant neural circuits. The third work suggests the possibility of learning vocalizations by a non-human mammalian species via circuits similar to our own.

Value: These articles together show how genetic analyses can lead to insights into the evolution of behavior. Further, they show how a brain can be built and adapted (or even exapted) from existing molecular and neural pathways in an ancestral species, resulting in the production of new behaviors as a function of such evolutionary pressures as sexual selection.

Biographical information: Erich Jarvis is an African-American neuroscientist with an incredible story that has been well chronicled. He has written a brief autobiography in which he reflected on being an underrepresented minority scientist (Jarvis, 2016) and had his life chronicled by PBS and on Wikipedia (see links below), so this account will be brief. Jarvis was born in Harlem, and later raised by his mother in a single-parent home in New York, but with help from his grandparents. His mentally ill father became homeless and was eventually killed in gang violence. His early years were not all doom and gloom, however. He went to the High School for the Performing Arts in Manhattan and trained in dance with a scholarship from the Alvin Ailey American Dance Theater. (One can get a glimpse of him dancing in the PBS video in the references.) The exacting and demanding aspects of dance training shaped his tenacious approach to his work as did his mother's insistence on ambition. At one point, Jarvis was faced with the choice of becoming a dancer or a scientist. It is fortunate for us that he chose neuroscience.

Jarvis went to Hunter College in New York for his BA and published six research papers in the course of his time as an undergraduate. He reached another crossroads as he finished his BA: should he go to graduate school, medical school, or try to do both? Again, we got lucky, and he went across town to Rockefeller University where he earned his doctorate studying with Fernando Nottebohm and stayed on as a postdoc in that lab. After serving on the faculty at Duke University, he returned to Rockefeller to fill the shoes of his former mentor and to continue to pursue the notable, ground-breaking research outlined below.

Jarvis's research is in comparative neurobiology. He has examined oscines (songbirds) and also non-oscine birds that don't sing but can also learn vocalizations such as parrots (Jarvis and Mello, 2000) and hummingbirds (Jarvis et al., 2000). Further, he has made important contributions to understanding gene expression differences between vocal learning species and species who don't learn their vocalizations (Hara et al., 2012; Pfenning et al. 2014).

Jarvis has not confined himself to avians, however, but has extended to mice, which also sing — particularly during sexual and agonistic encounters (Arriaga and Jarvis, 2013). Jarvis has pushed his studies of mice to explore possible parallels with a somewhat larger mammal: humans. Jarvis's lab discovered that mutations of the Foxp2 gene produced a somewhat parallel disruption in both mouse and human vocalizations (Chabout et al., 2016).

Jarvis's comparative interests have also brought him to draw inferences about not only bird evolution (Jarvis et al, 2014) but also brain evolution in general. Perhaps his most noteworthy publication was in *Science* (Jarvis, 2019) in which he draws together the many threads of his research and weaves them into a beautiful tapestry. In this article, he champions one of the central tenets of Darwinian evolution:

continuity among species. His bold thesis suggests that there are analogous areas for vocal imitation and vocal production in some bird and mammalian orders.

In his career, Erich Jarvis has been all over the map. Indeed, he is drawing the map by better describing not only the terra incognita of the neurobiology of vocalization but also the evolutionary processes underlying these behaviors.

Additional Teaching Resources: In 2015 Jarvis received the E.E. Just Award from the American Society for Cell Biology and published a brief but insightful autobiography and reflection on his experiences as an underrepresented minority scientist (Jarvis, 2016). This paper also includes a number of references to other writing about his life. The website www.thehistorymakers.org includes an extensive collection of videos of interviews with Jarvis, although many of these interviews are behind a paywall. A brief video on PBS including both biographical and scientific content is also available (https://www.pbs.org/video/profile-eric-jarvis-eqxihb/). Good information can also be found elsewhere online including his entry on Wikipedia (https://en.wikipedia.org/wiki/Erich_Jarvis) and his lab website (https://www.jarvislab.net/).

Audience: The teaching resources listed above could be used even at an intro level. The autobiography is inspiring, and the press releases provide a general audience window into their exciting work. The papers listed at the outset would take some unpacking but would be a worthy pedagogical effort.

STEVE RAMIREZ

Contributor: Ian Harrington and Kristen E. Frenzel
Topics: cellular basis of learning and memory, false memories, optogenetics
Primary Resources: Liu et al., 2012; Ramirez et al., 2013

Description: The two papers identified above were previously described by Linden (along with a paper by Reijmers et al., 2007) because of their pedagogical value in understanding the role of the hippocampus in memory formation using a number of techniques including optogenetics (see Harrington et al., 2015). In brief, these authors were able to identify hippocampal cells involved in the representation of an experience, exercise optical control of the activation of these cells, and to induce the recollection of fearful memories in physical situations where such memories had not ever been acquired. The techniques used are fascinating as are the efforts at experimental control. For additional details of this work and its use in undergraduate teaching, see Linden's full contribution (Harrington et al., 2015).

Biographical information: Unlike the other profiles included in this collection which have focused on either historical giants or those who are well into established careers, Ramirez is much earlier in his career and, thanks to the exuberance that seems to be his trademark, can come across to undergraduates as much more of a contemporary figure. Becoming a professional in the TED-talk era has only helped to make him and his work more accessible; the TED website lists the views of his 2013 video at over 1.1 million. It turns out that the best source for biographical information about Steve Ramirez is Ramirez himself. A brief biographical sketch can be found on his website (currently: https://www.theramirezgroup.org/team.html) and what he writes there is likely quite relatable to students. By his own description Ramirez was interested in a range of topics as an undergraduate and a little late to declare a major. A number of encounters with peers and other mentors, including a serendipitous encounter at a centrifuge with a former crush, led him to studying memory in the lab of Howard Eichenbaum. Following this formative lab experience, he found himself admitted to MIT as a graduate student where he would complete the work mentioned above in collaboration with Xu Liu in the lab of Susumu Tonegawa. (Sadly, Liu, Ramirez's friend, collaborator, and co-presenter of their excellent 2013 TED talk, died in 2015.) Following a junior fellowship at Harvard's Center for Brain Science, he found himself back at his alma mater, Boston University, as a faculty member and has garnered an array of accolades for his research to date.

There is one part of his biography, however, that feels especially important, both to him personally, and in terms of its potential impact on our students. Ramirez was born in Boston to parents who had arrived in the United States as undocumented immigrants from El Salvador. Although Ramirez gained US citizenship by virtue of his birth, his story brings attention to the issue of immigration status and higher education. A 2020 report indicates that there are currently some 450,000 undocumented students in postsecondary US institutions, representing about 2% of all students, with fewer than half being DACA-eligible (Feldblum et al., 2020). These students face a number of challenges, among them the Free Application for Federal Student Aid (FAFSA). Undocumented students are ineligible for Federal student loans (although they are eligible for some state, institutional, and other private scholarships), but some students who are US citizens with undocumented parents are hesitant to apply for federal loans for which they are eligible because it requires disclosure of information about their parents. What these statistics highlight is an inequity of access to higher education for people living in the US. The success Ramirez has had in research as a child of undocumented immigrants is inspiring. As he recently told us, "Whether you're a man or woman, gay or straight, from El Salvador or Canada—labels that often divide communities—the process of discovery itself can unify us at a fundamentally human level. If you work hard in research, you're going to push forward, you're going to make discoveries" (S. Ramirez, personal communication). And yet, for too many of our students, fears about their own immigration status and that of their family members can serve as a barrier to full engagement with our academic and scientific communities. If nothing else, stories like that of Steve Ramirez can help to serve as an example of the benefit that can come with equal and unbiased access to higher education.

Teaching Resources: A number of great teaching resources are available to help supplement the articles already mentioned. Chief among these, perhaps, is the 2013 TED talk Ramirez delivered with Xu Liu (https://www.ted.com/talks/steve_ramirez_and_xu_liu_a_mouse_a_laser_beam_a_manipulated_memory?utm_campaign=tedspread&utm_medium=referral&utm_source=tedcomshare). This can be used before or after having students work through the details of the more complex papers. A much shorter, teaser video is also available online from the Smithsonian Magazine https://www.smithsonianmag.com/videos/smithsonian-ingenuity-awards-2014-steve-ramir/). Given that several class sessions might be devoted to working through the methods, findings, and potential applications of this work, both of these videos (and others that can be found online) can be used to help students get oriented to the work initially and to regroup after spending more time with the details of the research. Students and instructors can also make good use of Ramirez's website where these and other resources have been curated (https://www.theramirezgroup.org/).

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