The National Institute of Neurological Disorders and Stroke:

Strategic Plan for Research 2021-2026

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Note to readers: *NINDS plans to publish the 2021-2026 Strategic Plan in a web-based format. The text below will populate the 2021-2026 Strategic Plan website, with links to web content on NINDS programs and resources. NINDS intends the 2021-2026 Strategic Plan to be a living document and will update the Strategic Plan website at regular intervals to inform stakeholders about implementation activities and progress made to advance neuroscience research. This will include new and upcoming programs and funding opportunities as well as new scientific advances.*

Message from the Directors

Neurological disorders—that is, diseases of the brain, spinal cord, peripheral nerves, and neuromuscular system—inflict an enormous toll of lost life, disability, and suffering on people of all ages throughout the United States and the world [*see **Burden of Neurological Disorders*** below]. Furthermore, the need for progress is growing more urgent. Brain disorders are becoming more common with the aging of our population, the high prevalence of poorly treated chronic pain is a major factor in the opioid crisis, and health inequities persist despite encouraging overall progress against many diseases.

There are formidable barriers to progress. Foremost among them is our limited knowledge of how the normal brain, spinal cord and nerves develop, process information, become susceptible to aging processes, respond and recover after injury, and integrate into the workings of a host of other body systems. Despite the challenges, over the seventy years since Congress established the Institute, research has driven remarkable advances in fundamental knowledge of how the nervous system works and in the diagnosis, treatment, and prevention of neurological disorders. When the Institute was born in 1950, how neurons generated electrical impulses or communicated with one another was still a mystery. Scientists can now explain these phenomena with intricate detail, leading to many advances for people with neurological disorders. Then as now, millions suffered from an astonishing variety of perplexing, troublesome, and debilitating signs and symptoms. Neurologists and neurosurgeons provided a diagnosis based largely on clinical observation and too often had little to offer beyond a diagnosis and a grim prognosis. Now, we are on the cusp of mapping the human brain in its exquisite complexity and can monitor the electrical activity of a million neurons simultaneously in an awake, behaving mouse. Dramatic advances in brain imaging, the advent of genetic testing, and development of many diagnostic tools augment clinical observation, often eliminating the years-long diagnostic odysseys that families endured in the past. Moreover, research has brought effective options when before there were none for common diseases including multiple sclerosis, Parkinson's disease, epilepsy, migraine, and acute stroke. Experimental treatments using combinations of devices, drugs, and rehabilitation, together with extraordinary persistence, have even enabled a few people paralyzed with spinal cord injuries to stand and take their first steps. Most recently a miracle gene therapy treatment for infantile spinal muscular atrophy, a fatal genetic disorder, has opened the door to an entirely new armamentarium to treat neurologic conditions. For stroke, breakthroughs in emergency treatments improve outcomes for many people, and, with major improvements in stroke prevention, the age adjusted stroke death rate has fallen by more than *seventy percent* since NINDS was established, according to the Centers for Disease Control and Prevention (CDC), saving millions of people from premature disability and death.

NINDS alone is not responsible for these advances. Many parts of the NIH, other government agencies, non-governmental organizations, and private sector companies in the United States and internationally have made substantial contributions to progress against neurological disorders. NINDS-funded research, however, has been pivotal, catalyzing progress across the public and private research ecosystem in many ways. Basic research on how the nervous system is organized and functions is funded predominantly by NIH and serves as the

foundation from which almost all clinical advances spring. For some advances, NINDS led research from early laboratory studies in animals through definitive clinical trials. In other breakthroughs, the Institute supported proof-of-concept demonstrations in experimental animals that sufficiently *"de-risked"* innovative therapeutic development strategies to attract private sector investment. NINDS research also identifies *risk factors* that guide prevention through epidemiological studies, develops *diagnostic tools and biomarkers* for targeting of interventions to people who will benefit, creates and distributes research *reagents and resources*, and validates clinical *outcome measures* to evaluate the effectiveness of interventions. NINDS supports training of the nation's neuroscience research workforce and disseminates timely and accurate information about neurological disorders to the research community, physicians, and the public. Most importantly, researchers in the public and private sector agree that NIH basic research on the nervous system in health and disease is the wellspring of progress.

Although we have come a long way, there is a long way to go. Drugs can treat the symptoms of Parkinson's disease, but do not slow the inexorable death of brain cells, nor has any treatment been proven to halt the progression of amyotrophic lateral sclerosis (ALS), Huntington's disease, or many types of dementia. No existing therapies are effective for about a third of people with epilepsy, prevention of epilepsy is still elusive, and all anti-seizure drugs carry troublesome side effects. Although advances in critical care have improved survival from severe traumatic brain injury (TBI), dozens of clinical trials of treatments have failed to improve long term outcomes for those who survive, nor do we fully understand the long-term consequences of mild TBI (concussions). The lack of effective non-addictive treatments for acute and chronic pain affects millions of people and is a major driver of the opioid crisis. After decades of progress, stroke rates are now increasing for some segments of our population, and substantial disparities persist. For hundreds of genetic disorders, many of which affect infants and children, we now know the gene mutations responsible, but have no disease modifying therapy. The imperative for progress is evident every day to people affected by neurological disorders, their families, and the physicians who treat them.

This Plan presents an overarching strategic framework to accelerate science that will result in improvements in quality of life for people with neurological disorders, and ultimately to prevent or cure these diseases. Planning at NINDS did not start and will not end with this Strategic Plan. This plan fits within the broad research goals of the Department of Health and Human Services Strategic Plan and the NIH Strategic Plan. Within the NINDS Strategic Plan's framework, several NINDS activities provide more detailed guidance. Indeed, assessing the landscape of public health needs and scientific opportunities, listening to stakeholders, identifying priorities, evaluating what is working, and deciding how best to move forward are integral to the Institute's daily activities. When appropriate to the state of the science, the Institute engages the research community and the public in more formal planning for specific diseases and on cross-cutting issues. NINDS also participates in NIH-wide and trans-agency planning on specific diseases and scientific topics and works with the National Academy of Sciences, other government agencies, and many private organizations on scientific workshops that guide priorities for the entire research community. Most importantly, the NINDS emphasis on investigator-initiated research and peer review constantly engages the insight and ingenuity of the Nation's research community to seek out public health needs and scientific opportunities.

In addition to priorities evident today, the NINDS Strategic Plan must prepare the Institute for tomorrow's unanticipated public health challenges and scientific opportunities. Past strategic planning could not, for example, anticipate the pain-opioid crisis nor the impact of the COVID-19 pandemic. The Institute is intensively engaged with its partners across the NIH in many aspects of COVID-19 research. Looking forward, the potential long term sequalae of infection will be a major focus in the coming months. NINDS also plays a leadership role

in the Helping to End Addiction Long term (HEAL) Initiative to advance non-addictive treatments for pain. Partnering with the National Institute of Aging and with special funding from Congress, NINDS has intensified efforts to understand and treat causes of dementia due to Alzheimer's disease, cerebrovascular disease, frontotemporal degeneration, Lewy body dementias, and mixed etiology dementias. Congress also enabled the development of transformative new research tools with the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative® through the 21st Century Cures Act to map, monitor and modulate brain circuits. The Institute's emphasis on foundational basic research, readily adaptable preclinical and clinical applied research programs, and sustaining a vigorous and diverse research workforce are among the overarching strategies that prepare NINDS for unexpected challenges and opportunities. NINDS is now poised to leverage powerful new genetic technologies, advances in data science and artificial intelligence (AI), and innovative research, diagnostic, and therapy device technologies that were all beyond the horizon during the previous strategic planning.

This NINDS Strategic Plan describes how the Institute will take on the currently manifest and yet unforeseen challenges of neurological disorders. The Institute's guiding vision is *a world that is free from the burden of neurological disorders*. Although the need is great, and the challenges daunting, I firmly believe real progress will most assuredly come from the dedicated scientists that NINDS funds. NINDS's role is to optimize the taxpayers' investment in neuroscience to maximize the impact and accelerate the pace of discovery.

To watch how this future unfolds, I invite you to monitor our website at https://www.ninds.nih.gov/. We will update this website as the Institute takes specific actions to implement the broad goals and strategies described in this plan.

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THE BURDEN OF NEUROLOGICAL DISORDERS

By some calculations of premature death, disability, and suffering, neurological disorders account for a greater burden than any other group of diseases (Nature Neurology 15:371-2, 2019) These diseases affect people of all ages—infants and children, young adults, and the elderly—and
Include some of the most common of all afflictions. For example:

- More than 25 million Americans have *chronic pain* every day and nearly 8 million people have pain so severe that it interferes with life activities.
- Almost 800,000 Americans have a *stroke* each year, 140,000 die, and stroke is the leading cause of serious, long-term disability in the United States.
- Traumatic Brain Injury (TBI) is the leading cause of death and disability in children and young adults. At least 5 million TBI survivors need long-term help for activities of daily living.
- 3.4 million people in the United States have *epilepsy*, 1 million are drug resistant, and 1 in 26 people will develop epilepsy in their lifetime.
- About 5 million people in the U.S. now have *dementia;* with the aging population this may reach 14 million by 2060.
- Migraine headache is the most common cause of missed work, affects 10% of all people and is three times more common in women.
- *Essential tremor, Parkinson's disease, dystonia, multiple sclerosis, autism, brain tumors, spinal cord injury, cerebral palsy, hydrocephalus*, and other common neurological disorders affect millions more.

Collectively *Rare disorders* also take an enormous toll. According to the NIH Office of Rare Diseases, of 7000 rare disorders overall, about 40 percent are neurological disorders and 90 percent of rare childhood disorders have major neurological effects.

About NINDS

The mission of National Institute of Neurological Disorders and Stroke (NINDS) is to seek fundamental knowledge about the brain and nervous system and to use that knowledge to reduce the burden of neurological disease. NINDS supports research that advances the diagnosis, prevention, and treatment of neurological disorders, that is, diseases of the brain, spinal cord, and neuromuscular system. Basic research to understand the nervous system in health and disease, which provides the foundation for public and private sector progress, is at the core of this mission.

NINDS is one of twenty-seven Institutes and Centers that make up the National Institutes of Health (NIH). The Institute has been a leader in the world of neuroscience for seventy years. Although the name of the Institute and the scope of its responsibilities have changed over time [*see **NINDS legislative history** box below*], NINDS has maintained its fundamental principles and core strategies since its inception.

The Institute's Extramural Research Program supports research at universities, medical centers, research institutions, and small businesses throughout the United States. The Extramural Research Program strongly emphasizes investigator-initiated research with rigorous peer review because of its long track record of driving progress. Augmenting investigator-initiated research, the Institute solicits research targeted to unmet public health needs, extraordinary scientific opportunities, and provision of resources that catalyze progress.

In fiscal year 2019, the NINDS budget of $2.274 billion supported 3,735 research grants and 657 research training grants across the United States. Research Project Grants, primarily investigator initiated, make up approximately 72 percent of the budget

The NINDS Intramural Research Program at the NIH campus in Bethesda, Maryland, has unique capabilities that complement extramural research. These include the John Edward Porter Neuroscience Research Center, which integrates the extensive NIH neuroscience research community across Institutes, and the NIH Clinical Center, the largest hospital entirely dedicated to research in the world. The Intramural Research Program is about 9 percent of the budget, supporting 47 principal investigators.

Throughout its history, in both extramural and intramural research, NINDS has emphasized basic research, while also supporting a full spectrum of innovative laboratory and clinical research to advance the field in diagnosis, therapy, and prevention for people with neurological disorders. Support for training of graduate students and post-doctoral researchers and for early stage investigators has been, and continues to be, a longstanding priority for NINDS.

NINDS collaborates with all parts of the NIH. In addition to many joint activities with individual Institutes and Centers, NINDS is a leader in NIH Blueprint for Neuroscience, which is a collaborative framework that includes the NIH Office of the Director and 14 NIH Institutes and Centers that support research on the nervous system. In recent years, NINDS has taken on leadership for large-scale trans-NIH Initiatives to which Congress has directed funding. These include the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative®, the Helping to End Addiction Long-term (HEAL) Initiative, and Alzheimer's Disease and Alzheimer's Disease Related Dementias (AD/ADRD) research. Beyond NIH, NINDS collaborates extensively with many other federal agencies, including the Departments of Defense and Veterans Affairs, the Centers for Disease Control and Prevention (CDC), the Food and Drug Administration (FDA), and the National Science Foundation. Similarly, NINDS interacts with the private sector via, for example, small business research (SBIR/STTR) programs, the Accelerating Medicines Partnership (AMP) for Parkinson's disease, the NIH HEAL Initiative, the Epilepsy Therapy Screening Program, and various clinical trials activities. These interactions are instrumental in advancing the NINDS mission.

NINDS legislative history

Congress, with the signature of President Harry S. Truman, established the Institute in 1950 as the *National Institute of Neurological Diseases and Blindness (NINDB)* through Public Law 81-692. In 1968, PL 90-489 renamed the Institute as the *National Institute of Neurological Diseases*, and the blindness program became the nucleus of NIH's newly established National Eye Institute. PL 90-636 then changed the name to the *National Institute of Neurological Diseases and Stroke*. In 1975 NINDS was renamed as the *National Institute of Neurological and Communicative Disorders and Stroke (NINCDS)*, reflecting the addition of a new program in communicative disorders. When the communicative disorders program became the nucleus of the National Institute of Deafness and Other Communication Disorders in 1988, NINCDS was renamed the *National Institute of Neurological Disorders and Stroke*, through PL 100-533, as it remains today.

Science: Support and perform rigorous and important neuroscience research.

To lay the foundation for progress against the multitude of neurological disorders, the Institute seeks to understand how the healthy brain, spinal cord, peripheral nerves, and neuromuscular system develop and carry out their functions, what goes wrong in disease, and why some people recover successfully but others do not. To reap the benefits from this basic research, the Institute must advance the diagnosis, treatment, and prevention of neurological disorders, both directly through NINDS supported research and indirectly by catalyzing private sector research and development. This broad spectrum of research is essential to improve our capability to prevent neurological disorders or to precisely provide the right care at the right time to each person when disorders occur. The following describes why each of these goals is vital to the Institute's mission and how the NINDS will support research toward these scientific goals.

Understanding the Brain, Spinal Cord, Peripheral Nerves, and Neuromuscular System

Understand the basis of nervous system function, from the perspective of molecules, cells, circuits, and whole organ systems.

Understanding the healthy nervous system is the foundation for public and private sector progress in preventing and treating all neurological disorders and for maximizing brain health. Although the potential long-term benefit of this basic research for people with neurological disorders is a strong motivation for researchers, scientists' natural curiosity about how the brain works and their insights into which questions may hold the key to fundamental advances often drives new discoveries with benefits that were completely unanticipated. A single major basic science discovery, whether from experiments in single cells, simple organisms, laboratory animals, or people, has the potential to elevate research for a host of different diseases. Fundamental studies on how genes and the environment guide brain development, on chemical signals by which brain cells communicate, on mechanisms of electrical activity in the brain and spinal cord, on supporting cells in the nervous system, on brain circuits that control complex behaviors, and on many other aspects of basic neuroscience underlie all of today's and tomorrow's treatments for neurological disorders. Similarly, the NINDS mission benefits enormously from basic research in many areas of science from across the NIH, National Science Foundation, and other organizations.

NIH is and will continue to be the world's leading supporter of basic neuroscience, with additional funding coming from disease organizations, private science foundations, and industry. Since the last NINDS Strategic Plan, NINDS has established an ongoing process to monitor the vigor of basic neuroscience research. The Institute has taken several actions to sustain these crucial lines of mechanistic, discovery research, including targeted funding for fundamental neuroscience, and published statements by the entire NIH leadership to the research community on the importance of basic research prompted by NINDS analyses. Engaging the diverse scientific perspectives and insights of thousands of scientists, engineers, and physicians to seek out the best opportunities to advance our understanding is the most effective path forward. Hence, NINDS will maintain its longstanding emphasis on investigator-initiated research, with targeted initiatives for individual investigators and teams to address opportunities or obstacles that investigator-initiated research is unlikely to address.

The BRAIN Initiative® , which is developing and applying new tools to understand how brain circuits process information, is the most ambitious basic neuroscience initiative ever undertaken. In 2019, a mid-course external review found that the Initiative is making significant progress on all major priorities of the plan, with many objectives accomplished, and unanticipated progress in some areas. Because of this remarkable progress, the review suggested that in addition to continuing on the productive path underway, the Initiative could now invest in a few large scale, transformative projects that might propel neuroscience far into the future. After assessing the feasibility and impact of potential transformative, the Initiative is focusing on three projects: 1) a comprehensive atlas of cell types in the human brain ("parts list"); 2) creating a "wiring diagram" of the

mammalian brain, beginning with synapse level "connectome" in mouse brain and the "projectome" of long range pathways in human and non-human primate brains; and 3) developing an armamentarium of tools and resources to precisely access and modulate specific brain cell types, with the ultimate goal of precision medicine applications in humans.

Understanding the Basic Mechanisms of Neurological Disorders

Understand what causes neurological disorders; how alterations at the genetic, molecular, cellular, and systems levels underlie symptoms and disease progression, and the basis of recovery and resilience, that is, why some people recover much better than others.

Understanding what causes each neurological disorder, drives its progression, and the factors that determine recovery are all essential for developing interventions to prevent or treat these diseases. Countless examples illustrate the value of understanding the underlying biology through the use of model organisms, tissue and cell platforms, and human subjects research for developing rational strategies to treat disease. Among these, for example: the discovery that dopamine, a brain signaling molecule, is lost in Parkinson's disease led therapy with the drug L-dopa, and studies on changes in brain movement control circuits led to Deep Brain Stimulation therapies. The recognition that many brain cells can be rescued if blood flow is restored rapidly following stroke led to effective emergency stroke treatments. Finding that the immune system attacks the insulating covering of nerve fibers in multiple sclerosis was pivotal in developing today's drugs that reduce symptoms and slow disease progress. The recent breakthroughs in gene targeted therapy for spinal muscular atrophy shows a path forward from recognition of underlying genetic causes for many other diseases.

As for basic research on the healthy nervous system, funding the highest quality investigator-initiated research grants will remain the Institute's core strategy for understanding the causes and consequences of neurological disease. Based upon input from our stakeholders via requests for information and workshops, NINDS will also target solicitations for grants to address salient opportunities or obstacles to progress that may not be addressed by investigator-initiated research. Several ongoing programs in epilepsy, traumatic brain injury, Parkinson's disease, ME/CFS, dementias and cross-cutting resources illustrate these strategies.

Seeing More Precisely – Biomarkers and Outcome Measures

Develop and validate biomarkers and outcome measures that stimulate therapy development and improve patient care.

Biomarkers are measurable indicators of normal biological processes, disease progression, or responses to therapeutic interventions. These "fit for purpose" measures improve care or accelerate the development of better therapies. By enabling researchers and physicians to *see more precisely* critical aspects of disease biology and response to treatment in individual patients, these indicators, together with development of more targeted therapies, can help get the right care to the right patients at the right time. Biomarkers may, for example, enable early detection of disease, identify patients who are most likely to benefit from a treatment, indicate whether a candidate drug has engaged the biological target it is designed to seek out, or determine whether underlying disease is progressing. Outcome measures assess the effects, both positive and negative, of an intervention or treatment on patients and are essential for testing the effectiveness of treatments. They include patient-reported quality of life assessments, laboratory tests of many types, and standardized clinical ratings by physicians or other health care professionals. Biomarkers and outcomes measures provide an essential foundation for precision medicine.

Basic research on disease mechanisms and observations by clinicians provide the initial impetus for the discovery and development of diagnostics, biomarkers, and outcome measures. However, the path from a potential marker to one with the demonstrated reliability and validity to be useful in therapy development or patient care requires a different approach than discovery research. Several targeted NINDS biomarker programs systematically will build on opportunities arising from basic research or clinical observations to carry out the rigorous, focused development and validation of biomarkers and outcome measures that are necessary before they can be relied upon in drug development programs and clinical trials. NINDS will continue to improve and expand its biomarkers programs to capitalize on emerging opportunities.

Improving Treatments

Accelerate the development of treatments for neurological disorders that precisely target disease biology, for each person, at the optimal time to improve the quality of life, complementing private sector research and development.

NINDS basic research identifies targets for therapeutic interventions, that is, research reveals the key steps in the disease process at which a drug or other therapy might act to counteract disease with minimal unwanted effects. Basic research also develops animal models, research reagents, diagnostics, biomarkers, and outcomes measures, all of which are essential for developing therapies. Beyond basic research, NINDS and the private sector have complementary roles in the development of treatments for neurological disorders, both in the preclinical (laboratory) and clinical stages. In the last several years, several large pharmaceutical companies have withdrawn entirely from development of therapies for nervous system diseases because of the enormous challenges entailed in developing drugs for the brain. The Institute will continue to monitor changes in private sector strategies and adjust its strategy accordingly to optimally complement, rather than compete with, the private sector.

Intervening more precisely – support preclinical development of small molecule drugs, biologics, and device therapies that act how, when, where, and on whom they can be most effective.

NINDS will continue to support translational research from early preclinical therapy development through first in human studies for small molecule drugs, biologics (including cell and gene targeted therapies), and devices. The goal is to design interventions with mechanisms and delivery that is precisely targeted to intervene in the disease process how, when, where, and on whom the treatments can be most effective. The more innovative a therapeutic strategy and the greater the risk for failure, the further NINDS is likely to advance development and thereby *de-risk* the future investment by industry.

Although basic research scientists are eager to see their findings translated into therapies that can help people, few academic scientists have the expertise and resources to pursue such development in their own laboratories. Thus, in addition to supporting translational research via traditional investigator-initiated grant programs, NINDS drug and biologics programs will provide expertise and contract-based therapy development resources that are not usually available to academic and small business researchers. Similarly, beginning fifty years ago NINDS pioneered the development of devices to treat neurological disorders, and the Institute will continue its longstanding support for the development, optimization, translation, and first-in-human testing of therapeutic and diagnostic devices for disorders that affect the nervous or neuromuscular systems. Milestone-gated funding for more advanced therapy development projects enables NINDS to be an effective steward of resources, shifting funds to the most promising opportunities as warranted by progress. Information about all of NINDS's translational research programs can be found at https://www.ninds.nih.gov/Current-Research/Research-Funded-NINDS/Translational-Research .

The recent advent of successful gene targeted therapies for a few rare genetic disorders heralds a new era for many devastating and heretofore untreatable neurological disorders, and NINDS will act aggressively to take advantage of these emerging opportunities. Many genetic neurological diseases are ultra-rare, in some cases only affecting a few people in the world. However, these disorders often have a devastating impact and collectively they impose a large, unmet need. The NINDS URGenT Network, now under development, will rapidly develop tailored therapeutic interventions using precision medicine platforms for the treatment of serious, life-threatening ultra-rare diseases. Although the challenges are daunting, a few remarkable examples have demonstrated that it is possible to develop therapies for ultra-rare disorders rapidly enough to benefit patients. The private sector is unlikely to take on this challenge, and thus this program is imperative for the Institute.

Testing more precisely – support clinical research that advances innovative treatments, new uses of existing interventions, comparison of the effectiveness of treatment options, preventive interventions, rehabilitation strategies, readiness for clinical trials, and other critical needs that complement private sector research and development

NINDS clinical research complements private sector clinical research and development. In addition to testing the safety and efficacy of innovative treatments for neurological disorders and stroke, the Institute supports epidemiological studies, testing of preventive interventions, comparison of existing therapies, exploration of new uses for existing treatment s, evaluation of rehabilitation interventions, validation of biomarkers and outcomes measures, and investigation of the causes of neurological disorders.

NINDS will continue to support early and advanced phase clinical trials and comparative effectiveness research of treatments and prevention for neurological disorders, as well as large epidemiological studies. NINDS clinical research infrastructure, including clinical research networks, improve the efficiency and effectiveness of clinical trials, and the Institute will take advantage of innovations, including adaptive trial designs and data analytics, to carry out these studies most efficiently and effectively. The Institute also supports studies on the natural history of disease that will inform interventional trials. The Institute's Common Data Elements project works with research and patient advocacy communities to develop data standards for neurological disorders that facilitate data sharing in a meaningful way and enhance data integrity. Interoperability is crucial as potential applications of data analytics and artificial intelligence interrogation of clinical data become more useful. Information about NINDS's clinical research programs, including currently available tools, can be found at https://www.ninds.nih.gov/Current-Research/Research-Funded-NINDS/Clinical-Research.

Preventing Neurological Disorders

Sustain the progress in stroke prevention and extend progress in prevention for neurological diseases beyond stroke, building on basic research advances in epilepsy, TBI, neurodegenerative diseases, chronic pain, neurodevelopmental, and other neurological disorders to develop effective interventions.

Progress in preventing stroke has had a major impact on public health. However, despite reductions in stroke rates across all ethnic groups, significant stroke disparities persist across population groups, and stroke rates are apparently rising in younger persons, after decades of improvement. Furthermore, the progress in preventing stroke has been the exception; there has been much less progress in preventing other neurological disorders. Basic research now underway provides the foundation for preventing other diseases, for example, by understanding why acute pain becomes chronic for some people and how brain trauma can result in epilepsy, and there are encouraging results from recent trials showing that progress in controlling major stroke risk factors may also slow the development of dementia. There is also increasing attention to the role of the

environment, including stress, environmental chemicals, and a variety of other factors, in many neurological disorders. Thus, both continuing the long-term progress in preventing stroke and extending progress to other neurological disorders will remain high priorities for NINDS in the immediate future.

Advancing Health Equity

Advance health equity for people of all ages, races, ethnicities, sexes, genders, socioeconomic groups, and geographic regions, guided by the recommendations of the ongoing NINDS health equity planning process.

Neurological conditions affect people of all ages, races, ethnicities, sexes, and genders, and can differentially affect individuals based upon these characteristics, as well as in association with geographic, socioeconomic, or other factors. The NINDS is committed to understanding what drives health disparities across the lifespan and to reducing the burden of neurological disease borne by underserved groups of society, including racial and ethnic minorities, rural, and socioeconomically disadvantaged populations, by funding a spectrum of research from basic science through clinical studies and through public information programs. Because improving health equity is so important, and progress has been so challenging, the Institute has established a new Office of Global Health and Health Disparities in the Division of Clinical Research.

Led by this office, the Institute has embarked on a planning process focused on health equity, within the broader framework of the overall NINDS Strategic Plan. NINDS is seeking extensive stakeholder input to inform our research investments in this space. A Working Group of NANDS Council with several notable experts in health disparities research has been charged with providing scientific guidance on how best to advance research on neurological health disparities and health equity, with an emphasis on addressing biologic, socio-demographic, economic and other social determinants of health. Additionally, a recent Request for Information (RFI) to gather information from extramural researchers and the public on known areas of disparity/inequity in neurological disease, treatment, and provision of services across the lifespan yielded nearly 150 responses. The planning effort will culminate in a public 2-day workshop, scheduled for September 2021, as well as published reports of the planning process, findings, and research recommendations.

Cross-cutting Strategies

Several core strategies are important across all NINDS scientific goals, from basic studies on the nervous system in health and disease through development of diagnostics, treatments, and prevention.

Rigor and Transparency

Promote scientific rigor and transparency throughout all NINDS programs and policies

All scientific progress requires rigorous, creative, and high-quality studies that build upon validated prior discoveries. Many scientific reports, however, do not transparently describe the design, methods, or analysis of experiments so that others may adequately assess their quality. Potential flaws in the practice of science that cannot be evaluated based on published reports undermine future research efforts. To maximize the value of the taxpayers' investment in our research, NINDS programs and policies must ensure that studies are conducted rigorously and reported transparently.

NINDS has been a leader within NIH and the research community in promoting rigor and transparency. In 2012, a major Institute workshop convened stakeholders from academia, industry, academic publishing, and government toward this end. That workshop, subsequent meetings, establishment of the NINDS Office of Research Quality (ORQ) and NINDS Rigor Working Group (NRWG), and several activities of this group have improved attention to rigor and transparency within NINDS, across the NIH, and in the research and publishing community.

Most recently, NINDS surveyed current training practices and convened a workshop that brought together subject matter experts with those capable of evaluating current educational practices to discuss how best to impart knowledge about the fundamental principles of rigorous research. Informed by this discussion, NINDS is developing a framework for advancing rigorous research that will include the formation of an educational platform on the principles of rigorous research as well as the establishment of networks of rigor champions in the research community who will contribute to the development of the educational platform and work together to change the culture of science to favor high quality research over novel but unsubstantiated findings[1].

Investigator-initiated Research

Maintain an emphasis on investigator-initiated research, balancing short and long-term investments, small and large-scale efforts, and revolutionary (high-risk, high reword) and evolutionary (high quality, more incremental) approaches

The NINDS will continue to rely primarily on investigator-initiated research to advance fundamental understanding of the brain, spinal cord, and neuromuscular system. Curiosity-driven, investigator-initiated research is especially well-suited to supporting discovery research, which engages researchers' insights about how the brain works and pursues new avenues revealed by unanticipated findings. There are myriad unsolved questions about the nervous system that research is unravelling at multiple levels of analysis, from molecules to the neural network dynamics underlying behavior of whole organisms, bringing to bear knowledge and methods from a wide spectrum of scientific, engineering, and medical disciplines. In this rapidly evolving landscape of opportunity, engaging the diverse perspectives and insights of thousands of scientists, engineers, and physicians to seek out the best opportunities to advance our understanding has been and continues to be the most effective path forward.

NINDS provides a variety of funding opportunities for investigator-initiated research with differing review criteria, funding levels, durations, component structures, and other characteristics designed to support small to large-scale research efforts, collaborations, and team science, including potentially "revolutionary" (high risk/high reward) research and "evolutionary" (high quality, more incremental) research that is also essential for progress. Similarly, the Institute supports both short term, exploratory studies and investigations which, by their nature, must be long term investments. For example, the Research Program Award (R35) grants can extend for eight years and support an investigator's overall research program rather than a discreet set of specific aims. Thus, the Research Program Award is especially suitable for innovative and long-term basic research.

Because individual investigators have historically driven progress, especially discovery research, in neuroscience, NINDS policies will maintain the vigor of the neuroscience research community, ensuring that as many laboratories as possible can be adequately supported. Investigators are especially vulnerable early in their careers, and NINDS will continue its aggressive policies (see, for example, funding strategies) to ensure that they have a fair chance. Similarly, the challenges of neuroscience dictate that NINDS must draw its workforce from the full breadth of the nation's talent pool, as discussed in the training and diversity sections of this plan.

To support the development of biomarkers, preclinical development of therapies, and large clinical studies, NINDS often relies upon targeted funding announcements with review criteria and grant characteristics designed to meet the special needs of more applied research and development, including milestone-based funding. Although these programs rely upon solicitations, the Institute also designs many of these targeted funding opportunities with a similar spirit to traditional investigator-initiated discovery oriented research programs by not focusing on specific diseases or approaches, but rather providing broad flexibility for

[1] Koroshetz et al., Framework for advancing rigorous research, Elife DOI: 10.7554/eLife.55915

investigators and teams to address needs within the NINDS mission and pursue the most promising opportunities for progress.

NINDS will continue to examine which funding mechanisms are effective for all types of research, including team science, and to modify these programs as warranted.

Diversity and Inclusion

Enhance the diversity and inclusiveness of our workplace and the neuroscience research workforce

NINDS has long recognized that achieving diversity in the neuroscience and biomedical research workforce is critical to realizing our research goals. Enhancing the diversity and inclusiveness of our workplace and the broader neuroscience and biomedical research workforce will enhance our overall creativity and ability to adapt. All of neuroscience benefits if we can engage all segments of society in our efforts to reduce the burden of illness due to neurological disorders and stroke.

As the U.S. population becomes increasingly diverse, reflecting that diversity in the biomedical research workforce is vital to the scientific enterprise and the NIH research mission. Diversity affects performance, creativity, and other organizational drivers of success (see Science of Diversity articles), and there are compelling reasons for NINDS to promote a diverse workforce and increase participation by underrepresented groups. Advancing diversity is expected to produce several tangible and overlapping benefits, including the recruitment of the most talented researchers and staff from all groups; higher quality research and training environments; broader perspectives in setting research priorities; more people from diverse backgrounds participating in clinical research studies; and a greater capacity to address health disparities.

At NINDS, we view diversity, inclusion, and equity as cross-cutting issues that are an essential part of the way we work to fund, conduct, and support research. NINDS has a comprehensive strategy to enhance diversity at all stages of the biomedical research career trajectory which includes targeted training programs, an assessment of diverse perspectives in our select pay process, and an integrated approach to increase workforce diversity across the Institute. Moreover, NINDS encourages activities to support diversity by all staff, throughout all corners of the Institute. To foster internal input and involvement, the Diversity Working Group (DWG), composed of program directors representing every scientific portfolio at NINDS, meets monthly to discuss issues related to diversity and to implement strategies for enhancing diversity in the neuroscience workforce.

Team Science

Support innovative team science approaches for emerging research opportunities of broad scope and complexity

Progress has brought an ever-increasing knowledgebase and armamentarium of technological capabilities to neuroscience. With this has come a trend toward increasing collaboration among scientists. To a large extent, researchers, as always, form temporary alliances to take on specific experimental challenges, and NINDS grants to individual investigators provide the flexibility to do so. For some types of research, such as clinical trials and drug development, team science has long been the norm, and NINDS has specific programs that address those needs. Team science has been less common in basic neuroscience research, although there are notable exceptions, including programs currently underway within the BRAIN Initiative® that bring together scientists and engineers from across several disciplines. NINDS is currently exploring programs to support team science that are currently underway across the NIH and beyond. The Institute is learning from these programs and assessing whether current NINDS grant mechanisms are optimal to support emerging research neuroscience opportunities of broad scope and complexity that may require a sustained team science approach. Beyond grant mechanisms, changes in the culture and reward systems of research may be necessary to fully realize the

potential of team science to advance the NINDS mission, and NINDS will work with the research community toward that end.

Neuroethics

Identify and navigate ethical challenges and implications arising from neuroscience by supporting neuroethics resources for the neuroscience community and fostering research and training in neuroethics

Advances in science can present ethical challenges. Existing ethical frameworks may require interpretation in new contexts as science moves forward. For neuroscience, this can be especially trenchant because of the brain's centrality to fundamental aspects of ourselves. As a specialization of bioethics that focuses on neuroscience, neuroethics can partner with neuroscience to scan the horizon for ethical challenges, identify and explore the underlying values and assumptions of diverse stakeholders, and assist in mitigating potential ethical concerns. Thus, neuroethics can empower neuroscience research and inform the design, conduct, interpretation, and application of research.

The BRAIN Initiative® has a robust neuroethics component that includes a neuroethics research portfolio and an NIH-external Neuroethics Working Group that serves to provide BRAIN with input relating to neuroethics. Building on this exemplar, NINDS has established a new NINDS Neuroethics Program that will work with NIH staff and stakeholders to identify and navigate ethical challenges and implications of neuroscience research programs and discoveries, and to facilitate neuroscience progress.

Patient Engagement

Increase patient engagement in all appropriate aspects of NINDS research to better address the priorities of patients and their families and to improve the efficiency and effectiveness of research

NINDS will engage patients and their families in setting priorities, planning, and conducting research. The priorities of patients and families may not always be apparent to those not experiencing the problems that a disease presents. Thus, for example, surveys of people with spinal cord injuries have revealed that walking may not be the highest priority; Parkinson's patients have stressed the importance of non-motor symptoms on their quality of life; and the epilepsy community has noted the impact of co-morbidities, the side effects of current drugs, and the concern about Sudden Unexpected Death in Epilepsy (SUDEP). Patient advocacy organizations also provide insight that can greatly improve the efficiency and effectiveness of research, not only in recruiting for clinical studies, but also in many other aspects of studies involving human participants, including reducing barriers to participation.

NINDS has some important activities in place to support engagement, as discussed in the Communications section of this plan. Notably, the annual NINDS Nonprofit Forum (NPF) is planned by a rotating Executive Committee that includes numerous patient advocacy groups. In 2020, an NIH HEAL Initiative virtual workshop "Engaging Patients in the Research Process" explored the benefits for research of engaging patients in the planning and oversight of clinical research and patient recruitment for pain research, considering successful examples from other areas of medical research that are relevant across many areas of NINDS research. NINDS is committed to increasing patient engagement in all appropriate aspects of clinical research across all areas of the Institute's mission.

Technology Access

Ensure that the researchers throughout the scientific community can exploit emerging technologies, resources, and knowledge, including those emerging from the BRAIN Initiative®

New technological research capabilities are emerging from NIH investments, most notably the BRAIN Initiative®. Among these, for example, are advanced microscopy methods, automated behavioral analysis tools, and large scale "-omics" analyses that can potentially be applied to many research questions but require substantial

resources. To maximize the effectiveness of all NINDS research, the Institute must ensure that these capabilities are widely available. Furthermore, a growing proportion of the NINDS budget is directed to special programs including the BRAIN Initiative®, the NIH HEAL Initiative, and AD/ADRD research. NINDS will coordinate management of these investments to maximize impact and efficiency.

NINDS will also continue to provide scientific resources that enhance the capabilities of investigators to carry out high quality research, while minimize unnecessary duplication of efforts and taking advantage of economies of scale. Current NINDS resources, for example, provide access to genetically modified mice, human post-mortem brain tissue and related biospecimens, genetic samples and cell lines, and validated monoclonal antibody reagents. As the scientific and technological landscape changes, the Institute must continually assess what resources are best provided centrally which are more appropriately focused on individual laboratories or institutions.

Models for Neuroscience Research

Maintain support for the full spectrum of neuroscience research models

Looking back at the paths of discovery that led to successful therapies for neurological disorders reveals that a wide variety of experimental models were essential in their research and development. Humans and simpler organisms share many fundamental aspects of biology. Simpler organisms provide extraordinary opportunities for scientific investigations. For example, studies in the fruit fly, *Drosophila melanogaster*, revealed fundamental principles of genetics, and the worm *C. elegans* helps scientists understand neuronal development because it has only 302 nerve cells, which have been completely mapped, compared to the 80 billion nerve cells in the human brain. Similarly, genetic engineering has enabled scientists to study basic capabilities like memory and to model the mechanisms of key steps in disease by creating mice with the mutations that cause human disorders. For some types of studies, non-human primates are critical model organisms because of their anatomical, physiological, and behavioral similarity to humans. NINDS will continue to support research across the full spectrum of models, as appropriate to the scientific questions, with careful attention to ethical conduct of research and oversight frameworks. The Institute also will continue to support novel research approaches that may reduce the necessity for using animal models and improve the efficiency and effectiveness of research. This includes, for example, research on cells and organoids derived from human induced pluripotent stem cells, computer modeling, and an array of technologies, including advanced imaging techniques, that can non-invasively study the structure, function, and biochemistry of the human brain.

Data Sharing and Data Science

Develop and implement policies, infrastructure and resources to take advantage of data science and foster sharing of high value data among the research community

The NIH policy on data sharing notes that sharing scientific data helps validate research results, enables researchers to combine data types to strengthen analyses, facilitates reuse of hard to generate data or data from limited sources, and accelerates ideas for future research inquiries. As NIH implements this policy, which requires all NIH funded research to include data management and sharing plans, the amount, emphasis, complexity, and cost of creating, curating, harmonizing, storing, accessing, and reusing neuroscience data will grow substantially in the next 5-10 years. As data from emerging technologies grows in scale and more powerful analysis tools emerge, issues for the research community more broadly will have a major impact on the effectiveness of NINDS. Among these for example are ensuring appropriate rewards and credit for creating and sharing data; determining how best to take advantage of burgeoning progress in the related areas of artificial intelligence and machine learning, which Institute investigators are rapidly applying across many areas of basic and applied research; and how to foster a neuroscience workforce trained in cutting-edge data practices.

NINDS is currently developing an NINDS Data Science Plan, which will be aligned with the NIH Strategic Plan for Data Science and guide the Institute in developing data sharing principles, policies, infrastructure and resources to maximize the opportunities and cost effectiveness of its research investments

Collaboration and Partnership

Fostering productive collaborations and partnerships in their many forms is a major strategic priority across all scientific goals, both with respect to NINDS programs and for research projects themselves.

Collaborations and partnerships of many kinds are essential for advancing the NINDS mission and are becoming ever more crucial as science advances and reveals intersections between the interests of NINDS and other organizations and among researchers with different areas of expertise. Integration among NINDS extramural programs is essential to ensure the seamless flow of insights among basic, preclinical, and clinical research. The Intramural Research Program provides an environment for collaborations across Institute, disciplinary, and basic-clinical boundaries that has historically been a strength of the program. The NIH Blueprint for Neuroscience provides a framework for collaboration and coordination among the many parts of the NIH whose missions intersect the brain and nervous system. Among the many reasons for increasing collaboration of NINDS with all parts of NIH is a growing recognition of the importance of studying how the brain (and nervous system generally) influences and is influenced by other regulatory and organ systems in the body. NINDS has several longstanding collaborations with the Food and Drug Administration, the Centers for Disease Control and Prevention, the Department of Defense, Department of Veterans Affairs, and other Federal agencies. Beyond these ongoing relationships, the BRAIN Initiative®, Helping to End Addiction Long-term (HEAL) Initiative, Accelerating Medicines Partnership Parkinson's Disease (AMP-PD), and other recent activities are paving the way for more productive interactions with industry, non-governmental organizations, and agencies with which NINDS has less commonly collaborated.

NINDS Intramural Research Program

Exploit the NINDS Intramural Research Program's unique capabilities to advance the NINDS mission

Because it is not tethered to extramural grant review cycles, NINDS Intramural Research Program (IRP) is in a unique position to capitalize on both long-term and high-risk, high-reward science that is more difficult for the extramural community to undertake. Additionally, the flexibility of the intramural funding structure allows the NINDS IRP to rapidly respond during public health emergencies. To fully realize its potential, the NINDS IRP is engaged in a detailed planning process to identify areas of science and scientific resources that should be augmented within the NINDS IRP; enhance clinical care within NINDS; increase collaboration across the basic to clinical spectrum; and with other Institutes and extramural researchers; and ensure that evaluations of faculty, staff, and trainees reward high quality, innovative research and excellence in training and mentoring.

Training and Workforce Diversity: Fund and conduct neuroscience research training and career development programs to ensure a vibrant, talented, and diverse neuroscience work force.

Today's research trainees are an integral part of the neuroscience research workforce, and they will become tomorrow's leaders in neuroscience discovery and innovation. Excellent mentorship and training are critical to the development of exceptional future scientists and are therefore critical to the NINDS mission. NINDS supports neuroscience research training and career development through individual, institutional, and national awards, and the NINDS Intramural Research Program provides opportunities for research training on the NIH campus in Bethesda, MD. These extramural and intramural programs span basic, translational, and clinical neuroscience research training initiatives at multiple career stages, from summer experiences for high school and undergraduate students to mentored career development awards for new research faculty. Rigorous research

training, strong mentorship, and ample opportunities for professional development provide trainees with a foundation for pursuing a wide range of careers in academic or industry research as well as teaching, science policy, science writing, research administration, among others.

NINDS is committed to supporting a diverse and inclusive neuroscience workforce. The objectives related to diversity in this section of the plan focus mainly on training and career development, as one important part of a cross-cutting strategy to promote a culture of inclusive excellence and diverse representation. NINDS intends that all trainees in the NINDS intramural research program or supported with extramural NINDS funds, whether through specific NINDS training and career development programs or research project grants, receive excellent scientific training, professional development, and mentorship. NINDS can directly influence training quality in the intramural research program and in extramural programs designated for research training and career development, yet many more trainees are supported through extramural funding for research projects, where this influence is less direct. However, institutions and investigators receiving support through training mechanisms overlap with those receiving research funds, creating a bridge for broader impact. In addition, there are other means for NINDS to endorse the view that excellent training, mentorship, professional development, diversity, and inclusive environments are essential for high-quality research and a thriving neuroscience community. Through the following objectives, NINDS aims to enhance its efforts in research training and workforce diversity to keep pace with increasing complexity in neuroscience research and to address current and emerging challenges and opportunities.

Scientific Training

Support training across the breadth of basic, translational, and clinical neuroscience research to foster advances and innovation.

NINDS supports and provides training across the spectrum from fundamental basic science to translational and clinical research and must continue to align programs to unique and evolving training needs and challenges in these areas. Scientific advances often occur when investigators recognize the relevance of discoveries made in an entirely different discipline. Moreover, investigators will often be best positioned to make important discoveries when they understand the uses of a wide array of methods and technologies. Therefore, training in neuroscience research must extend beyond proficiency in an individual line of study so that investigators are prepared take on new directions, adopt and develop new approaches, and work collaboratively and in teams to share expertise and resources. Consequently, NINDS will continue to empower the research community to direct training to areas of need and opportunity as well as incentivize and support broad, cross-disciplinary training in both content and technology that will seed innovation, collaboration, and novel discoveries. NINDS will also implement strategies for training in data science, neuroethics, health disparities, and other cross-cutting or emerging approaches with the potential for wide-ranging application to neuroscience research. Finally, NINDS will work to enhance coordination and awareness about programs and policies for research training.

Strengthen training in principles of rigorous research, experimental design, and quantitative skills.

Rigor in scientific research, sound experimental design, and quantitative analytical methods are essential to continued progress in neuroscience. NINDS has championed efforts to promote rigor in the biomedical research community and recognizes that research training programs can be an effective way to improve the rigor of scientific research conducted by trainees as well as established investigators who serve as training mentors. For example, NINDS has incorporated requirements in extramural institutional training programs for intensive, formal training in experimental design, statistical methodology, and quantitative literacy and also provides funding to these programs to integrate a statistician into programmatic activities and to fund workshops on

quantitative analysis. However, opportunities remain for strengthening these efforts across neuroscience research training within both the NINDS extramural and intramural communities. NINDS will enhance the effectiveness of training in principles of rigorous research, experimental design, and quantitative skills by expanding emphasis in review, evaluation, and interactions with the research community. In addition, NINDS will work to improve, develop, and disseminate resources to facilitate training in these areas for researchers and research support staff at all career stages for continuous learning.

Diversity and Inclusion

Support programs and policies that address challenges to achieving diversity and inclusion.

Scientific discovery and innovation depend on a pool of highly talented scientists from diverse backgrounds, and NINDS has long recognized that achieving diversity in the neuroscience workforce is critical to realizing our research goals. NIH encourages institutions to diversify their student and faculty populations to enhance the participation of individuals from groups that are underrepresented in the biomedical, clinical, behavioral, and social sciences, including racial and ethnic minority groups, individuals with disabilities, individuals from disadvantaged backgrounds, sexual and gender minorities, and others disadvantaged by circumstances that have negatively impacted their educational opportunities (Notice NOT-OD-20-031). The NINDS Office of Programs to Enhance Neuroscience Workforce Diversity (OPEN) coordinates NINDS extramural diversity activities spanning the training pipeline. These include innovative programs for neuroscience education outreach at the college and even high school level and training and mentoring initiatives that specifically promote career progression across critical transition points for trainees and junior faculty. In addition, NINDS recently expanded criteria for funding meritorious grant applications beyond the payline to consider the value of diverse perspectives a project or investigator adds to the field or workforce. The NINDS IRP also coordinates and participates in programs that bring diverse students and research trainees to intramural NIH laboratories for research training experiences.

However, gaps remain for achieving diversity, including for racial/ethnic diversity at the level of NIH research project funding (R01s) and NINDS intramural faculty, which may result from multiple complex biases and disparities that create disadvantages to career success. To further enhance its diversity and inclusion efforts, NINDS will implement new and continued strategies that reduce barriers to career advancement for vulnerable and marginalized researchers and support increased diversity across all programs and career stages. NINDS will support programs and policies that promote success in independent research careers, such as the Diversity K award and the Common Fund FIRST programs, as well as create programs and policies that retain diverse trainees and faculty in the NINDS IRP. NINDS will also partner with other NIH Institutes, Centers, and Offices, as well as professional societies, institutions, non-profit organizations, and others with shared and complementary goals regarding diversity.

Support programs and policies that promote inclusivity and cultural competence.

A diverse research workforce engages different perspectives, creativity, and individual enterprise to address complex scientific problems. However, retaining diverse talent will require environments that embrace and value different perspectives and contributions and a research workforce that is culturally competent, or able to understand, communicate, and effectively interact with people across cultures and backgrounds. In order to tap into the full potential of an increasingly diverse workforce, NINDS must support and promote inclusion – active, intentional, and ongoing engagement that increases cultural competence and awareness, empathic understanding of the complex ways individuals interact within systems and institutions, and feelings of belonging. NINDS will promote inclusivity in intramural and extramural environments through strategies to

create and support a positive culture that will reduce incidents of harassment, microaggressions, and unconscious bias. NINDS will also integrate diversity and inclusion goals in processes and programs that are not just diversity-targeted, address the potential for bias in program and scientific review, and provide opportunities for training that expands awareness and knowledge of barriers to diversity and inclusion. Finally, NINDS will communicate and foster the value of diversity and inclusion across all programs and career stages and evaluate the outcomes of our efforts.

Mentorship

Promote mentorship as an essential component of research training and workforce development.

Scientists consistently rate great mentorship as the most important factor in their success. Likewise, good mentors know that strong mentorship benefits their own research and science overall, as well-trained individuals with confidence to take on challenges will be more creative and productive. Mentors pass on scientific wisdom, advise on designing experiments and analyzing data, and help trainees decide when to continue a difficult project. They give mentees opportunities to become known in the scientific community, help them learn to obtain funding and communicate with journal reviewers and editors, and support them in exploring career paths and navigating transitions. Mentees, too, have important roles and responsibilities in successful mentoring relationships. Broadly, effective mentorship helps mentees mature intellectually and professionally, develop and maintain confidence, and persevere in the face of obstacles. For all these reasons, mentorship is also critical for enhancing workforce diversity.

NINDS emphasizes the need for strong mentorship in extramural and intramural training and has invested in programs and resources that support effective mentoring practices and relationships. Leaders of NINDS-funded institutional training programs are expected to provide oversight of mentorship to ensure that all trainees and scholars obtain appropriate guidance and support, as well as finish their training on an appropriate timeline. To promote intellectual ownership for trainees, NINDS encourages creative projects for individual fellowship (F) and career development awards (K) that are generated via intellectual collaboration between mentees and mentors. Moreover, NINDS requires that all K awardees have ownership of their projects, which they can take with them without competition from their mentors. In 2018, NINDS created the Landis Award for Mentorship to recognize outstanding mentors, as well as signal to the community the importance that NINDS places on contributions to research through mentorship as well as scholarship.

To ensure that the entire workforce has access to superior mentorship, NINDS will strengthen emphasis on high-quality mentorship across NINDS research training programs and support the development, coordination, and dissemination of resources and tools to facilitate mentorship training for mentors and mentees. NINDS will also continue to reward and incentivize dedication to excellence in mentorship and will strive to communicate the value of mentorship across all programs and career stages.

Professional Development

Foster a holistic approach to professional development for the neuroscience workforce.

Professional readiness and success for the neuroscience workforce depend on more than scientific knowledge and research skills. In recent years, training programs in biomedical research have embraced the importance of professional development encompassing areas such as communication, leadership, management, networking, and exposure to a variety of potential career paths. NIH has been a champion of a more holistic approach to professional development, as demonstrated by efforts such as the NIH Broadening Experiences in Scientific Training (BEST) initiative and the broad array of services provided the NIH Office of Intramural Training & Education (OITE). NINDS expects strong commitments to professional development in its extramural programs for training and career development and supplements activities offered by funded institutions with workshops

Diversify stakeholder interactions and better understand all stakeholders' needs.

NINDS regularly engages with different stakeholders and strives to better understand their needs. Despite several successes, there are opportunities to build upon these efforts. Diversifying who we engage with to reach organizations and individuals we may be missing is an especially high priority. NINDS will continue to plan and conduct ongoing outreach activities tailored to the needs of different stakeholders, while exploring new venues and mechanisms to enhance the breadth and diversity of input.

Amplify messaging through traditional and emerging communication platforms and enhanced partnerships.

NINDS uses a wide variety of communication tools and platforms, including websites, traditional media (e.g., press releases and science news articles), social media, digital and multimedia (e.g., podcasts, videos, and mobile apps), conference exhibits, public talks, and print brochures and publications, among others. Still, there are several opportunities to enhance how NINDS content is presented, packaged, and distributed, as well as to explore emerging communication technologies and platforms that might help broaden our reach. One of the most efficient ways of expanding NINDS's reach is to cultivate communication partnerships, leveraging the extensive social networks of our many stakeholders. To this end, NINDS collaborates with many professional societies, nonprofit organizations, and other federal agencies on various communication and engagement efforts. Opportunities exist, however, to strengthen and expand such partnerships.

Systematically assess and evaluate communication efforts to refine and adopt the most effective approaches.

NINDS uses web analytics and other tracking efforts to assess some aspects of our communication efforts; however, a more robust analytics approach and larger suite of metrics are needed to fully measure effectiveness. NINDS also appreciates the value of applying a more systematic approach to our assessment efforts, including identifying the goals and appropriate analytical methods prior to each communication and engagement effort. Having robust analytics is key to identifying knowledge and resource gaps and spurring new content strategies to improve engagement.

Timeliness, Clarity, and Transparency

Communicate how the Institutes operates and makes decisions in a timely, clear, and transparent manner.

An important goal for NINDS is to provide information about our activities and decision making to individuals and organizations who are interested in and affected by what we do. By promoting understanding of our operations and strategies, we can work better with the research community writ large.

Engage diverse stakeholder communities on NINDS's priorities and widely communicate funding opportunities.

Fulfilling the NINDS mission depends on accurate, timely, clear, equitable, and broad communication of scientific priorities and funding opportunities. NINDS routinely seeks input on research gaps and opportunities, most intensively through the National Advisory Neurological Disorders and Stroke (NANDS) Council, frequent topical workshops, and strategic planning efforts where insights and advice are provided by researchers, other subject matter experts, and the public. More can be done, however, to optimize how the Institute gathers and incorporates this critical input in a systematic way across the broad swath of NINDS's mission areas. Additionally, once final decisions are made, we must ensure that they are clearly and broadly conveyed. For example, while all NIH funding opportunity announcements (FOAs) are made public through the NIH Guide, researchers often find it difficult to find the most relevant FOAs, and the intent of those FOAs is not always clear without interpretation from NINDS staff. NINDS seeks to develop new strategies to ensure that the entire NINDS community is fully aware of and has a strong voice in informing our policies, funding opportunities, and research priorities. Moreover, NINDS appreciates that personal relationships – between Program Officers; NINDS leaders;

and scientists, mentors, and trainees funded by NINDS – are a critical component of cultivating a sense of belonging in the research community.

Communicate easy-to-understand information on NINDS operations, policies, guidance, and decisions.

Understanding the "ins and outs" of how NINDS operates, especially the grant application process and how to comply with award requirements, is a complex undertaking. Information overload is a major challenge. NIH and NINDS websites contain extensive information for potential grant applicants; however, they can be intimidatingly dense and technical resources, in part because navigation often involves jumping back and forth between NIH-wide and NINDS-specific sites. NINDS strives for an open-door policy to allow our research community to get the guidance they need. Extramural program staff field several types of questions on a regular basis (often via email and over the phone), including choosing the right funding opportunity, hallmarks of successful grant applications, and aspects of review. While these ad-hoc communications can be quite effective, some applicants do not know the best way to engage with NINDS to get answers to their questions. To help anticipate and respond to applicant questions, NINDS seeks to improve how we communicate with researchers and make ourselves more accessible to the scientific community, especially those who have little or no prior experience submitting NIH proposals, in particular: trainees, new investigators, small businesses, and underrepresented scientists.

Dissemination

Disseminate research outputs to improve health and instill a broad appreciation for the value of neuroscience research

Translating the potential of NINDS-funded research into real-world impacts requires communication, coordination, and cooperation among numerous stakeholders and communities within and beyond academic neuroscience and neurology, including public and private partners and patient and citizen communities. NINDS seeks to promote and support these interactions and create opportunities for the fruitful exchange and dissemination of all the of outputs of NINDS investments with the ultimate goal of promoting neurological health among all members of our society.

Disseminate NINDS-supported knowledge, resources, and tools to enhance research capabilities and drive improvements in health practice.

Publications are just the first step in converting the outcomes of research into advances in knowledge and health. Translating NINDS-funded research into real-world impacts requires extensive communication and cooperation among numerous communities—in particular, with media outlets and reporters, medical and public health practitioners, nonprofit organizations and nongovernmental organizations, pharmaceutical and biotech companies, patients, and the broader public. NINDS will continue to vigorously disseminate research findings, while also cultivating new dissemination channels. In addition to new knowledge, NINDS's investments also yield research infrastructure, tools, reagents, data sets, and innovative technologies, which in many ways are even more challenging to disseminate than research articles. The exchange of these resources among researchers and health practitioners, however, is crucial to supporting a steady pace of progress and translation of knowledge into care.

Increase the public's understanding of neuroscience through educational engagement and provide trustworthy information on neuroscience, neurological disorders and stroke.

NINDS employs several initiatives to communicate health information that patients and caregivers need, as well as to educate the public on neuroscience research and the importance of brain health. For example, NINDS provides public health information for more than 250 neurological diseases and develops science education

review rates as outstanding or an encouraging number of applications from investigators new to a field. Intermediate monitoring may focus, for example, on what publications emerge, whether clinical trials are efficiently conducted, or the extent to which intended research resources are created. In the long term, an evaluation looks directly at whether the goal of the initiative is accomplished, e.g. is a causative gene, biomarker, or therapy developed; is a resource used for valuable research; do trainees succeed; does a clinical trial network improve efficiency and effectiveness of trials; or have stroke rates decreased as intended.

Basic research makes up the largest part of the NINDS research portfolio and presents the greatest challenge to evaluation. Several studies have confirmed the importance of basic research for medical progress, but also consistently shown that the value of basic research often does not become apparent for decades after the research is published and cannot be meaningfully evaluated relying on quantitative measures such as bibliometrics (measures based on number of publication and citations). For these reasons, NINDS evaluations of basic research focus on qualitative evaluation of scientific content, including peer review for continuing support. The large number of prestigious research awards to NINDS investigators provides some assurance that NINDS supports high quality innovative research. These awards include numerous Nobel, Lasker, MacArthur, Breakthrough, and other honors. The Institute also performs thorough retrospective reviews of major advances in treatment of neurological disorders, which trace key contributions from NINDS research.

The Strategic Planning Process

NINDS launched the current strategic planning process in early 2019. Through this process, the Institute aimed to identify priority goals and objectives for NINDS to ensure its operations and investments advance the NINDS mission and cultivate a culture of scientific excellence and organizational health. As the Institute grows and adapts in response to the complex needs of the public, the strategic planning process allows NINDS to 1) identify and reinforce practices, policies, activities, and actions that advance our mission, and 2) identify practical ways to improve and innovate in order to better serve the research community and the public.

To begin, the NINDS leadership formulated overarching goals focused on four broad topics:

1. *Science:* Support and perform rigorous and important neuroscience research.
2. *Training and Diversity:* Fund and conduct neuroscience research training and career development programs to ensure a vibrant, talented, and diverse neuroscience work force.
3. *Communications:* Promote dynamic communication and diverse stakeholder engagement to accelerate scientific progress and reduce the burden of neurological disorders.
4. *Workforce Culture:* Create and sustain a supportive work culture for the NINDS workforce that becomes the model for biomedical research and the neuroscience community.

The Institute charged Task Forces (see Appendix) made up of staff from across NINDS and NIH to focus on each of these goals. Over the next several months, each Task Force performed a thorough assessment of the current NINDS landscape and the existing practices and policies to help inform the goals and strategies discussed in this document.

NINDS also sought input from a wide variety of stakeholders at several points throughout the planning process. In July 2019, NINDS published a Request for Information (RFI) to gather public input regarding the four broad strategic goals. NINDS received 95 responses from a broad range of groups, including principal investigators, researchers, trainees, patients, patient advocates, professional societies, non-profit organizations, health care providers, other research institutions, science administrators, and members of the public. In addition, there were multiple discussions with the National Advisory Neurological Disorders and Stroke Council and the deputy

director, Dr. Nina Schor, presented at various meetings, including the annual NINDS Nonprofit Forum and with professional societies, to gather additional input. Further, NINDS held a series of six external discussion panels of individuals offering their individual insights on basic research, therapy development, training, diversity, career development, and communication strategies.

Appendix

Taskforce Rosters & Steering Committee

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