Strategic Plan
National Institute on Deafness and Other Communication Disorders (NIDCD)
FY 2009-2011

THE NIDCD STRATEGIC PLAN PROCESS

The NIDCD strategic plan for human communication research is a collaborative effort in which NIDCD staff and administrators, the scientific community, professional and advocacy organizations, and the public provide input for the direction of NIDCD research. Every three years, the NIDCD strategic planning process begins by convening a small group of distinguished scientists, clinicians, and members of the National Deafness and Other Communication Disorders (NDCD) Advisory Council to serve as the Strategic Planning Working Group. Their charge is to identify priority research areas within NIDCD's mission, while considering research and trans-NIH initiatives currently supported by the Institute. The full NDCD Advisory Council membership, NIDCD staff, individuals and representatives of public and private organizations, as well as scientific organizations, are also invited to provide input into the planning process, which helps to ensure that the public's perspective is assimilated into the recommendations for the Strategic Plan. Through this process, the Advisory Council reviewed and updated the plan in 2002 (FY 2003-2005), in 2005 (FY 2006-2008), and in 2008 (FY 2009-2011).

NIDCD BACKGROUND

Approximately one in six Americans will experience a communication disorder to some degree in his or her lifetime. For those individuals, the basic components of communication (sensing, interpreting, and responding to people and things in our environment) can be extremely challenging. In October 1988, Congress established the NIDCD as a component of the National Institutes of Health (NIH). The NIDCD manages a broad portfolio of both basic and clinical research focused on understanding the normal processes and disorders of human communication. The NIDCD advances human communication and mitigates the associated disorders by conducting and supporting research and research training in the normal and disordered processes of hearing, balance, smell, taste, voice, speech, and language. These processes, which can be grouped into three program areas of hearing/balance, smell/taste, and voice/speech/language, are fundamental to the way we perceive and participate in the world around us.

The NIDCD seeks to answer (a) fundamental scientific questions about normal function and disorders, and (b) patient-oriented scientific questions regarding the optimal means for preventing, screening, diagnosing, and treating disorders of human communication. Not only do these disorders often compromise health, but they also affect the emotional, social, recreational, educational, and vocational aspects of a person's life. The cost of these disorders in quality of life and unfulfilled potential is substantial. In this way, NIDCD strives to reduce the costs of communication disorders, both direct and indirect, on individuals, families, and society. As our population ages and as survival rates improve for medically fragile infants as well as after injuries and acquired diseases, we can expect increases in the prevalence of communication disorders.

NIDCD-SUPPORTED RESEARCH ADDRESSES COMPELLING PUBLIC HEALTH NEEDS

Since NIDCD's establishment 20 years ago, research opportunities have led to scientific breakthroughs in the study of genes, proteins, sensory and supporting cells, and molecular processes that directly affect communication disorders. These advances have been accompanied by substantial progress in behavioral studies that increase our understanding of how communication processes contribute to a person's health and how communication disorders can be prevented, diagnosed, and treated.

Diseases and disorders of human communication are significant health problems for Americans of all ages and they cross all ethnic and socioeconomic lines. They frequently occur with other medical conditions. The NIDCD has compiled statistics related to communication disorders in the three program areas of the Institute. These statistics can be viewed at http://www.nidcd.nih.gov/health/statistics/.

Why NIDCD supports Hearing and Balance Research

Hearing impairment, deafness, and balance disorders can impose a heavy social and economic burden on individuals, their families, and their communities. Millions of Americans experience some form of hearing or balance disorder, including: middle ear infections (otitis media), noise-induced hearing loss, tinnitus, age-related hearing loss, dizziness, and vertigo, at some point in their lifetime, especially in early childhood or old age. Accordingly, research projects within the NIDCD Hearing and Balance program encompass a significant portion of NIDCD's portfolio. Both hearing and balance disorders are prevalent, decrease quality of life, and cross all ethnic and socioeconomic lines. To study normal and disordered functions of the auditory and vestibular systems, NIDCD utilizes a wide range of research approaches, such as molecular genetics, cellular, systems, biomedical imaging, nanotechnology, psychoacoustics, and structural biology. Mouse models of hereditary hearing impairment have been instrumental in mapping and cloning many deafness genes. Because of the utility of the mouse for such studies, additional mouse models of deafness are being created through mutagenesis and screening programs as well as targeted mutation of deafness genes found in humans. In addition, mouse models are being used to study the function of the proteins encoded by deafness genes and to test therapeutic approaches. These advances offer researchers many opportunities to study deafness, hereditary factors involved in hearing loss, and genes that are critical for the development and maintenance of the human ear. Great strides are being made in the study of auditory sensory cells and of characteristics of the inner ear's response to sound. The NIDCD also supports research efforts to improve or develop alternative and augmentative communication (AAC) devices, such as cochlear implants, advanced directional microphones for hearing aids, vestibular implants, and other neural prostheses. The NIDCD has supported research that will help lead to the improvement or prevention of hearing and balance disorders, e.g., otitis media, noise-induced hearing loss, tinnitus, age-related hearing loss, dizziness, and vertigo.

Why NIDCD supports Smell and Taste Research

The NIDCD Smell and Taste program supports the study of the chemical senses (smell and taste) to enhance our understanding of how individuals communicate with their environment and how chemosensory disorders can be identified and treated. Smell and taste play important roles in preferences and aversions for aromas, specific foods, and flavors. By providing knowledge on food preferences, research on smell and taste may help increase our understanding of obesity and diabetes. Serious health problems like obesity, diabetes, hypertension, malnutrition, Parkinson's disease, Alzheimer's disease, and multiple sclerosis are all accompanied or signaled by chemosensory problems. The NIDCD supports research to study the health risks associated with compromised smell and taste function. The NIDCD also supports molecular biological studies of smell and taste receptor cells that provide important insight about how the chemical senses detect substances in our environment. Olfactory sensory neurons are exposed to the environment and are susceptible to damage by pollutants and airborne toxic substances. Because the olfactory epithelium has the capacity to replace damaged neurons, scientists are able to study the olfactory system as a model for understanding neuronal degeneration and regeneration, as well as some aspects of stem cell biology. NIDCD-supported research on molecular and cellular biology, biophysics, and biochemistry of the olfactory and gustatory systems is paving the way for improved diagnosis, prevention, and treatment of chemosensory disorders.

Why NIDCD supports Voice, Speech, and Language Research

Voice, speech, and language are tools that all individuals use to communicate or share thoughts, ideas, and emotions. The NIDCD Voice, Speech, and Language program continues to determine the nature, causes, and prevention of voice, speech, and language disorders. Disorders involving voice speech, or language, as well as swallowing, can have an overwhelming effect on an individual's health and quality of life; they affect people of all ages with or without hearing impairment, including children with autism and adults with aphasia or dysarthria. The NIDCD supports research to examine how individuals generate speech and comprehend language. Studies in the voice and speech program focus on determining the nature, causes, treatment, and prevention of a variety of disorders of motor speech production throughout the lifespan. Substantial progress has been made in the development of AAC devices to facilitate the expressive communication of persons with severe communication disabilities. Language researchers supported by NIDCD are also exploring the genetic bases of child speech and language disorders, as well as characterizing the linguistic and cognitive deficits in children and adults with language disorders. NIDCD-supported researchers are developing effective diagnostic and intervention strategies for people with voice, speech, or language impairments.

Why Research Training and Career Development is Essential

The number of Americans with communication disorders will increase as the nation's population increases and as survival rates improve for a wide range of medical conditions with associated communication disorders. In response, the NIDCD has placed a strong emphasis on research training and career development opportunities to ensure a productive, creative, and innovative cadre of qualified scientists to address the growing need for researchers in the areas of human communication and communication disorders. The NIDCD has focused on mentored career development programs for clinical investigators, fellowships for predoctoral postdoctoral fellows, and support for investigators who are just beginning independent research efforts. In addition to offering support for individual fellowships and grants, the NIDCD has utilized institutional training grants to build strong training environments and facilitate opportunities for predoctoral students, postdoctoral fellows, medical students, and residents to gain important research experiences that will prepare them for subsequent research careers as independent investigators.

The NIDCD has continuously adapted and expanded its research training and career development efforts to focus on training, supporting, and encouraging new investigators and building shared research resources. In 2000, the NIDCD developed a unique expedited fellowship grant review and award process in which the time between application submission and award is now significantly reduced. In this way, highly promising students receive funding for their mentored research training sooner, while unfunded applicants have the opportunity to respond to critiques and reapply during the next cycle. Applicants for pre- and postdoctoral fellowships, including dual-degree (M.D./Ph.D.) students training as physician scientists have benefited greatly from this expedited review and award process, which helps minimize application delays for potential trainees and maximize the entry of new scientists into research careers within NIDCD's mission areas.

The NIDCD recognizes the value of developing a broad and diverse pool of promising investigators and physicians, representing the full spectrum of health professions, into research areas relevant to the Institute and utilizes an array of training and career development approaches to achieve this goal. NIDCD has helped well-trained investigators as they transition to become independent NIDCD-supported researchers. This is facilitated through informal consultation with program staff and through NIDCD's customized process for addressing concerns raised during peer review of grant proposals. For the latter, new investigators who have submitted an unsuccessful, but promising, R01 application can address concerns in a letter to the NDCD Advisory Council. If the issues are addressed satisfactorily, the grant application will be considered for high program priority funds within the same funding round.

There is a need for trained individuals (clinician-researcher M.D and Ph.D.) to bridge the gap between fundamental science and active care. After completing their research training, these individuals are able to initiate and support new directions for scientific discovery as trained specialty clinicians. In addition, they can organize and execute clinical trials and other forms of "real world" assessment of new therapies. Developing a cadre of translational researchers who are well prepared to collaborate with practicing clinicians, educators, and other health-care professionals requires the following:

- Identifying and stimulating medical and doctoral students to a career in NIDCD mission areas;
- Creating research-rich residency, post-residency, and postdoctoral training environments;
- Training M.D. and Ph.D. students together to create more productive, broad-based research teams;
- Supporting the delicate transition funded junior faculty;

- Assisting the scientist to establish a sustained research career.

Only by maintaining and extending NIDCD's established commitments to research training and career development will the research community be in a position to meet the strategic research priorities put forth in this document. Driven by compelling public health needs along with recent scientific progress, the NIDCD prioritizes its research investment to identify the most promising opportunities for prevention, diagnosis, and treatment, thereby improving the quality of life for people who face the challenge of living with a communication disorder.

SCIENTIFIC PROGRESS MADE IN THE COMMUNICATION SCIENCES

Research has produced many important discoveries and technologies to help people with communication disorders in hearing, balance, smell, taste, voice, speech, and language. For example:

- Vaccines prevent many illnesses that once were major causes of hearing loss, such as measles, mumps, meningitis, and rubella.

- Researchers have a greater understanding of the effects of hearing loss on language development in early childhood. This understanding has led to the development of prompt interventions, enabling children with hearing loss to acquire speech and language skills on schedule with their peers.

- Health professionals are identifying newborn babies with hearing loss and toddlers with speech and language problems at an early age so that developmental consequences are minimized through early intervention.

- Scientists have identified genetic mutations that lead to some inherited forms of hearing loss. They also have a better understanding of the functions of many of the proteins these genes encode. The era of precise genotype-based diagnosis may be at hand for these disorders.

- Researchers have identified some of the genes that control the development of the inner ear. In addition, they have identified genes that control how sensory hair cells are organized and oriented within the inner ear.

- Scientists have identified special molecules that are critical to sensory hair cell function. Significant progress has been made in defining how these molecules are organized and how they function in converting sound vibrations into electrical impulses that are interpreted by the brain.

- Vocal fold lesions often result from unhealthy voice use, which can have a negative effect on vocal tissues and physiology. Some voice disorders may be treated or prevented by changing vocal patterns and use, or through surgery.

- Intensive voice treatment can improve speech and voice in individuals with Parkinson's disease. In addition, intensive treatment helps respiratory and laryngeal systems to function better, which further strengthens the voice.

- Prolonged exposure to excessive noise levels results in hearing loss. This understanding has led to the increased use of ear protection by people who are routinely exposed to loud noise on the job or in recreational activities. To help raise awareness, in 2008, the NIDCD launched a new public education campaign to prevent NIHL in tweens (children ages 8 to 12), entitled *It's a Noisy Planet. Protect Their Hearing*. This campaign is designed to help parents and other adults encourage children to adopt healthy hearing habits before and during the time that they develop listening, leisure, and working habits.

- Scientists have a better understanding of how infants with severe to profound hearing loss learn sign language as well as similarities in how the brain processes sign language and spoken language.

- Scientists have learned that the more we communicate with children, through either spoken or sign language, the faster they learn language and the more proficient they become.

- Researchers understand more about the reading abilities of adults who are deaf. This information may lead to improved methods of reading instruction for children with hearing loss.

- Scientists continue to understand more about the biology of neurons. For example, research has shown that nerve cells on either side of a synapse are highly plastic, capable of regrowing and rewiring themselves throughout a person's life. These mechanisms are important in the olfactory system where neurons are renewed on a continuous basis.

- Cochlear implants allow many children who have a profound hearing loss to acquire speech and language skills at the same level as their peers and to attend mainstream schools.

- Improved hearing aids have been designed to work better in noisy environments by detecting the direction from which sounds arise.

- Advances in technology and science have created new opportunities to design devices that restore or improve function for people with balance, voice, and speech disorders. For example, research with vestibular devices (similar to the cochlear implant) in animals may lead to treatment for individuals with a balance disorder. In addition, electronic larynxes (the organ that produces voice) and computer-aided speech devices have been dramatically improved.

- Scientists have identified the genes that code for olfactory receptors. This pioneering advancement, which earned the discoverers the 2004 Nobel Prize in Physiology or

Medicine, together with the discovery of the genes for many taste receptors, opened new frontiers in understanding chemosensory disorders.

- It is now widely recognized that the olfactory system continues to undergo a profound level of sustained neurogenesis that provides for the replacement of both sensory neurons in the nose and neurons in the brain.

- New non-invasive brain imaging strategies, such as functional magnetic resonance imaging (fMRI), are providing new and often unexpected insights into the functional organization of the neural circuits that mediate hearing, balance, smell, taste, voice, speech, language, and other mechanisms of communication.

- Through genetic studies, researchers have begun to identify some of the genes associated with stuttering, phonological disorders, and language disorders.

- Various motor, linguistic, emotional, and cognitive challenges have been shown to contribute to developmental stuttering.

- People with head and neck cancers are benefiting from new surgical approaches and combinations of chemotherapy and radiation that preserve voice and speech better than older treatments.

- Scientists have identified many of the genetic mutations and epigenetic alterations causing head and neck cancer. Studies of resulting alterations in gene and protein expression demonstrate a network of signal, transcription, and protein alterations that may provide targets and biomarkers for use in prevention and therapy.

THE FUTURE OF COMMUNICATION SCIENCES: WHAT NEEDS TO BE STUDIED?

Despite considerable scientific advances to help people with communication disorders, many challenges remain. For example:

- Can we develop a way to study sensory input processing in the laboratory that more realistically reflects the complexities of the real world?

- How does the brain acquire, process, and interpret complex communication signals (e.g., speech, or speech in the presence of background noise) in normal and pathological conditions?

- Can we pinpoint how and where in the nervous system certain communication disorders, such as tinnitus, originate so that new treatments might be developed?

- Given our new understanding of the genetic and molecular basis of many communication disorders, is it possible to use genetic or molecular interventions to prevent these disorders or restore normal function?

- What proteins are produced or not produced when a communication organ, such as the larynx, is overused? Do certain genes or the natural aging process increase the organ's vulnerability to overuse?

- How can existing or new diagnostic tools, such as brain imaging, gene-based diagnostics, and computer-based testing programs, help doctors choose the best treatment for people with communication disorders?

- How does a person's ability to communicate change during the natural progression of a disease, particularly in aging or neurodegenerative diseases, and how can this information be used to deliver the most effective treatment?

- Why does a particular treatment for a communication disorder work well for some individuals but not for others?

- Are there differences in terms of the basis of some communication disorders or in the interaction of the environment?

- Why do certain communication disorders (e.g., stuttering) resolve spontaneously for some children, but persist for other children?

- What methods can be used to identify infants at risk for communication disorders and what types of intervention would be most beneficial?

- What are the best ways to help children with communication disorders learn to communicate?

- How can devices and treatments for communication disorders be improved or developed? What are the best techniques for assessing performance, so that improvement can be measured objectively and devices are adjusted for optimal results? Which devices and treatments can help the greatest number of people with a particular disorder?

- How can basic and clinical research and research training be used to address the need to eliminate gender, racial, ethnic, or socioeconomic health disparities in communication disorders?

- Which parameters define ranges of normal function, dysfunction, and organization of hearing, balance, smell, taste, voice, speech, and language?

- How can altered signal pathways, transcription factors and regulated genes and proteins that promote development of head and neck cancer be targeted for prevention and therapy?

NIDCD RESEARCH PRIORITY AREAS

With help from scientists and the public, the NIDCD has identified four areas that offer distinctive opportunities to investigate the normal and disordered processes of hearing, balance, smell, taste, voice (as well as swallowing), speech, and language to further increase our knowledge in the human communication sciences. These priority areas are:

I. Molecular and Non-Genetic Bases of Normal and Disordered Communication Processes

II. Development, Deterioration, Regeneration, and Plasticity of Sensory Processes Mediating Normal and Disordered Communication

III. Perceptual, Cognitive, Sensorimotor, Sensorimotor, Behavioral, and Environmental Factors Affecting Processing in Normal and Disordered Communication

IV. Development and Improvement of Devices, Pharmacologic Agents, Behavioral Strategies, and Treatments for Diagnosis, Habilitation, Rehabilitation, and Prevention of Human Communication Disorders

These four research areas are described in greater depth in the following section. A detailed list of the NIDCD's research priorities is included for each area. NIH is supporting Translational Research that takes knowledge from the bench to the bedside. All studies, whether from laboratory, clinic, or bedside, should meet the highest standards of scientific rigor.

I. Molecular and Non-Genetic Bases of Normal and Disordered Communication Processes

Genes and the proteins they encode (the molecular structure of living cells) are known to play a key role in many communication diseases and disorders; however, this area of research requires much more intense study. Likewise, more research is needed on non-genetic factors that also affect communication processes, such as infectious, toxic, and environmental exposures. Both molecular and non-genetic research are priorities for the NIDCD.

Understanding Molecular Causes of Communication Processes and Disorders

One of the most rapidly developing areas of research involves efforts to determine the identity, structure, and function of genes, a discipline referred to as structural and functional genomics. The Human Genome Project has shown that human beings have about 22,000 genes. Considerable progress has been made in identifying which genes are involved in human communication and how these genes are altered in individuals with communication disorders. Hereditary disorders result not only from abnormalities in single genes but from combinations of particular forms of genes. Genetic mutations play a role in a variety of communication disorders, including at least half of all cases of congenital or early childhood-onset hearing loss. Individual variations in the severity of hearing loss are common and typically attributed to environmental factors and modifier genes, which do not cause communication disorders but can affect the severity of a disorder caused by a mutation. Understanding the genetic basis of hereditary disorders can help clinicians select the most effective treatments and enable families to make informed decisions as they deal with these disorders. Much of the success and progress in gene identification is a direct result of the willingness and generosity of families with hereditary communication disorders who agree to participate in studies with clinicians and scientists. Without them, research in this field would not have advanced to its current state.

Genes direct the formation of specific proteins in cells and influence their structure and function. Proteomics is the study of how proteins interact within cells. Proteins are the building blocks of all living cells. They allow cells to grow and divide during an embryo's development, and they help mature cells to function. The cells, in turn, form every internal system in the human body. Mutations in one gene can have a dramatic effect on complex functions such as hearing, balance, smell, taste, voice, speech, and language. Understanding how function is altered in individuals with communication disorders is an important step in developing precise molecular diagnoses, pharmacological treatments, and behavioral interventions.

Mutations in genes contribute to numerous communication disorders, either directly by causing a critical group of cells to malfunction, or indirectly by increasing the body's sensitivity to damage from infections, certain drugs or medications, and/or environmental exposure to toxins, excessive noise, or nutritional deprivation. Continued research is needed to help scientists identify and characterize genes and modifier genes and to understand their function in complex communication disorders with multiple deficits that overlap with other conditions (such as hearing loss, stuttering, speech sound disorders, autism, Fragile-X syndrome, anosmia, Parkinson's disease, Alzheimer's disease, cancer, eating disorders, and dyslexia). This knowledge will enable more accurate diagnosis and classification of individuals with communication disorders. This knowledge can also be used in the long-term planning of clinical interventions. For example, children diagnosed with a mild hearing loss at birth caused by a gene mutation that will cause progressive hearing loss or deafness by their teen years may benefit from early education programs so that they may achieve their full potential. Similarly, early diagnosis of Alzheimer's disease may be achieved through testing of olfactory function.

Understanding Non-Genetic Causes of Communication Processes and Disorders

Not all communication disorders have a genetic basis. Some are rooted in external factors, and others result from a combination of genetic and external factors, and for still others the cause(s) remain unknown. For example, hearing loss can occur as a result of infections (e.g., otitis media), noise exposure, or toxicity associated with certain medications or other chemicals. Infants with hearing loss may have difficulty learning to speak or understanding language later in life if appropriate education and training are not provided. At any age, impaired language skills affect a person's ability to function in today's complex, communication-driven society. Speech and language impairments can be caused by a variety of developmental or acquired neurological problems or injuries. Diseases of the larynx can be caused by infections, by the presence of tumors or trauma, or harmful vocal behaviors. Furthermore, in occupations with high voice usage, such as lecturing or singing, voice problems can limit a person's ability to perform certain tasks at work, resulting in missed workdays, or the need for an individual to change their occupation. Olfactory function is also directly tied to environmental variables. As levels of pollution increase, loss of olfactory sensory neurons increases along with potential loss of olfactory sensitivity.

Goals for Strategic Plan Priority Area I

Research is needed to help determine the molecular (proteomic and genomic) and non-genetic (infectious, environmental, and toxic) causes of communication disorders in the following areas:

- Use genomic, proteomic, informatic, bioinformatic, and expression profiling technologies, as well as other molecular biological and genetic approaches, to understand the molecular bases of normal and disordered human communication. This includes gene identification, regulation, and expression, as well as identification of associated mutations.

- Transfer emerging technologies in genetics and molecular biology (including DNA microarrays, biomarker identification, and other genomic strategies) to the clinical setting.

- Encourage the use of multidisciplinary approaches to prevent, diagnose, and treat communication disorders.

- Identify environmental exposures that contribute to communication disorders. Determine ways to prevent these exposures and reduce their harmful effects.

- Expand observational and epidemiological studies aimed at better specifying and validating the various diagnostic categories for which causes are sought.

- Encourage multidisciplinary collaboration between scientists in diverse fields (such as chemistry, biology, pharmacology, genetics, engineering, and medicine) and clinicians (such as otolaryngologists, speech-language pathologists, and audiologists) to develop methods for preventing, detecting, diagnosing, and treating communication disorders.

- Study common variations in human DNA and their impact on susceptibility to human communication disorders.

- Investigate complex disorders of human communication caused by interactions of several genes. Identify and analyze factors that influence variability and susceptibility to disease and response to treatment.

- Develop *in vitro* and animal model systems to study the function of specific disease genes; identify and isolate specific cell populations; and investigate cellular processes by using techniques such as gene and protein expression systems, organ and cell culture systems, and stem cell research.

- Explore the pathogenesis, treatment, and prevention of viral and bacterial infections that may contribute to communication disorders.

- Determine the cellular and molecular mechanisms underlying the degeneration and regeneration of tissue.

II. Development, Deterioration, Regeneration, and Plasticity of Sensory Processes Mediating Normal and Disordered Communication

In certain parts of the human body, such as the olfactory system, cells that are damaged by illness or injury can be replaced by the regeneration of healthy cells. Yet, other parts of the body, including the highly specialized hair cells of the inner ear, do not regenerate spontaneously. Understanding how the brain and the sensory and motor organs involved in human communication recover, respond, or adapt to injury or damage is another research priority for the NIDCD.

Increasing the Potential for Recovery

Until recently, scientists believed that hair cells in mammals, which are critical for hearing and balance, could never be replaced if they were injured or destroyed. However, birds and fish can regenerate hair cells from nearby supporting cells which reenter the cell division cycle. Research supported by the NIDCD has shown that if certain genes are expressed in the inner ear, this process also can happen to a limited extent in mammals. This discovery suggests that it may be possible to regenerate hair cells in humans. Before genes are introduced into humans, however, risks and long-term health consequences must be understood.

Human olfactory receptor neurons in the nose and interneurons in the central olfactory structures of the brain show a remarkable ability to regenerate throughout life. There is a need to study the unique ability of these regenerated cells to make proper connections that sustain the ability to recognize and discriminate odors. Knowledge of how these neurons regenerate could enable researchers to develop clinical intervention strategies that promote nerve cell regeneration throughout the central nervous system.

The central nervous system adapts to changes by reorganizing connections among neurons. When a part of the brain involved in speech and language is injured [by a stroke, traumatic brain injury (TBI), or an infection], adaptive changes in connections between neurons may allow other parts of the brain to learn or take on that function. Understanding this process, called plasticity, could lead to treatments that restore speech, language, and other functions.

Adaptation to change can also have harmful consequences. Many people whose auditory systems are damaged acquire tinnitus, a disturbing condition marked by ringing, roaring, clicking, or hissing in the ear. Most treatments available today involve learning how to live with tinnitus or covering up the tinnitus with other sounds. Currently, there is no cure for tinnitus. Understanding what changes in the auditory system lead to tinnitus and determining where they occur are important steps in developing treatments. Plasticity is also important to the function of the vestibular (balance) system. Damage to one’s vestibular organ is rapidly compensated by changes that occur in the brain. Scientists need to understand how the vestibular system compensates in order to develop treatments for vestibular disorders.

Adults who suffer brain damage from a stroke or TBI often experience problems expressing their thoughts through speech and language. These speech and language disorders severely limit a person's ability to communicate and often restrict job opportunities. Additional research is needed to understand how young children recover from, or adapt to, severe brain damage so that new methods can be developed to promote recovery in adults.

Early in life, sensory cells develop connections with specific brain regions. The ability to develop these critical brain connections may be lost forever if they are not made very early in life. Research is needed to identify critical "windows of opportunity" for developing brain connections essential for normal communication. Important research findings in this area have already been used to mobilize major national public health efforts, such as the hearing screening of millions of newborns each year.

Stem cells have the ability to regenerate and differentiate into a multitude of specialized cells. Improved understanding of stem cell differentiation could lead to the development of treatments that effectively regenerate cells that have been damaged or destroyed in the organs of the ear, nose, and mouth as well as in the brain.

Goals for Strategic Plan Priority Area II

Research is needed to determine how development, deterioration, regeneration, and plasticity contribute to the communication process in the following areas:

- Characterize age-related changes in structural and functional plasticity of communication processes. This information may also lead to further understanding of how these structures degenerate, or regenerate.

- Develop and apply techniques such as functional magnetic resonance imaging (fMRI), magnetic encephalography (MEG), positron emission tomography (PET), and diffusion tensor imaging (DTI) to assess structural and functional plasticity in the brain during maturation and in response to pharmacologic or other interventions.

- Determine the cellular and molecular mechanisms underlying the degeneration and regeneration of sensory cells, such as cochlear and vestibular hair cells, olfactory cells, and gustatory cells. Such information may lead to the development of new therapeutic interventions.

- Use of *in vitro* assays to investigate molecular factors involved in stimulating embryonic and adult stem cells to differentiate into specific cell types used in communication.

- Investigate cellular and molecular mechanisms used by the body to protect or repair damaged receptor cells in the auditory, vestibular, olfactory, and gustatory systems. Develop methods to enhance these processes to improve survival of sensory cells following trauma or disease.

- Determine and categorize mechanisms involved in the development, maturation, aging, and recovery of function needed for communication, such as cell proliferation, differentiation, neuron axon targeting, pattern formation, cell death, and survival.

- Understand changes in the brain that result from the loss of sensory input, such as deafness, anosmia (inability to smell), or aguesia (inability to taste). Such knowledge is important for making the best use of drug treatments, behavioral interventions, and assistive devices.

- Develop animal models for human disease to study the underlying processes of communication disorders. For example, due to the subjective nature of tinnitus, the ability to find a suitable animal model has been challenging.

- Define improved clinical interventions based on studies of neuroplasticity as it occurs in normal development and in response to injury. Develop evidence for the best timing, quantity, and method of treatment.

III. Perceptual, Cognitive, Sensorimotor, Behavioral, and Environmental Factors Affecting Processing in Normal and Disordered Communication

Obtaining a more detailed understanding of how the brain acquires, organizes, and interprets information and how those processes contribute to communication is another research priority for the NIDCD.

Perceptual and Motor Processing

Human communication relies on complex perceptual skills by using the senses (hearing, vision, touch, pain, smell, and taste) to receive and interpret information from objects and sources in the outside world and from changes in our movements and spatial orientation (vestibular senses). Sensory information is first processed by peripheral systems (e.g., the inner ear) and then relayed and further processed and analyzed by the brainstem and brain. Human communication also requires cognitive abilities, such as attention, memory, and learning, as well as interactions among and between sensory and non-sensory systems. Human communication also requires motor execution. Exactly how all of these processes work and interact in normal or disordered communication or modify our behavior is not well understood. While scientists have learned a great deal about how sensory receptors and motor systems function, far less is understood about how sensory and motor information is processed in the brain and the impact on human behavior. For instance, communication disorders can occur even when the peripheral sensory organs appear normal.

Recently, new methods have been developed to study what happens in the central nervous system after sensory organs receive information. With computerized neural imaging, it is now possible to directly view regions of increased blood flow in the brain. Although the temporal and spatial resolutions are limited, this advanced technology allows scientists to image brain activity as information flows from sensory organs to the brain. For example, a functional magnetic resonance imaging (fMRI) scan can be used to observe brain activity as a person processes written, spoken, or signed words. Research using brain-imaging techniques is allowing scientists to challenge the old belief that a fixed part of the brain is reserved for organizing language. Studies in both adults and children indicate that brain organization can be modified. After an injury to either the right or left side of the brain, the organization of language that normally occurs in those locations begins to appear in other brain regions, and in some cases may allow relatively normal language abilities to be restored. These new imaging strategies are crucial for understanding higher order communicative functions such as language.

These new imaging techniques supplement and complement behavioral and physiological procedures that have revealed normal and pathological function of the processing and analysis of signals from sources in our world. Recent research has shown that the brain has increased difficulty in listening to a specific sound when an interfering sound changes in an unpredictable manner. The increased degradation in performance cannot be explained by interactions that occur in the ear when both sounds are present. This implies that neural processing in the brain is responsible for the increased difficulty. These difficulties may provide a clue as to why many listeners with hearing impairment have difficulty processing sounds in noisy environments where the interfering noise is often unpredictable.

Perception from Periphery to Cortex

The goal of understanding communication is to be able to describe how sensory input (e.g., sounds, flavors, odors, or the position of the head with respect to gravity) ultimately leads to a behavioral or perceptual output or response. Research using several animal models and specific perceptual abilities has revealed a coherent story of neural processing from the periphery to the cortex and the resulting behavioral output. For example, NIDCD-supported research has advanced our understanding of the ability of the barn owl's peripheral and central nervous system to localize mice based on sounds of their movements. Such research holds promise for understanding more complex systems and behaviors, as seen in human perception and communication.

Cognitive Processing

Improved methods of functional brain imaging, together with modeling of complex systems, work in concert to provide an understanding of multiregional brain activation. Scientists are seeking to understand the way in which various parts of the brain attend to sensory stimuli, prioritize or gate incoming information, and engage in complex tasks such as object recognition, language comprehension, and language formulation. A better understanding of these neural processes will improve our understanding of both normal cognition (e.g., different aptitudes, discriminative or detection ability, learning ability) and cognitive disorders. These methods also are the means by which scientists can study the neural reorganization that occurs following brain injury or that results from various kinds of treatment. The use of functional imaging and neural modeling to study the effects of clinical treatment may lead to better treatment methods and point to new discoveries of brain functions underlying normal and impaired cognitive processes. For example, brain scans of individuals with autism as they process language reveal key structural and functional differences when compared with brain scans of individuals who do not have autism. These imaging techniques have been used to study changes in the brain following therapy for aphasia, activation of cochlear implants, and stuttering and can be applied to individuals with language impairment.

Along with advances in brain imaging techniques, better behavioral indices are needed to identify children who are at risk for language delay. For example, many children with pre- or perinatal unilateral brain lesions have early language delays. These early delays are transient for some children, but persistent for others. New studies suggest that the gestures made by children with brain injury before they develop useful speech can help differentiate persistent language difficulties from difficulties that are transient. Behavioral indices can be used by clinicians to identify children who are likely to have persistent language difficulties. This early identification may be useful in implementing intervention at a time when language-learning is likely to be most malleable.

Goals for Strategic Plan Priority Area III

Research is needed to determine perceptual and cognitive processing (how individuals learn to communicate) in normal and disordered communication in the following areas:

- Develop and implement high resolution imaging methods that can be applied to both *in vivo* and *in vitro* models to assess function at the synaptic, cell and systems levels in normal and dysfunctional communicative systems.

- Investigate the perceptual, cognitive, and behavioral consequences of disordered communication and measure changes that result from treatment, including how the development of language is affected by variations in the quality, quantity, and timing of linguistic input, in both monolingual and multilingual speakers.

- Combine cellular, molecular, and physiological approaches with behavioral analyses in basic science and clinical studies to understand normal mechanisms of sensory processing, cognition, and perception.

- Continue to refine the understanding of how peripheral sensory and motor systems process and code stimulus events and how failure of these processes cause various communication pathologies.

- Develop diagnostic tools and interventions that exploit both the manual and oral modalities (sign, speech, gesture) to improve language-learning in children at risk for delays. Investigate the time course of various cognitive and linguistic processes through approaches such as event-related potentials (ERP), which are brain responses resulting from a thought or perception.

- Investigate the connections and interactions between cognitive as well as behavioral/emotional processes and the development and maintenance of various child-onset communication disorders.

- Investigate acquisition, use, and social/cognitive impact of varying sign language systems, in deaf and hard of hearing individuals, as well as for the purpose of augmentative communication in individuals with disabilities.

- Examine the causes of individual differences in normal and impaired communication. These individual differences are especially apparent for those with communication disorders or diseases. Personalized or tailored diagnoses and treatment approaches should be developed.

- Use imaging, multi-electrode, and multi-unit recording methods such as positron emission tomography (PET), functional magnetic resonance imaging (fMRI), electroencephalography (EEG), and magnetoencephalography (MEG) in animal models and humans to dissect the pathways and define the location and sequence of neuronal activity essential for peripheral and central processing of sensory input. Identify and define abnormal neural pathways and spatiotemporal neuronal activity patterns associated with disordered communication, especially in humans.

- Develop *in vitro* bioreactor technologies to test the cellular and extracellular response of ear and vocal fold tissues to mechanical stress.

- Improve the ability to measure neural function in animals over a long period of time to allow the study of the behaving animal in order to more accurately reflect neural processing in real world situations.

- Investigate the neural basis of sensory integration, with particular emphasis on the mechanisms by which peripheral auditory and vestibular signals are compared and combined with visual, touch, or pressure cues to create a robust auditory percept and spatial orientation.

- Investigate how changes in the central vestibular system allow people to be aware of and adapt to their spatial orientation by changing their visual field, gait, or balance as a means of recovery from vestibular trauma or injury.

IV. Development and Improvement of Devices, Pharmacologic Agents, Behavioral Strategies, and Treatments for Diagnosis, Habilitation, Rehabilitation, and Prevention of Human Communication Disorders

A core mission of the NIDCD is to enable individuals who have, or who are at risk of having, communication disorders to maximize their quality of life. The NIDCD is committed to conducting and supporting research to develop devices or interventions that improve or restore communication abilities, or prevent communication disorders.

Improving/Restoring Communication Abilities and Preventing Communication Disorders

As described in the previous sections, NIDCD-supported scientists have made significant progress in recent years toward understanding human communication and its disorders. These advances were made possible by breakthroughs in genetics as well as other basic sciences and technologies, such as microelectronics and behavioral science. It is anticipated that continued progress in interventions will result from new knowledge about the function of the brain and other organs important for communication as well as genes associated with specific communication disorders.

Clinical researchers use this new knowledge to study human behavior and disease. For example, hearing screening programs around the country are identifying infants and young children who have significant hearing loss. The technology for screening newborns was developed as a result of basic laboratory studies that measured electrical signals from auditory centers in the brain (auditory brainstem response) and sounds generated by the inner ear (otoacoustic emissions). Rigorous clinical trials should be performed to determine the most effective treatments for infants who are hearing impaired, including hearing aids and cochlear and brainstem implants, as well as the most effective intervention strategies.

Clinical research is also needed to describe how hearing, balance, odor detection, language, and speech abilities evolve over an individual's life span. Differences between individuals may be tied to an underlying gene or genes, which in turn may help identify people who are at greater risk for developing problems. Once this information is obtained, clinical trials are needed to find safe and effective ways to treat specific communication disorders through behavioral interventions, medications, or other therapies. Several examples include laser therapy to treat cancer on the vocal folds, electrical stimulation through cochlear implants, medications to treat tinnitus, and physical therapy involving special positioning of the head for loss of balance (positional vertigo).

NIDCD is committed to research aimed at advances in basic science research and in bioengineering to help individuals with all types of communication disorders. Some examples include:

- Cochlear implants have helped many children who were born deaf as well as individuals who became deaf later in life. According to the U.S. Food and Drug Administration data from 2006, more than 110,000 people worldwide have received cochlear implants. In the United States, roughly 23,000 adults and nearly 15,000 children have cochlear implants. Most adults who have received an implant have benefited greatly and many are able to communicate effectively by telephone after an extensive training period. Continued research on cochlear implants and sound processing should help to further improve the performance of cochlear implants and the communication for implant users in noisy environments while increasing our understanding of the auditory system. Methods need to be developed to assess performance of cochlear implants in order to provide future recipients with more effective implants. Research is also needed to determine whether deaf children would benefit from having implants in both ears. Studies also need to be done to determine which methods best help young implant users learn language. These studies need to consider the type and amount of instruction, as well as the appropriate developmental stage to begin intervention.

- Although hearing aid technology has advanced rapidly over the past few decades, hearing aids are not particularly effective when a listener tries to pay attention to a single speaker among many competing speakers or when there is a lot of loud background noise. To meet these needs, research needs to improve directional hearing aids and other hearing aid technologies that will help users understand speech from specific sources within a noisy environment.

- Speech and voice disorders can negatively affect quality of life across the lifespan and may be associated with neurological, psychological, and learning disorders. While pharmacological and surgical interventions may provide some relief, behavioral intervention remains the primary form of treatment. Research needs to address the role of neural plasticity and behavioral treatment in disorder management. In addition, much progress has been made in developing augmentative or assistive communication devices that help individuals with speech or language disorders.

- Scientists are taking advantage of bioengineering advances to develop and improve technologies that enable communication. Examples include the electro-larynx, which partially restores voice after the larynx is removed; digital programmable hearing aids that fit inside the ear canal; cochlear and brainstem implants, which improve the communication ability of adults and children with profound hearing loss; and computer programs that treat disorders associated with childhood language and learning disabilities.

- Using biological principles of odor recognition, scientists have developed “electronic noses” with biosensors to detect and discriminate complex chemical signatures of importance to biomedicine, biodefense, and biosafety.

Basic science advances should be accompanied by clinical research to ensure that these interventions are safe, efficacious, and used to maximum benefit. The ultimate utility and success of current and future devices or other interventions depends on clinical research studies with volunteers who use the devices or interventions.

Goals for Strategic Plan Priority Area IV

Research is needed to improve the quality of life for individuals with hearing, balance, smell, taste, voice (including swallowing), speech, and language disorders through assistive devices, drugs, and other therapeutic interventions in the following areas:

- Capitalize on emerging technologies to improve treatment devices that enhance communication, including brainstem implants and drug-delivery devices.

- Continue to support multi-disciplinary investigations of the impact of habilitative/rehabilitative interventions and strategies on outcomes in individuals with hearing loss, as well as for individuals with communication disorders.

- Use clinical trials and other studies to evaluate the safety and efficacy of newly developed devices, drugs, and other medical and behavioral therapies for individuals of all ages with communication disorders. Use these studies to develop and assess medical and behavioral interventions for infants and children who have a communication disorder.

- Increase the effectiveness and efficiency of early diagnosis and early prevention of communication disorders by developing and refining diagnostic criteria and improving diagnostic tools and technologies.

- Screen FDA-approved drugs as potential therapies for communication disorders.

- Capitalize on recent advances in understanding the role of olfaction and gustation in eating behavior to gain further insight into the current crisis in obesity, diet, and nutrition.

- Develop cost-effective techniques to assess the various patterns of communication currently used in the United States, including languages and dialects, in order to accurately identify communication disorders in all cultural and ethnic groups.

- Information from epidemiological (including longitudinal), biological, and behavioral studies can be used to develop recommendations to prevent communication disorders or to minimize their effects.

- Develop engineered reconstructive tissues for restoring function in individuals who have suffered structural loss through disease or trauma.

- Integrate information from epidemiological, biological, and behavioral research studies to develop strategies for prevention of communication disorders.

- Determine if there are any effects of race, ethnicity, language use, and socioeconomic status on the choice of medical and behavioral interventions.

- Encourage inter-disciplinary research between neuroscientists, pharmacologists, physicians, communication scientists, and practitioners to facilitate high-quality studies, of the effectiveness of treatments for communication disorders.

SUMMARY

Disorders of human communication, including hearing, balance, smell, taste, voice, speech, and language, affect millions of Americans. Fortunately, over the past few decades, research has greatly advanced the understanding of human communication and communication disorders. There is a greater understanding of how information is received and interpreted in the brain and how an individual's communication abilities can be compromised by factors such as infection, loud noise, and genetic abnormalities and differences. In addition, many new technologies have been developed to improve or restore communication.

Research opportunities have led to scientific breakthroughs that directly affect the understanding of communication disorders. These advances have been accompanied by progress in behavioral studies that increase the understanding of communication processes in health and disease. New imaging techniques, electronic devices, computer databases, animal models, and clinical trials have enhanced our ability to understand, prevent, diagnose, and treat disorders of human communication.

A crucial component to advancing the mission of the NIH and the Institute lies in sustaining a strong and responsive research training and career development program. To reach this goal, the Institute encourages and supports the complete career development continuum from predoctoral and postdoctoral fellowships (via National Research Service Award grants) to mentored career development awards (K-series awards), and culminating in new independent-investigator NIH R01 awards.

The NIDCD is committed to continuing its progress in the science of human communication, in preventing communication disorders, and improving clinical decision-making for the prevention, diagnosis, and treatment of communication disorders. NIDCD-supported research has been essential to many of these advances but many opportunities remain. The strategic priorities outlined in this plan provide a guide for future scientific initiatives and investigator-initiated research aimed at improving the quality of life for individuals who face the daily challenge of living with a communication disorder.