

New Frontiers in Environmental Sciences and Human Health



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U.S. Department of Health and Human Services
National Institutes of Health
National Institute of Environmental Health Sciences

Published by *Environmental Health Perspectives* (ISSN 0091-6765),
a publication of the Public Health Service, U.S. Department of
Health and Human Services. [NIH Publication 2006-218]



Printed on 30% post-consumer
waste recycled paper.

A New Vision



The environment represents a key contributor to human health and disease. Exposures to many substances, such as pollutants, chemicals, allergens, and natural toxins, all originate from the environment and can have a detrimental effect on health. Diet and lifestyle can interact with these environmental factors and increase or decrease their effects on health. Some of these environmental factors are under our own individual control, while others need to be controlled at the source through formal public health decisions.

At the National Institute of Environmental Health Sciences (NIEHS), our work is driven by a desire to understand how the environment influences the development and progression of disease. As we move forward, we will focus our research on scientific questions that form the basis for identification and prevention of hazardous exposures and that lead to improvements in health.

The NIEHS vision is to prevent disease and improve human health by using environmental sciences to understand human biology and human disease. This new vision will require a change in the way we conduct basic science. Traditionally, this research was carried out by single investigators working on narrowly defined hypotheses. Our new strategy adds integrated science teams conducting disease-focused research on complex hypotheses

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regarding the interplay of environmental agents and other risk factors, such as genetics, age, diet, and activity levels. Recent advances in technology make this multifaceted research possible.

The scientists and staff of the NIEHS are committed to identifying and pursuing new frontiers in biomedical research that are likely to have the greatest impact on human health. Through a comprehensive strategic planning process, the NIEHS has developed a new set of goals for 2006–2011, which we believe will allow us to fulfill this vision.

I was personally involved in the strategic planning process and am fully committed to the goals outlined in this document. I want to personally recognize and thank the dedicated individuals, both within the NIEHS and in our extended community of investigators, clinicians, and interested public, who participated in this planning process. Without their dedicated efforts on our behalf, the development and refinement of these strategic initiatives for the NIEHS would not have been possible. Among many, the members of the National Advisory Environmental Health Sciences Council deserve special recognition for their continued leadership and critical and objective guidance to our institute.

These strategic initiatives form a blueprint from which we will move forward to apply environmental sciences to human health. There is much we plan to

achieve, and I am excited about the opportunities before us. However, this plan is only our starting point. If we are to succeed, we'll need to be persistent, but also remain nimble and responsive to opportunities and challenges that are currently unforeseen. This is part of the excitement of beginning this endeavor, because encountering these unknowns will help us tweak the path for achieving our vision.

We find ourselves at an exciting time when new technology and testing methods are creating unique opportunities for scientific discovery. The time is right for increasing our knowledge of the cellular and molecular effects of environmental exposures. When we succeed, you will be able to better understand the health risks associated with environmental factors in order to protect your own health. And, state and federal authorities will possess the scientific knowledge needed to make the most appropriate public health decisions.

Sincerely,



David A. Schwartz, MD

*Director, National Institute of Environmental Health Sciences
and National Toxicology Program*

New Frontiers

We have mounting evidence that environmental factors contribute substantially to most diseases of major public health significance. Most of the principal causes of death in the United States (cancer, chronic lung disease, diabetes, metabolic disorders, and neurodegenerative conditions) are known to have significant environmental causes. In addition, environmental effects on chronic, nonfatal conditions (birth defects, asthma, neurodevelopmental dysfunctions, and reproductive problems) are also well-documented. Results from studies of twins reveal that development of chronic human disease owes as much, or more, to environmental components as it does to genes.

The ways in which our environment affects diseases and health conditions can differ from individual to individual depending on temporal factors (age and developmental stage), spatial factors (geographic location), and unique circumstances (comorbid disease, nutritional status, socioeconomic status, and genetics).

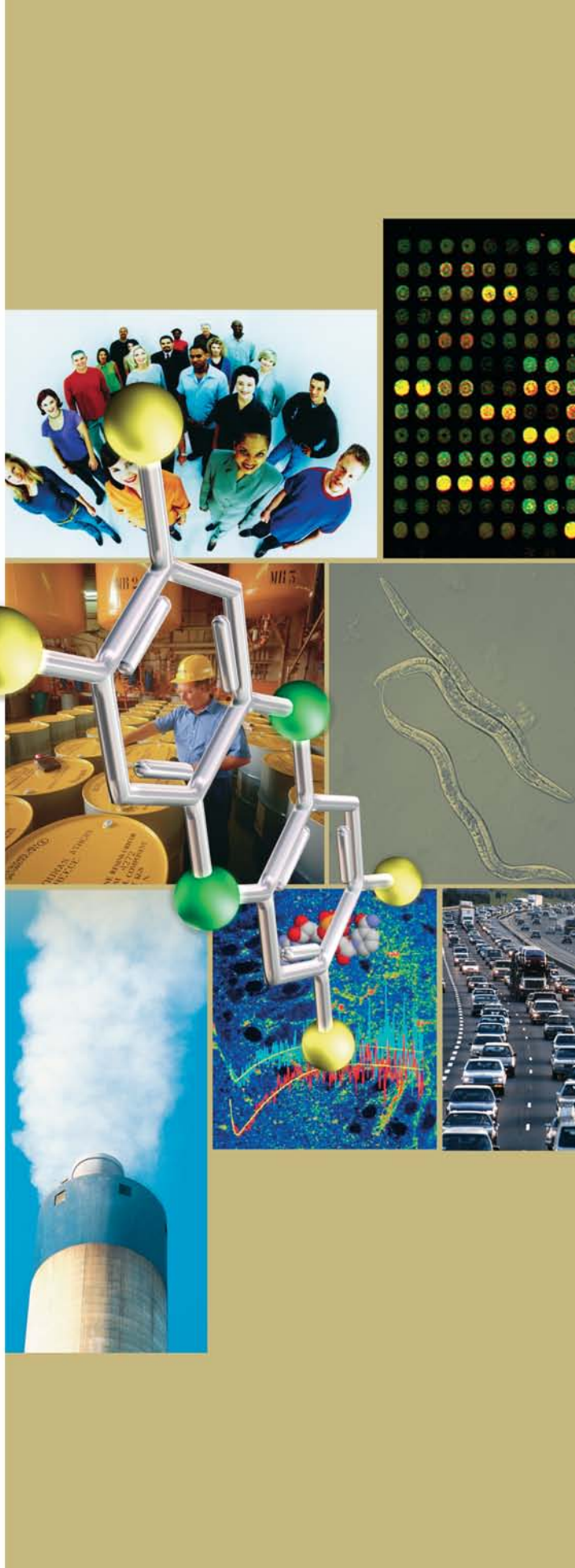
This strategic plan describes the three critical challenges facing environmental health sciences and goes on to set major goals for the NIEHS to achieve.

What do we mean by “environment”? In the broadest sense, the environment is what is all around you; it consists of the chemicals, foods, drugs, and natural products that you touch, eat, and breathe in everyday life. In practice, the NIEHS focuses its resources on studies of the effects of environmental agents that fall into three main categories: pollutants and chemicals such as lead, mercury, and ozone; useful commercial products that enter our environment and may have health implications, such as pesticides and herbicides; and natural toxins that are part of our everyday life, such as toxins produced by molds and dust mites. However, many other factors known to be important for health status, such as diet and exercise, can work separately or in combination with environmental agents (and with host factors such as genetic makeup) to influence human health and disease. The “environment” studies conducted by the NIEHS will continue to focus on understanding the fundamental changes in basic biology caused by exposure to environmental agents. However, this work will not be in isolation, and the integration of our environmental health science mission with understanding the health implications of these other health-determining factors is one key to improving our health by improving our environment.

And what do we mean by “environmental disease”? All diseases generally have complex etiologies that allow for multiple causal and pathogenic factors including exposure to environmental agents. Experience tells us that virtually all human diseases can be caused, modified, or altered by environmental agents. Hence, it is not possible to develop a definitive list identifying the diseases that are clearly caused by environmental factors. Instead, as is the case for environmental agents, one key to improving human health is identifying and understanding the basic biological processes that are altered by environmental factors, and that stimulate disease processes to begin or the course of the disease to be substantially altered.

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The fundamental mission for achieving the NIEHS vision lies in understanding the complex relationship between environmental risk factors and human biology within affected individuals and populations, and in using this knowledge to prevent illness, reduce disease, and promote health. To accomplish this, the NIEHS will support research and professional development in the environmental health sciences, environmental clinical research, and environmental public health.



Critical Challenges

To succeed, the NIEHS must address three critical challenges:

The First Challenge—Programmatic Scope:

What diseases and what exposures will be the focus of the NIEHS research portfolio?

In general, the NIEHS will set research priorities to focus on diseases for which there is a strong indication of an environmental component and for which there is high or increasing prevalence in the U.S. population. In addition, the NIEHS will focus on exposures that carry the highest risk to the largest population or hold the most promising hope of clarifying an important disease process. In this way, the NIEHS can optimize the future utility of the scientific research we support today and have the largest impact on human health in the near future. However, the NIEHS will continue to fund higher-risk research efforts aimed at identifying more diseases that are impacted by environmental exposures as well as classical research aimed at evaluating the potential for health implications of emerging environmental exposures.

The Second Challenge—Integrative Science:

Given the explosion in new science that has occurred in the last decade, how will we focus our research efforts on the most appropriate science for a given disease and the related environmental exposures?

The NIEHS will take a leadership role in improving human health by using environmental exposures to understand human biology and human disease. This vision is a complex one, requiring a change in approach to basic research, moving from our traditional science base of single investigators with a clear hypothesis to integrated research teams addressing the complex hypotheses associated with the interplay of environmental factors with many other factors (e.g., genetics, lifestyle, age, sex) on disease incidence and prognosis. The NIEHS is in a unique position to focus on the interplay between environmental exposures, vulnerable populations, human biology, genetics, and the common diseases that limit our longevity and quality of life. As we increase our understanding of how the human genome functions, the classical approach to environmental health research that focuses on identifying health hazards will be expanded to develop and use better tools, both to understand disease etiology as well as to fill data gaps regarding environmental health hazards. This knowledge, in turn, will improve our ability to identify important environmental toxicants, determine how past and present exposures contribute to an individual's disease status, and improve the clinical outcome of environmentally caused and mediated disease.



The Third Challenge—Public Health Impact:
How will we develop the scientific knowledge that empowers people to improve their environmental choices, allows society to make appropriate public health decisions, and results in our living healthier lives?

The NIEHS will develop initiatives aimed at identifying the complex factors in our environment than can increase one's risk of disease. The research supported and conducted by the NIEHS already forms the basis through which most public health agencies identify and manage harmful environmental exposures. We know that with the right information, it is possible to improve our lives by taking steps to avoid harmful environmental exposures and lifestyles. Having that knowledge available, either directly or through our medical providers or community organizations, is key to making this happen. Everyone's environment is important to his or her health, but different groups of people are exposed to different agents by virtue of where they live, work, and play. And two people exposed to the same environmental agent could respond differently due to other factors such as genetics and age. The ways in which environmental agents increase disease risks for an individual are still poorly understood. As the NIEHS moves forward, we are committed to supporting the basic research that drives the scientific basis for health decisions, as well as the applied research that fills gaps in our understanding of environmental health risks.

Our Commitment: To move our vision forward, the NIEHS will identify and fund the best science possible to address the diseases and exposures that are likely to have the greatest impact on human health.

NIEHS Goals: Today and Beyond

The following seven goals represent strategic investments that ensure all three major research components of the NIEHS (intramural, extramural, and the National Toxicology Program [NTP]) continue to have the greatest impact on preventing disease and improving human health. These seven goals form the core of the NIEHS Strategic Plan and outline enhancements to the current NIEHS research portfolio that will expand our basic and applied science efforts in both exposure-oriented and disease-oriented research, improve the scientific utility of community-based research by embracing a wider geographic approach to identify more diverse environmental and genetic factors, and provide needed support for recruiting and training tomorrow's scientists. These seven goals span all three critical challenges. Our commitment to these goals through existing programs and new initiatives will allow the NIEHS to maximize the benefits of our research investments for the nation's health.

GOAL I:

Expand the role of clinical research in environmental health sciences.

The NIEHS will encourage research that emphasizes the study of environmental exposures to inform clinical research. Traditionally, environmental impacts on disease have been studied from either the perspective of the exposure or the perspective of the disease. Advances in biology over the last few years have been remarkable in creating the opportunity to address environmental disease from a more integrated perspective. One important area where this integration could take place is within an expanded clinical research program. This approach will use environmental exposures to provide a greater understanding of human disease by strengthening the evidence that a given exposure is toxic, determining how specific environmental exposures affect disease etiology and progression, and using environmental exposures to identify molecular targets to determine susceptibility and intervention. Diseases for which environmental health sciences can provide important clinical insight include (but are not limited to) such common disorders as immune-mediated diseases, neurodevelopmental disorders, neurodegenerative diseases such as late-onset Parkinson's disease, cardiovascular diseases, reproductive disorders, and lung diseases, especially asthma. There are three major steps that must be accomplished for this effort to be successful.

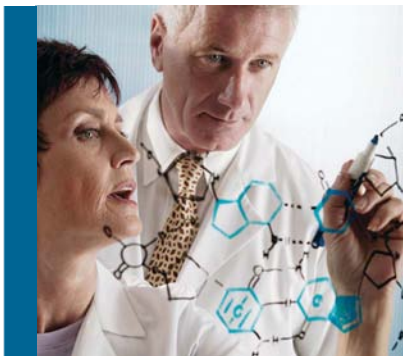
Encourage clinical research that emphasizes the use of environmental exposures to understand and better characterize common, complex diseases. This approach assumes that common, complex diseases are syndromes that represent many pathological entities,

and that environmental agents can be used to narrow the pathophysiological phenotype so that an exposure–response relationship can be investigated. For example, in complex diseases such as asthma, individual responses to different environmental agents can help aggregate patients into discrete subtypes that can more effectively be evaluated for the specific pathogenic mechanisms that are causing symptoms. In this way, environmental agents can provide the key to differentiating among the numerous phenotypes for such complex diseases. Assuming the different phenotypes are linked to different mechanisms, this will generate the following immediate public health benefits: improved understanding of host susceptibility, stronger linkages between exposure and disease, improved disease prevention, and the development of clinically relevant biomarkers that can be used to identify additional environmental agents of concern.

Develop improved research models for human disease using our knowledge of environmental sciences and human biology. Knowledge of comparative genomics linked with an added emphasis on research findings from humans now offers new opportunities for developing models of human disease and disease pathogenesis that enhance understanding of the linkage between genes, exposures, biology, and disease. With more creative application and development of these models, the NIEHS hopes to identify critical pathways that improve our ability to extrapolate and translate laboratory findings to humans. In addition, improved *in vivo* models could be used to uncover new mechanisms associated with disease. One important area with high priority will be epigenetics, where environmental influences might have a particularly strong impact. Finally, a wide

array of genetically modified animals can provide researchers new resources for conducting experiments in comparative biology, identifying conserved biological responses that uncover new biological mechanisms, and testing the importance of genes in exposure–response relationships.

Enhance the role of the clinical investigator in environmental health sciences. A clinical research program requires physicians and Ph.D.s who are trained to conduct and/or support clinical research in environmental health sciences. Medically trained scientists are familiar with the varied manifestations of human disease and can focus their own research on scientific questions that are clinically relevant. In addition, the integrative possibilities for using clinical research to address exposure-specific or disease-specific environmental questions necessitate physician-scientists providing support to basic or public health investigators who wish to focus their interests on clinically relevant areas of human disease. Another possibility for strengthening the focus on clinical research includes enhancing the biomedically related dimensions of doctoral training programs.



GOAL II:

Use environmental toxicants to understand basic mechanisms in human biology.

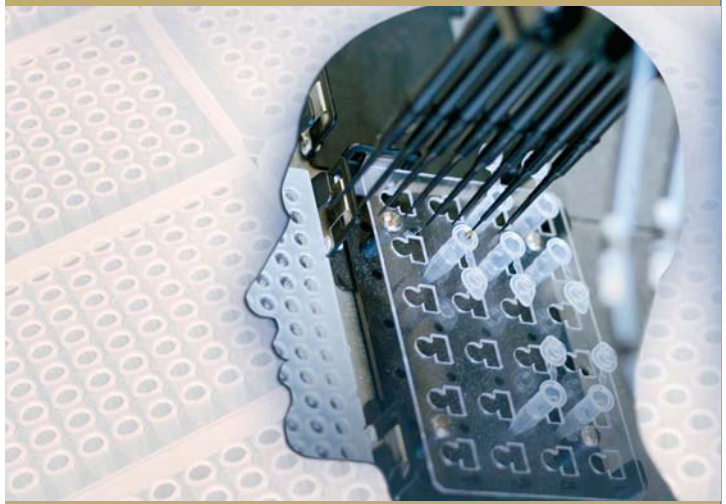
Studying environmental exposures can provide a controlled method for targeting and manipulating cellular machinery in ways that provide insight into both basic biology and the mechanistic events leading to clinical disease. Because environmental agents can operate early in the disease process, they indicate useful techniques for uncovering very early events in disease pathogenesis. These techniques can be used to identify methods to diagnose diseases before they are clinically evident, to develop early interventions that prevent progression to end-stage disease, and to identify targets for screening additional environmental agents. In this way, environmental agents have tremendous potential for use as probes in understanding the processes of common chronic diseases, as well as identifying possible routes for intervention. Through this goal, the NIEHS will expand the “toolbox” developed under the National Institutes of Health (NIH) Roadmap initiative titled “New Pathways to Discovery.” This expanded “toolbox” will enhance technologies for environmental research over the next decade. The initial efforts under this initiative will concentrate on three fundamental biological processes, elucidated below, having immediate implications for environmental health sciences.

Support research that improves our understanding of signal transduction pathways and their influence on disease.

Cells respond to environmental signals, toxicants, and stressors through multiple mechanisms, many involving communication pathways such as signal transduction. The identification, quantification, and interpretation of the signal transduction pathways affected by the environment that play critical roles in human diseases are likely to present new avenues for therapeutic intervention and prevention of environmental disease. Of immediate importance is increasing our knowledge of the pathways involved in oxidative stress, inflammation, and apoptosis, as well as the impact of these processes on common diseases. These processes are increasingly recognized as important pathways that underlie many environmentally induced diseases. These pathways and their responses to environmental insults will help to uncover causes and treatments for a variety of human diseases.

Expand our understanding of environmental influences on genome maintenance/stability and its impact on human health.

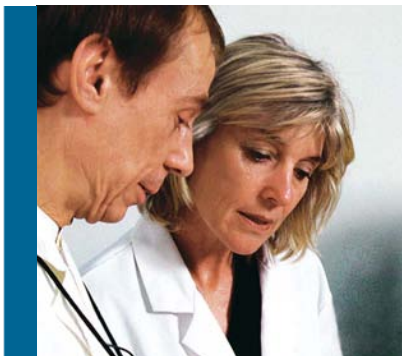
Human cells are astonishingly good at defending the integrity of their genome using DNA repair and other damage-tolerance systems to limit the impact of assaults on their integrity. Environmental exposures have been shown to create DNA damage, but can also affect the ability of a cell to repair DNA once damage has occurred. The failure to repair DNA damage can initiate a large number of human diseases, and more effort is needed to evaluate the role of the environment in altering genome maintenance and stability. Thus, the study of environmental factors that modify DNA damage, repair, and maintenance is an important area of investigation, particularly with regard to aging, cancer, and cell death.



Lead a concerted effort to improve our understanding of epigenetic influences on health. A dynamic interplay exists between the input received from the extra-cellular environment and the expression of genes within a cell. Integration of the key cellular signals to produce very specific genomic responses is essential to proper cellular function and disease avoidance. Environmental signals can alter the functioning of genes in many ways, both directly and indirectly. Epigenetics refers to a group of mechanisms that regulate patterns of inheritance and gene expression without changing DNA sequences and that are potentially crucial in the interface between genes, environment, and disease. These mechanisms include, but are not limited to, DNA methylation, imprinting, and histone acetylation and post-translational modifications. The overall impact of environmental changes on these mechanisms remains poorly understood, yet the consequences of modifying them can result in an increased risk of developing cancer, immunologic diseases, and other complex diseases.

NIH Roadmap: The NIEHS participates in, and benefits from, a number of Roadmap initiatives. For example, since August 2005, the NIEHS, through the NTP, has formally participated in the NIH Roadmap Molecular Libraries Initiative (MLI). This collaborative effort is aimed at assisting the MLI project leaders with development of their screening program by adding a toxicity testing capability to the MLI effort. In addition, this collaboration is allowing rapid implementation of the NTP's High Throughput Screening Assays program by providing the NTP access to established testing laboratories through interinstitute cooperation. Specifically, the NTP, through its association with the MLI, has the opportunity to generate information that links data on the biological activity of environmental substances generated from high-throughput screening assays with toxicity end points identified in the NTP's toxicology testing program.

The NIEHS is one of 27 research institutes and centers that comprise the National Institutes of Health (NIH).



GOAL III:

Build integrated environmental health research programs to address the cross-cutting problems in human biology and human disease.

Interactive, team-based scientific research will be needed to optimize our ability to integrate research from all levels of investigation in order to contribute to overall health and reduce the burden of complex, multifaceted diseases. The study of how an environmental agent affects molecular targets, cellular function, tissue function and organism survival will need to be related up and down a continuum of biological complexity that ultimately informs us about the etiology, pathogenesis, and distribution of disease. Scientific contributions from epidemiology, toxicology, molecular and cellular biology, bioinformatics, clinical medicine, and many other fields will need to be coordinated and integrated. This collaborative approach will enable us to fully understand complex diseases and identify the most likely environmental links, and more effectively reduce health risks and disease burdens in human populations.

Promote interdisciplinary, integrative research approaches. The NIEHS should design and implement models for research that integrate clinical, epidemiological, and toxicological research with basic mechanistic studies to address disease etiology, pathogenesis, susceptibility, and progression. By fostering such broad-based, collaborative research, the NIEHS will increase the relevance of basic scientific discoveries in environmental health sciences to human disease and rapidly and more effectively move this knowledge into clinical and public health application, ultimately improving human health. As a first step, the NIEHS research

programs will be reoriented to foster collaborations across teams of scientists with complementary skills and areas of expertise. These collaborations will enable the NIEHS to better address important research needs and enable the institute to better align with cross-NIH efforts such as the NIH Roadmap for Medical Research (<http://nihroadmap.nih.gov>).

Identify and remove barriers to integrative research.

Integrative research requires teams of investigators who are willing to cross the boundaries of their own disciplines to develop research that they simply can't do on their own. The NIEHS will examine how the current structure of incentives and grants (e.g., peer review, training, and funding mechanisms) can be changed and use this information to encourage the creation of the integrated research teams that will be needed to perform future environmental health research.

Improve and expand access of researchers to advanced technology and scientific infrastructure.

The face of modern environmental health research is constantly changing, and new technologies have played an important role in driving these changes and leading to new discoveries. Cutting-edge environmental health research utilizes these newer, resource-intensive technologies in many ways, such as the use of mass spectrometry and NMR in metabolomics and proteomics research. These technologies are expensive and require expertise that is not always available at every institution or in every research group. For this reason, the NIEHS will foster efforts to coordinate and collaborate in the use of technologically advanced instruments and to provide access to conceptually demanding scientific infrastructure, ultimately accelerating discoveries in environmental health sciences.



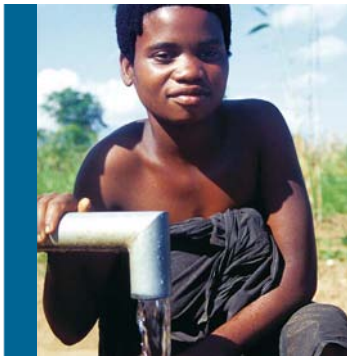
GOAL IV: Improve and expand community-linked research.

The NIEHS has a noted tradition of supporting research relevant to understanding health disparities and concerns of disadvantaged communities. Different groups of people are exposed to potentially toxic agents depending on where they live, work, and play. Differences in the environment are thought to contribute substantially to the excess burden of disease found in minority populations or impoverished communities. Examples of health indicators for which these disparities exist include shorter life expectancy, higher cancer rates, more birth defects, greater infant mortality, and higher incidence of asthma, diabetes, and cardiovascular disease.

The ways in which poverty and other factors create these health disparities are still poorly understood. However, there is increasing evidence that poor and minority groups are burdened with a disproportionate share of residential and occupational exposure to hazardous substances such as metals, pesticides, wood dusts, and air pollutants. In addition, the increasing mobility of our population raises the likelihood that exposures occurring remotely must be accounted for in assessing environmental exposure history as a contributor to disease burden. Thus, environmental exposures represent an important area of investigation for understanding and ameliorating the health disparities suffered by the disadvantaged of this nation and around the world.

The NIEHS is the primary federal agency responsible for supporting research, prevention, and training efforts to reduce the adverse health impact of environmentally related diseases.

DISCOVER: The NIEHS is developing a new research grant program called DISCOVER (Disease Investigation for Specialized Clinically Oriented Ventures in Environmental Research). DISCOVER will bring together basic, clinical, and population-based scientists to conduct integrative research programs on (1) understanding the etiology and pathogenesis of human diseases influenced by environmental factors, (2) using exposure to understand the interplay between genetic and environmental factors, and (3) applying available state-of-the-art technologies and methods to improve human health.



Therefore, the NIEHS has taken a lead role both in investigating the environmental influences on these conditions in minority and socioeconomically disadvantaged populations and in developing tools and strategies that will prove effective for reducing health disparities. We will continue to support research, both domestically and globally, that can offer important insights into how to reduce exposures and disease incidence in these community settings.

Focus on populations that are exposed to high concentrations of environmental agents that are thought to cause human disease. NIEHS-supported scientists have long recognized that exposures to environmental pollutants vary by locality around the world and can offer fruitful avenues for defining the impact of the environment on human health. The likelihood of exposure to environmental toxicants increases in most economically disadvantaged communities and is associated with an excess disease burden in these communities. Studies on the higher levels of environmental exposure in defined communities can lead to insight into potential health effects and can also offer unique opportunities for teasing apart different cellular pathways that contribute to the development of complex diseases. Use of newly developed technologies in exposure assessment and exposure biology will also facilitate this research, leading to a greater understanding of disease risk, pathogenesis, and prevention.

Focus on diseases that are unevenly distributed and have a high impact on morbidity and mortality. Variations in the incidence of diseases offer clues that may suggest where environmental agents are contributing to disease pathogenesis. The NIEHS will aggressively pursue research that follows up on these clues to target the most prevalent and severe

diseases. Targeting these diseases, which have great variation across communities, maximizes the probability that this research will have the greatest possible impact on major problems in public health.

Develop a program in global environmental health. In the modern global economy, very few environmental concerns can be truly described as affecting only a single country or geographic region. As the nation's premier environmental health research institute, the NIEHS has an obligation to address environmental health issues both nationally and globally. By expanding the definition of community to include a broader global perspective, the NIEHS is able to create the partnerships necessary for an effective global research strategy. The NIEHS is in the process of cultivating partnerships to better leverage resources in pursuit of new and emerging opportunities in global environmental research.

Build capacity to pursue research in global environmental health. One of the major deterrents to bringing cutting-edge mechanism-driven environmental health research to bear on global health problems is a lack of proper research training and access to a research infrastructure in many countries. The NIEHS will pursue three avenues for increasing the current capacity of trained personnel and research infrastructure: (1) develop training opportunities for young investigators from other countries; (2) work with universities to develop regional environmental health centers designed to work in collaboration with U.S. agencies operating overseas, nongovernmental organizations, and host governments; and (3) encourage all three major components of the NIEHS (intramural, extramural, and NTP) to have international partners.

GOAL V:

Develop sensitive markers of environmental exposure, early (preclinical) biological response, and genetic susceptibility.

Without accurate, personalized measures of exposure, we simply will not be able to assess the importance of the environment on human health. Thus, improvement in exposure assessment has to be one of the top priorities for research in environmental health science. Identifying and characterizing past environmental exposures is currently very difficult, if not impossible, for many agents of concern. The methodologies for detection and measurement of the actual exposure sustained by a human or other organism is most often weak and imprecise. This is in striking contrast to the robust tools we employ in the fields of genetics and genomics. In order to advance the field of environmental health sciences, we need personalized measures of environmental exposure that rival the ability to measure genetic variability between individuals. The increasing sophistication of our understanding of the biological pathways involved in host response to a given exposure points the way toward the use of that knowledge in the development of improved methods for detecting and measuring environmental exposures.

Develop validated biomarkers of exposure, susceptibility, and effect. The NIEHS, through the Genes and Environment Initiative, plans to support the development of biomarkers that would be accurate for the relevant timeframes (such as previous or historical exposures), be mechanistically linked to diseases of interest, and serve to link environmental exposures with biological effects. The ultimate goal is integration across biomarkers, allowing researchers to study disparate biological responses

to exposures. Modern molecular biology has provided biomedical research with an array of technologies that allow us to look at large numbers of genes, proteins, and other cellular components using small biological samples. It is possible that these same technologies may hold some promise for registering changes in cellular components following environmental exposures that remain in the body for a sufficiently long period of time to serve as biomarkers of past exposure. It would be particularly valuable to focus on a specific exposure–disease relationship and address it using multiple exposure assessment tools. Research areas with a critical need for specific biomarkers include common biological responses (inflammation, oxidative stress, apoptosis, and DNA damage), markers of gene and protein expression, and markers of organ dysfunction.

Develop new exposure technologies. Measurement of exposures in the general environment may also be improved through the use of newer technologies. These technologies need to be cheaper, faster, and better than those currently available. Practical needs, such as real-time measurement of exposures, detection of low doses, quick turnaround, and high throughput, are minimal requirements of this objective. The NIEHS will also capitalize on continued improvements in portability and sophistication of personal monitoring devices, field monitoring devices, and surveillance kits. Of particular interest is the use of nanotechnology for low-cost, micro-scale characterization of environmental and biological samples and in imaging technologies to evaluate environmental exposures. Imaging technologies are a potentially rich area for innovation in environmental health research and can be used to identify functional changes in exposure



and effects (e.g., MRI to quantify manganese and iron in the brain). Accelerator mass spectrometry may be another ultrasensitive tool for detecting exposures, and molecular imaging may be useful for investigating protein–protein interactions.

Address institutional barriers to effective exposure assessment and toxicity assessment in humans.

In many evaluations of health risks, among the biggest hurdles to overcome are the historical approaches and means by which previous evaluations were conducted. The changing face of biomedical research, however, requires a fresh evaluation of how we evaluate exposures and risks. Acceptance of new methods and techniques requires a number of scientific tasks that the NIEHS can lead. Examples include standardization and validation in sampling methodologies, development of exposure assessment strategies and tools, and illustration of the use of novel biomarkers and predictive models. Improved bioinformatics will also be needed to analyze and link the large data sets currently being generated. Additionally, the NIEHS will work to develop protocols and controls that ensure appropriate use of biomonitoring and biomarker data in human studies, including attention to ethical concerns.

GOAL VI:

Recruit and train the next generation of environmental health scientists.

The NIEHS is committed to cross-disciplinary training to attract the next generation of environmental health scientists and train them for the interdisciplinary research of the future. Environmental health scientists will need to be conversant in more than one discipline so that their research will have the greatest impact on understanding human health and disease. Along with developing interdisciplinary teams of scientists to work together on important environmental health issues, the NIEHS will extend its current commitment for training in the disciplines of epidemiology, exposure assessment, toxicology, cell and molecular biology, genetics, and bioinformatics, and will add cross-disciplinary training. In addition, the NIEHS must find a way to attract the brightest young students and scientists into our field in order to ensure that the full promise of environmental health research is met. This is especially true for scientists in fields that have not traditionally focused on environmental health, such as medicine, computer science, bioengineering, and biophysics.

Increase recruitment of talented students into environmental health sciences.

A variety of strategies will be pursued to increase the visibility of the field of environmental health sciences and to create incentives for recruitment. Providing field experiences for interested students, increasing the likelihood of funding for future researchers, aggressively recruiting students at health fairs and scientific meetings, and creating customized approaches for attracting students at various points in the educational pipeline (high school, college, and graduate

school) will increase awareness and interest. The NIEHS will enhance opportunities for young, motivated high-school and undergraduate students to participate actively in research.

Engage the broader biomedical community in environmental health research. Schools of medicine, schools of public health, and traditional graduate science programs have an important role to play in the overall effort to provide a more robust focus in environmental health sciences. The success of the clinical research program is linked to our ability to integrate environmental health science more effectively into medical school curricula and research so that future physicians are better equipped to consider and understand the interaction of environment with human health. In addition, public health scientists are traditionally trained in multiple fields and are an excellent resource for helping the NIEHS develop the research teams of the future. However, the underpinning of all of our research efforts is based in fundamental research and will require continued support of trainees in basic disciplines in the biomedical sciences.



ONES: The Outstanding New Environmental Scientist

(ONES) Award is a first independent research grant designed to attract the most talented younger researchers into the field of environmental health sciences. The NIEHS aims to identify a cadre of outstanding scientists in the early, formative stages of their careers who are interested in developing a career in environmental health sciences research, and to provide a strong start for these individuals. These grants will assist young scientists in launching innovative research programs focusing on problems of environmental exposures and human biology, human pathophysiology, and human disease.



GOAL VII:

Foster the development of partnerships between the NIEHS and other NIH institutes, national and international research agencies, academia, industry, and community organizations to improve human health.

The NIEHS depends on strong partnerships with a wide variety of organizations and agencies to achieve its mission. Community groups are key partners in identifying environmental issues and diseases of concern, as are regulatory agencies, academia, and industry. Studies can be initiated more successfully and results will be more useful if the perspectives of all stakeholders are represented in the planning process.

Engage partners across disciplines in government, academia, and industry to expand the reach and relevance of environmental health sciences. Unlike many other fields of research, environmental health science research is not limited by an organ system, a methodological approach, a single disease, or a population. Its multidisciplinary nature offers great promise, but also presents challenges. Since research activities are usually organized around disciplines and institutions, there are barriers to collaborations across disciplines and missions. Public investments will be optimized by developing ways to integrate across multiple disciplines and research groups.

Provide leadership in developing partnerships to facilitate critical studies. Many organizations and agencies have access to long-standing study populations that are relevant to issues other than those they were originally assembled to address. In many cases, other organizations or agencies will have questions or concerns in environmental health sciences that might be answered most effectively by

using an existing study population. The NIEHS intends to provide leadership in developing means for scientists from multiple organizations and agencies to share access to study populations and/or their data. This leadership will include enhancing the stability/accessibility of databases, repositories, and registries through partnerships with other organizations. These types of partnerships will also be brokered to provide more opportunities to study unique populations through twin registries, occupational cohorts, and large cohorts that cannot be assembled by a single agency. Through these partnerships, the NIEHS will also investigate identification of high- and low-exposed populations that could be used in comparative studies. Partnerships could also help develop tools to better assess social and economic inequities that are becoming increasingly important in understanding relative disease risks within a population.

Work with agency, industry, and community partners to enhance communication and translation of research results into effective means to protect public health. The NIEHS needs to reach out and engage its key partners, both to ensure we are funding the best and most relevant science and to ensure that we are making the greatest possible impact on the nation's health. We will continue to improve our ties to our partners, to ensure that the best science is brought to the processes of health care, community intervention, and regulatory decision-making.

SUMMARY

The scientific challenge posed by environmental health science research is to support the best science possible to develop the tools and information needed to improve the health of humans worldwide. This challenge will require a very broad scientific view with the ability to focus on the questions that are relevant to the practical needs of the public while providing flexibility to address the needs of the future. The researchers and staff supported by the NIEHS are dedicated to using what we know regarding the interaction of humans and other organisms with their environment to understand human disease and improve human health. The strategic goals outlined in this document focus on the future and describe the directions for environmental health sciences to support the best science possible into the 21st century. With the hard work and dedication of us all, the NIEHS can move into this new era of exciting challenges that hold the promise of better environmental health.



Genes and Environment Initiative:

In an effort to accelerate our understanding of how genetic and environmental risk factors influence health and disease, the NIH has launched the Genes and Environment Initiative (GEI).

The GEI has two main components: a system for analyzing genetic variation in groups of patients with specific illnesses, and an environmental technology development program to produce and validate new methods for monitoring environmental exposures that interact with a genetic variation to result in human diseases. The NIEHS is taking a lead role in the environmental technology development program, and the GEI Working Group is co-chaired by NIEHS director David Schwartz and Francis Collins, director of the National Human Genome Research Institute.

This initiative is seen as so important to the advancement of biomedical research that companies including Pfizer, Inc., of New York, NY, and Affymetrix, Inc., of Santa Clara, CA, announced they will jump-start the GEI by contributing over \$20 million dollars to the project through a public-private partnership known as the Genetic Association Information Network (GAIN).

The Process

The development of the NIEHS Strategic Plan followed a detailed and accelerated timetable beginning in the spring of 2005, and engaged a broad spectrum of individuals—investigators, clinicians, other scientists, engineers, policy advocates, and interested citizens—in providing their perspectives and opinions to the institute. The initial step in the process was an invitation to NIEHS stakeholders to help identify promising areas of need and opportunity in the environmental health sciences, as well as to suggest new potential directions for the NIEHS and its research programs. Key milestones in the planning sequence included the following initiatives and events:

NIEHS staff, with additional input from area investigators in Research Triangle Park, formed a strategic planning working group to develop the procedures, format, and timetable for the overall strategic planning process and to define some of the key issues.

Following an announcement in the *Federal Register*, a six-question web survey was posted on the NIEHS website between June 22 and August 5, 2005. The questions posed were:

1. What are the disease processes and public health concerns that are relevant to environmental health sciences?
2. How can environmental health sciences be used to understand how biological systems work, why some individuals are more susceptible to disease, or why individuals with the same disease may have very different clinical outcomes?
3. What are the major opportunities and challenges in global environmental health?
4. What are the environmental exposures that need further consideration?
5. What are the critical needs for training the next generation of scientists in environmental health?
6. What technology and infrastructure are needed to fundamentally advance environmental health science?

Over 400 responses were received from scientists and clinicians in universities, other research institutions, and government, as well as from advocacy groups and individual citizens. NIEHS staff worked at length to distill all the input into a single summary document.

Over 400 responses were received from scientists and clinicians in universities, other research institutions, and government, as well as from advocacy groups and individual citizens.

Using the input from the web survey, six broadly defined discussion topics were identified as being central to strategic decision-making on the future direction, emphasis, and priorities of NIEHS programs.

In September, senior NIEHS staff made a detailed presentation on the strategic planning process at the scheduled meeting of the NIEHS National Advisory Environmental Health Sciences Council. Questions and discussions at the meeting explored options for analysis and decision-making in key areas.

To continue the strategic dialogue, a “Strategic Planning Forum” was hosted by the NIEHS on October 17 and 18, 2005, in Chapel Hill, North Carolina. The forum was co-chaired by Dr. Frederica Perera, professor of environmental health sciences and director of the Columbia Center for Children’s Environmental Health at Columbia University’s Mailman School of Public Health, and Dr. Gerald Wogan, Underwood-Prescott Professor of Toxicology Emeritus and professor of chemistry emeritus at the Massachusetts Institute of Technology. Over 90 invited scientists, clinicians, and persons representing support and advocacy organizations participated in a highly interactive program involving intense, small-group discussion on six core topics related to future NIEHS priorities. Each discussion group was given specific issues and questions to consider in their respective topic area; was asked to reach a general consensus on their conclusions; and reported their outcomes at a plenary session that followed. The procedure was followed through three successive cycles to cover all six topics. Additionally, following the plenary

presentations, all participants were asked to list the proposed priorities they felt were most important in each topic area. Questions were also posed at the conclusion of the meeting for the attendees’ consideration and response.

The substantial input from the Strategic Planning Forum was gathered and analyzed by NIEHS staff and advisors. Recommendations and subject area priorities were weighed, as were the detailed transcripts from every discussion group. Summaries from the discussion sessions were combined into a formal “proceedings” of the forum.

Additional discussions were held in November 2005 with members of the NIEHS Public Interest Liaison Group, representing nongovernmental medical, environmental, and policy organizations with interests in the institute and the future direction of environmental health research, research applications, and policy. Emerging NIEHS scientific priorities were the central topic of the discussions.

The draft NIEHS Strategic Plan was posted on the NIEHS website for public comment in December 2005. Feedback from the website was gathered for consideration as the document continued to be revised.

Key components of the NIEHS Strategic Plan were shared with staff at an all-hands meeting in January 2006 hosted by the institute director.

Following advanced distribution, the proposed NIEHS Strategic Plan was presented to and discussed at the NIEHS National Advisory Environmental Health Sciences Council meeting in February 2006. In response to the council discussion, the plan was further revised and finalized.

Appendix

Participants at the NIEHS Strategic Planning Forum

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The NIEHS, located in Research Triangle Park, North Carolina, is one of 27 research institutes and centers that comprise the National Institutes of Health (NIH), U.S. Department of Health and Human Services (DHHS). The mission of the NIEHS is to reduce the burden of human illness and disability by understanding how the environment influences the development and progression of human disease.

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Published by *Environmental Health Perspectives* (ISSN 0091-6765),
a publication of the Public Health Service,
U.S. Department of Health and Human Services.
[NIH Publication 2006-218]



U.S. Department of Health and Human Services
National Institutes of Health
National Institute of Environmental Health Sciences