
Microbial life dominates Earth’s biosphere and affects all other life forms in myriad ways that are mostly beneficial, but at times deleterious. Since microbes affect all major human activities, microbiological research has important roles to play in the development of sustainable solutions to contemporary and future challenges. Within the United States and worldwide, increasing populations and changing demographics, large-scale changes in land use, changes in climate, and limitations on fossil fuel supplies pose major challenges that must be addressed to assure economic growth, healthy human populations and environments, and national security.

By exploring microbial ecosystems, the nation’s microbiologists conduct widely diverse research that is increasingly critical to:

- ensuring environmental and human health in a rapidly changing world
- developing energy security through alternative energy sources
- discovering new biotechnology resources and contributing to economic security

Key Recommendations

To ensure the robust microbiological research mandated by our current and future challenges, the American Society for Microbiology (ASM), comprising more than 42,000 members, recommends that the new Administration:

- coordinate and centralize data from existing and planned programs (e.g., National Ecological Observatory Network, U.S. Geological Survey, U.S. Environmental Protection Agency), to identify connections among changes in demographics, climate, and land use, changes in patterns of microbe diversity, and changes in water quality and water-borne disease incidence;
• expand existing programs and develop new ones to monitor currently important and emerging plant, animal and human pathogens, and to respond to disease outbreaks that pose threats to food supplies and plant resources;

• invigorate training programs to provide a scientific workforce capable of meeting the challenges posed by multi-faceted, complex environmental problems;

• support efforts to enhance plant biopolymer degradation for biofuel production using novel microbes and bioengineering;

• fund research to enhance the yields and cost-effectiveness of butanol production with novel microbes and with synthetic biology to improve performance of known butanol-producing microbes;

• support efforts to increase the understanding and efficiency of bioelectricity production from wastewater treatment and other processes, and to incorporate bioelectricity generation into wastewater treatment systems;

• establish strategically targeted programs to assess broadly the potential for commercial applications of the Nation’s microbial resources;

• implement recommendations from the National Research Council of the National Academies of Science to establish metagenomics programs that will promote discovery of microbial diversity and economic potential; and

• establish a national facility for cataloging, cultivating and archiving the Nation’s microbiological resources.

**Microbiology Research Essential to National Interests**

The Nation’s economic vitality, security, and overall health depend in profound ways on microbes, due to their ubiquitous distribution, abundance and astonishing capabilities. The federal research portfolio recognizes the centrality of microbes to public health and well-being, supporting a broad range of microbiological research initiatives through the National Science Foundation, the National Institutes for Health, the National Aeronautics and Space Administration, the Department of Energy, the Environmental Protection Agency, and the U.S. Department of Agriculture, among others. Research supported by these agencies has generated new knowledge about microbes, some of which has resulted in new products and services that contribute to the Nation’s ability to compete in a global marketplace, to preserve environmental health, and to limit the impact of diseases.

Challenged by rapidly changing physical and economic environments, the Nation must invest even more vigorously and broadly in basic science, including the microbiological sciences, in order to maintain its global competitiveness and scientific leadership. Educating a scientifically literate workforce and generating new knowledge are essential for meeting the many challenges posed by global change, which includes but is not
limited to climate change. The Nation’s ability to predict and react to future change depends fundamentally on taking proactive steps now to ensure that scientific and technological infrastructures are broad in scope, while adding depth to training programs in both schools and the workplace.

The American Society for Microbiology and its more than 42,000 professional scientists, clinicians, educators and students stand ready to continue their discovery of the largely uncharted microbial world, and to use new knowledge to help address the critical needs and issues involving microbes vis-à-vis our national security and economic, energy, and public health resources.

What are the primary issues and critical needs involving microbes and environmental health?

Primary Issue: “One Health, One Environment”

For more than a decade, the ASM has promoted the concept of “one health, one environment” now adopted by the NIH, USDA, EPA and other agencies (*Emerging and reemerging infections diseases of plants and animals*, ASM-PSAB, 1996). This concept recognizes that human health depends in large measure on environmental health, which includes all aspects of the natural functions of ecosystems and the health of natural plant and animal communities. Human, plant and animal health are interconnected and each depends upon dynamic interactions with both beneficial and pathogenic microbes, many of which are affected by human activities in a variety of sometimes unpredictable ways.

Critical needs for research:

- The United States has experienced and will continue to experience significant changes in human demographics due to immigration and other factors, but the effects of changing demographics on patterns of disease distribution and incidence are not sufficiently understood.

- Where population densities are low, natural geographic barriers can limit disease transmission, but how such barriers are now changing and will change in the future is not well-known. Nor is it known whether such barriers can be engineered to limit the spread of disease.

- Accurate assessment of the programs that control outbreaks of waterborne diseases is currently curtailed by underreporting of disease incidence and lack of data aggregation. Expanded metrics for disease surveillance and enhanced methods of detection are needed, especially for emerging pathogens.

- The impacts on waste treatment systems caused by changing land use (as related to sources of potable groundwater and surface water), climate change, and changing demographics are not understood.
The relationship between indoor air quality and increasing population density is unknown, but likely negative, and needs to be addressed.

The effects of increasing environmental stresses on plant susceptibility to disease are not well-delineated, and surveillance of agricultural pathogens and other pathogens of natural plant communities is currently inadequate to predict and control disease outbreaks.

Our future workforce might be unable to meet the demand at all levels for individuals with microbiological expertise. For example, budget reductions at EPA have severely limited workforce training and the extent of the academic network on which EPA relies, constraining EPA’s ability to fully address current and future knowledge gaps.

Recommendations:

- develop centralized databases for reporting disease incidences and related population and environmental variables, which will facilitate rapid identification and analysis of temporal and spatial trends in disease

- coordinate and centralize data from existing and planned observing programs (e.g., National Ecological Observatory Network, U.S. Geological Survey, U.S. Environmental Protection Agency) so that changes in demographics, climate and land use can be related to changes in microbial diversity and to changes in water quality and water-borne disease incidence

- expand existing and develop new programs for monitoring currently important and emerging plant, animal and human pathogens, and for responding to disease outbreaks that pose threats to food supplies and plant resources

- invigorate training programs to provide a scientific workforce capable of meeting the challenges posed by multi-faceted, complex environmental problems

What are the primary issues and critical needs involving microbes and alternative bioenergy sources?

Primary Issue: Energy security for the United States depends on use of a broad mix of sustainable non-fossil fuel alternative energy sources. Microbes represent important sources of sustainable energy through biofuel production (ethanol, butanol, hydrogen), methane production and bioelectricity generation.

Establishing sustainable energy independence for the United States clearly requires greater use of non-fossil fuel energy sources. Microbes offer multiple possibilities for alternative energy sources, especially via biomass and waste conversion to biofuels, bioelectricity generation through coupling waste treatment and other processes, and
production of methane gas. In order to realize the full potential of bioenergy, however, a number of basic challenges must be solved. Among others, these include enhancing yields and use of methane from waste organic matter.

**Critical needs for research:**

- The conversion efficiency of cellulose and other plant polymers to fermentable substrates remains an important factor limiting costs and biomass sources for biofuel production. Improving conversion efficiencies requires greater understanding and control of the complex mechanisms involved in cellulose breakdown.

- Butanol represents a more desirable biofuel than ethanol, but the acetone-butanol-ethanol process for producing butanol is inefficient and must be improved for yield and cost efficiency.

- Realizing the largely untapped potential for bioelectricity production from wastewater and other materials requires greater understanding of the basic microbial processes involved and efforts to incorporate bioelectricity production into wastewater treatment system designs.

**Recommendations:**

- support efforts to enhance plant biopolymer degradation for biofuel production using novel microbes and bioengineering to increase the performance of existing polymer-degrading systems

- enhance the yields and cost-effectiveness of butanol production with novel microbes and apply synthetic biology to improve performance of known butanol-producing microbes

- support efforts to increase the understanding and efficiency of bioelectricity production from wastewater treatment and other processes, and to incorporate bioelectricity generation into wastewater treatment system designs

**What are the primary issues and critical needs involving microbes as environmental and economic resources?**

**Primary Issue:** Microbes have been underexploited as commercially valuable resources for biotechnology and other industries, for alternative energy generation, and for solutions to environmental problems.

Microbes provide numerous products and processes that support many billions of dollars of annual economic activity in sectors as diverse as the health and pharmaceutical industries, food and agriculture, biotechnology, energy, bioremediation and waste
treatment, and mining, among others. For example, a single product, DNA polymerase, from a single organism has transformed many industries and provided the foundation for much of biotechnology and its profoundly important applications throughout society.

Nonetheless, there are no federally supported initiatives to systematically explore the diversity of microbes within the United States and their potential economic applications. The absence of such federal programs contrasts dramatically with initiatives supported by other governments, such as those in Germany, Japan, China, and Korea. It is likely that far-sighted programs by other nations to discover and commercially develop microbial resources might limit future biotechnology growth in the United States.

**Critical needs for research:**

- Hot springs and other thermal features are well-known sources of novel microbes and potentially valuable microbial products, but microbial diversity within the many thermal environments of the United States has been explored to only a limited degree.

- Soils harbor extraordinary levels of microbial diversity and offer great promise for commercially important products like antibiotics, but neither the diversity nor biotechnological potential of soil microbes has been surveyed strategically.

- Marine and other aquatic environments contain many novel but largely uncharacterized microbes that have considerable potential as sources of valuable bioproducts, including uses in pharmaceuticals and bioremediation, but microbes in these environments have been only minimally characterized.

**Recommendations:**

- establish strategically targeted programs to assess broadly the diversity and potential for commercial applications of the Nation’s microbial resources

- implement recommendations from the National Research Council of the National Academies of Science to establish metagenomics programs that will promote discovery of microbial diversity and economic potential

- establish a national facility for cataloging, cultivating and archiving the Nation’s microbiological resources

There is no doubt that microbes directly impact human, animal, and plant populations worldwide, as both benefactors and fearsome threats. There also is no doubt that our national and global environments are changing. It is likewise certain that vigorous basic and applied research on the Earth’s inestimable interactions with microbes will continue to strengthen our ability to respond positively to these changing environments.