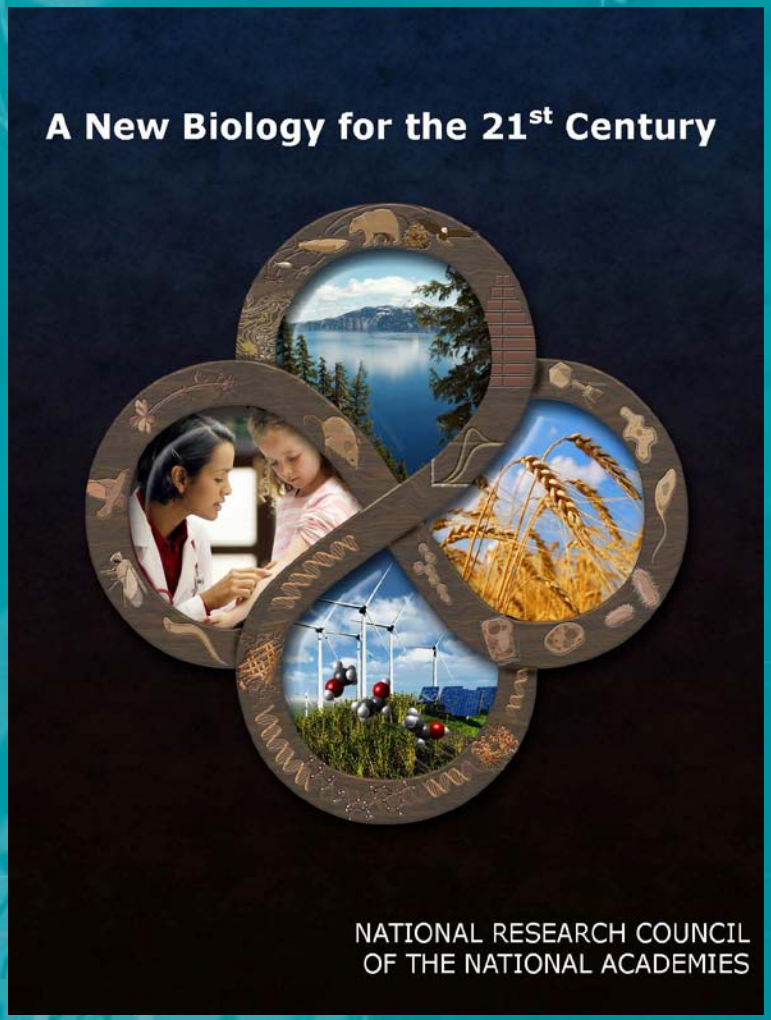

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Board on Life Sciences

A New Biology for the 21st Century

Committee on a New Biology for the 21st Century

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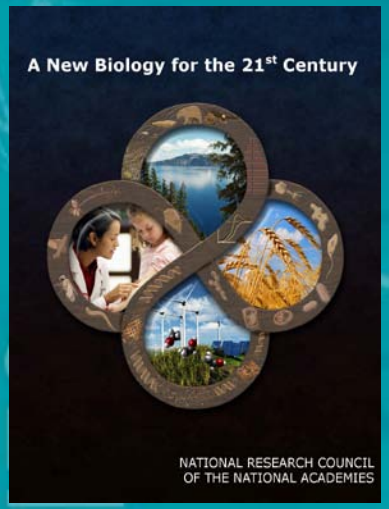

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Biology is at an inflection point

-- poised to help solve major societal problems

Relatively small investment in inspiring and crucial challenges will solve critical problems and lead to development of cross-cutting technologies and sciences that will leverage the value of all biological research.

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A moment of unique opportunity –

Why now?

- Integration of subdisciplines within biology
- Cross-discipline integration: life science research by physical, computational, earth scientists, engineers
- Technological advances enable biologists to collect data unprecedented in quantity and quality
- Past investments providing value beyond expected

An opportunity to accelerate the emergence of a New Biology with impact at an unprecedented scale

RECOMMENDATION:

Launch a National New Biology Initiative

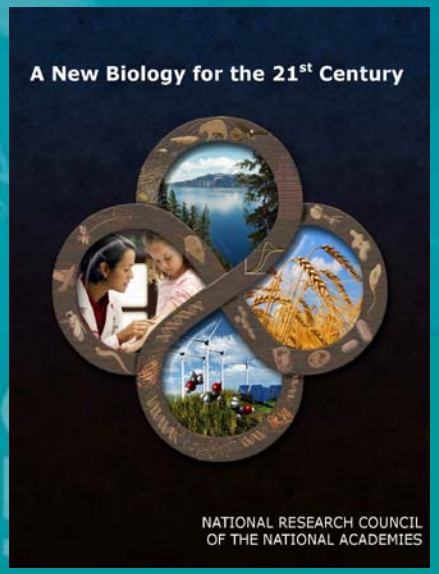
a multi-agency, multi-year, multi-disciplinary initiative to capitalize on the extraordinary advances recently made in biology and address four major societal challenges.

Why a National Initiative?

- big goals capture imaginations, drive innovation *(e.g., man to the moon, human genome project)*
- need the expertise of many federal agencies, scientific communities, academic and private sectors
- need multi-agency collaboration and leadership to define best investments in foundational sciences and technologies, and to advance interdisciplinary education
- need dedicated funding on a long time horizon to inspire scientists, maximize impact from investments in science and technologies

New Biology could affect urgent problems:

- *Nearly a billion undernourished in ’07; still increasing, especially where food supply already inadequate*
- *Human activities are stressing, altering and destroying ecosystems we rely on*
- *Transportation fuels depend almost fully on limited non-renewable resources*
- *Healthcare decisions based on statistics; rely on costly technologies that may not benefit a given individual*



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What the New Biology could do

Food

Adapt any food crop to any growing condition

Environment

Diagnose and repair ecosystem damage

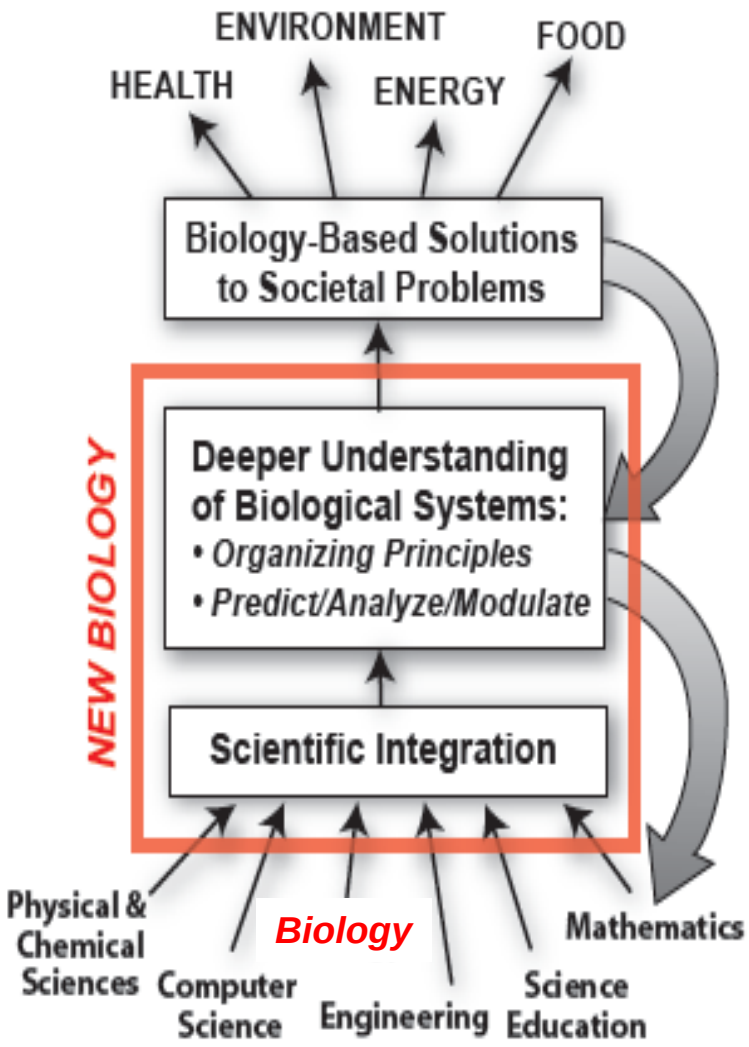
Energy

Expand sustainable alternatives to fossil fuels

Health

Achieve individualized surveillance and care

What is the New Biology?



The New Biology Food Challenge

Adapt any food plant to any growing condition
***Mission:* sustainable local food production**

What is needed:
- genetically informed breeding and transgenics
- recognition of importance of biodiversity, systematics, evolutionary genomics
- analysis of crops as ecosystems

Requires fundamental understanding of:
- plant development, growth and productivity
- plant tolerance of extreme conditions
- plant adaptation to climate change

The New Biology Environment Challenge

Develop early warning of reduced ecosystem services, and effective restoration strategies

Mission: halt and reverse ecosystem damage

Multiple ecosystem stresses: pollution, over-harvesting, habitat fragmentation, climate change

What is needed:

- comprehensive, quantitative measure of ecosystem services
- monitoring and early markers of ecosystems at-risk
- fundamental understanding of ecosystem restoration
- development of ecosystem engineering: basic science of ecosystem function integrated with problem-solving methods

The New Biology Energy Challenge

Meet Renewable Fuel Standard 2022 goal: 4x increase in economical biofuel production

***Mission:* sustainable alternative to fossil fuels**

To succeed, must approach biomass-to-biofuel production process as an integrated system

What is needed:

- develop energy crops that produce readily converted biomass
- engineer microbial biocatalysts with high conversion rates and yields
- engineer biofuel production process engaging plant scientists, microbiologists, ecologists, molecular geneticists, process engineers

The New Biology Health Challenge

Achieve early diagnosis, individual disease risk assessment, prevention and treatment

Mission: individualized health surveillance and care

The deep knowledge gap between genotype and phenotype means that treatment is based on statistical likelihood of response: not individual circumstances

What is needed:

- modeling interactions among individual's genotype, microbiome, physiology, environment, history
- network and pathway analyses, and comparative biology
- define networks that monitor, report, and react to changes in health, thus enabling surveillance
- develop conceptual and technical capacity to monitor metabolome as integrated phenotypic readout

Interconnected problems, Interconnected solutions

The challenges cannot be met in isolation

- To meet the environment challenge, the food challenge must be met without increased land and water use, fertilizer and pesticide release, and fossil fuel input
- meeting the health challenge depends on maintaining ecosystem services
- meeting the energy challenge with biofuel production cannot come at the expense of food production

Interconnected problems, Interconnected solutions

One biology: <u>same science</u> supports all four missions

Some examples:

- understand genotype–phenotype connection
- biodiversity: recognize and employ evolutionary adaptability
- networks: unravel and apply complex system logic

Interconnected problems, Interconnected solutions

One biology: <u>same technologies</u> support all four missions

Some examples:

- information infrastructure: make results of all scientific research fully interoperable
- imaging: see biological processes at all scales
- high throughput: make monitoring metabolomes and proteomes as routine as genome sequencing

Coordinated investment, big impact

- Enabling the New Biology leverages investment across the life sciences
- National Initiative will provide funds to enable interagency efforts to solve common problems cooperatively
- Costs low compared to:
  - benefit
  - current spending for research
  - cost of *not* addressing the challenges

Ongoing committee commitment to implementation

Dissemination:

Agencies briefed:

- NIH: Director's office and I/C Directors
- NSF: Biology and Engineering Directorates
- DOE: Office of Science
- USDA: National Institute of Food and Agriculture

Other Briefings:

- Senate Health, Education, Labor and Pensions committee
- OSTP, NEC
- Coalition for the Life Sciences (November)
- American Institute of Biological Sciences (December)

Potential follow-up activities through the NRC Board on Life Sciences

Workshops on the four challenges

Brainstorming workshops to bring together agencies, scientific communities, private sector to develop strategic options, identify critical knowledge gaps, technology needs, immediate priorities, milestones.

New Biology Roundtable

Ongoing NRC forum to convene stakeholders from government, academia, private sector: opportunity to communicate, build networks, identify common opportunities and challenges.

Acknowledgments

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for entrusting us with this task.

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