


# FUTURES RESEARCH FRAMEWORK FOR BIOMEDICAL RESEARCH AND DEVELOPMENT

INSTITUTE FOR ALTERNATIVE FUTURES 2029  
PROJECT INTRODUCTION AND INVITATION



The 2029 Project is a review of current developments in a wide range of fields to stimulate thinking on the part of those involved in biomedical R&D. The Institute for Alternative Futures developed this framework to guide our research. This is a critical first step in creating an initial map of R&D areas. This research framework will serve as a knowledge management tool throughout the project.

In constructing this framework, IAF reviewed the National Academy of Sciences (NAS) taxonomy developed to map the many areas of doctoral research (<http://books.nap.edu/books/030909058X/html/19.html#pagetop>). We take heart from a comment in the introduction to this taxonomy:

*“The construction of a taxonomy inevitably confronts limitations and requires execution of somewhat arbitrary decisions.... The committee wanted its taxonomy to be forwardlooking and to recognize evident trends in the organization of knowledge.”*

Our 2029 research framework gives priority to fields that appear particularly important to biomedical R&D. Like the NAS panel, IAF has set categories in science where interdisciplinary learning is blurring traditional lines and creating many interconnections. While we cannot adequately reflect these interconnections in this outline format, they are an important aspect of our mental framework as we do this research.

IAF held an initial team review of its research framework and identified an initial set of developments that seem to be on the critical path to accelerating biomedical research and advancing global health. We will be including short summaries of these key areas to explain their potential significance.

We now make this framework transparent in its current state of imperfection to invite you into our learning. If we have omitted any major categories that should be included for biomedical research, please let us know. If you would like to nominate a topic for additional attention on the critical path, please make this case to us. To share your learning with this project, please contact the 2029 Project leader, Jonathan Peck, IAF vice president at [jpeck@altfutures.com](mailto:jpeck@altfutures.com) or 703-684-5880.

## **I. LIFE SCIENCES**

*All life sciences are evolving from current disciplines, typically changing most strikingly at the boundaries between disciplines. The past two decades have seen remarkable progress in molecular biology, but the thrust of recent learning appears to be moving towards understanding the cell, physiology and ecology. Some of the findings from lower-order systems (e.g., molecular biology receptor systems) initially anticipated to predict effects in the higher-ordered systems (e.g., human response to a “rationally designed” drug) show the limits of reductionist thinking. Still more and more scientists network across the multiple disciplines and add to knowledge that is accumulating at a growing rate. The accumulated knowledge may form a hierarchy of holons (complex systems that are composed of less complex systems and are also parts of more complex systems) called a holonarchy.*

### **A. Molecular biology**

1. Genomics
2. Proteomics
3. Metabonomics
4. Single molecule techniques
5. Bioinformatics

### **B. Cell Biology**

1. Functional Pathways
2. Cellular Components



**C. Biochemistry**

1. Combinatorial Chemistry
2. Click Chemistry
3. Biochips and Labs-on-a-chip
4. Custom Drug Design

**D. Systems Biology**

1. New Measurement Tools (e.g., Biomarkers)
2. Cross-Disciplinary Models

**E. Ecology and Evolutionary Biology**

**F. Pharmacology and Toxicology**

1. Pharmacokinetics
2. Pharmacodynamics

**G. Neuroscience and Neurobiology**

**H. Chronic Diseases**

1. Cardiovascular Disease and Diabetes
2. Cancers
3. Neurological Degenerative Diseases
4. Immunological Diseases

**I. Infectious Diseases**

1. HIV
2. Influenzas
3. Emerging Diseases
4. Malaria and Tuberculosis

**II. PHYSICAL SCIENCES, MATHEMATICS and ENGINEERING**

*The infrastructure for biomedical research and much of the knowledge is supported by the multiple disciplines working in these areas. As physicists, mathematicians and engineers engage with scientists trained in the life sciences, surprising discoveries and remarkable tools emerge. Fundamental concepts that develop within the physical sciences contribute to and enter into biomedical research as they merge with the life sciences. The path forward in biomedical knowledge is marked by a widening of disciplines and approaches that brings scientists from very different backgrounds into a shared arena for discovery and invention.*

**A. Nanotechnology and MEMS**

1. Nano-Devices
2. Nanomaterials

**B. Physics**

1. Imaging

**C. Biomedical Engineering, Devices, and Procedures**

1. Implants
2. Neurological-Silicon Interface
3. Advanced Materials



#### 4. Tissue Engineering

##### ***D. Statistics and Probability***

### **III. INFORMATION TECHNOLOGY & MANAGEMENT**

*Exponential growth curves show how rapidly computational power, connectivity and knowledge aggregation have changed science. After 33 doublings, the scale of change with the next doubling challenges the imagination to describe what comes next. IT speeds learning from within biomedical science to healthcare and society, and it brings learning back and forth across all the boundaries dividing disciplines, endeavors and cultures. This will happen faster and more powerfully as computers achieve an artificial intelligence that both supports and increases human intelligence. Learning that was presented in text may move to faster medium, graphics video and virtual realities. The interface between information technology and people is sure to change and the rate of change is sure to increase.*

##### ***A. Exponentially Increasing Computing Power***

##### ***B. Software and A.I.***

##### ***C. Data Storage***

1. Genetic Databases
2. Proteomic Databases
3. Epidemiologic Databases
4. Outcomes Databases

##### ***D. Networks***

1. PDAs and Wireless
2. Multimedia

##### ***E. Modeling & Simulations***

1. Virtual Human Initiative & Virtual Organs
2. Preclinical Models
3. Clinical Trial Simulations


##### ***F. Ontology and Knowledge Management***

### **IV. SOCIAL SCIENCES**

*The research agenda for social science becomes more central to biomedicine as the duality of mind and body gives way to new knowledge about the interconnections between them. New knowledge from social science will likely be especially important to biomedical research addressing prevention of chronic disease, mental health and the role of community in health. Human behavior is such a key factor in the prevention agenda that the old divisions between so-called soft science and hard science may disappear. Cost-effectiveness studies have already ushered economics into clinical research. Other social sciences such as sociology and psychology will likely follow as scientists accept new ways of looking at group dynamics that affect immune response and variations in efficacy such as the placebo effect. The impact politics and globalization will have on the business models supporting biomedical research will also lead to further boundary crossing, especially as scientists turned entrepreneurs or business executives seek new ways to gain support for the biomedical research endeavor.*

##### ***A. Psychology and behavior change***

1. Groupware
2. Mental Health

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3. Social Marketing
  4. Information Therapy
  5. Health Media
  6. Personality, Creativity and Team Performance

***B. Sociology***

1. Communities
2. Health Disparities

***C. Politics***

1. Public Support
2. Genetic Engineering and Stem Cells
3. Bioterrorism
4. Open Source Research

***D. Economics***

1. Intellectual Property
2. Business Models
3. Product Pipelines
4. Globalization

**VI. ENVIRONMENT & POLLUTION**

*Understanding both the harmful and positive effects of the environment in an interconnected world is a fast-evolving scientific discipline. Pollution's effects on health may be higher than traditional epidemiologists believe. In our globalized and industrialized world, new human-made components are introduced into ecosystems at a scale and reach that makes controlling their effects difficult to assess or control. Many environmentalists assume meddling with nature is detrimental and advocate for the precautionary principle. If human interference in nature is likely to be harmful, then unexposed and unharmed populations probably do not exist. Most of the testing of toxic substances is necessarily done in animals. To know whether substances are toxic to humans requires data from studies on human populations. These epidemiological studies are often limited by populations that can be too small and time exposures that are usually too short. As for the beneficial aspects of the environment, studies now document that contact with nature enhances mental health and strengthens the mind's contribution to the body's health.*

***A. Environmental Epidemiology***

***B. Ecosystems Science***

***C. Eco-psychology***

***D. Environmental justice***

**VI. HEALTHCARE DELIVERY ADVANCES**

*Biomedical research both creates healthcare delivery advances and receives new learning from patients and providers that helps shape the agenda for new innovation. Early in the history of medicine, research and clinical medicine were tightly tied together before they became more distinct and separate. They may be rejoined through pervasive information systems that reduce the lag time between new knowledge and its application for improved healthcare delivery and faster, more targeted innovation.*

***A. Integrated Delivery & Monitoring Systems***

1. Electronic medical records

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2. Bio-monitors
  3. Product Monitors

***B. Health & Prevention***

1. Nutrition
2. Obesity
3. Community Infrastructure

***C. Chronic Care***

1. Patient-Centered Care
2. Health Management Systems

***D. Acute Care***

***E. End of Life Care***

***F. Incentives & Economics***

1. Evidence Based Medicine & Outcomes Research
2. Quality & Patient Safety

**VII. COMPLEMENTARY/ALTERNATIVE AND INTEGRATED MEDICINE**

*Complementary and alternative approaches are being integrated into conventional medical protocols as research clarifies their efficacy and patients favor their use. Customized medicine, self care and holism require a closer look at the individual. Some alternative medical systems have extensive knowledge of individual difference built into diagnostic and therapeutic systems. The complementary and alternative field raises important questions about what works and how—because of the efficacy of the interventions themselves, because they unleash self-healing capacity, or because they involve strong practitioner/patient relationships. A greater emphasis on outcome measures will bring new insights to both conventional and complementary and alternative medicine.*

***A. Alternative Medical Systems***

***B. Mind-Body Interventions***

***C. Biologically Based Therapies***

***D. Manipulative and Body-Based Methods***

***E. Energy Therapies***

**VIII. THEORY AND PHILOSOPHY**

*Beliefs arise from an older part of the brain that connects with the limbic system. When the newer part of the brain responsible for the cognitive processes we call higher reasoning examine those beliefs, theory is produced. Theories combine some of the emotional aspects of belief (e.g., excitement, provocation, disbelief) while engaging the rational mind to create tests, find principles, propose refinements and formulate laws. Periodically, new theories emerge that have a long-lasting impact that re-directs and re-energizes science. The potential exists for biomedical research to be profoundly altered by new theories over the next 25 years, much as physics was by quantum and relativity theories 100 years ago. While Darwin's theory of evolution has organized and excited research in biology for over a century, unlike physics there are no equivalent "laws of biology." A more powerful theory could come in the next two decades, potentially addressing philosophical questions such as materialism as well. Various philosophies have competed throughout history (e.g., materialism vs. idealism) with periodic ascendance and descents in terms of popularity and influence. In recent years the objective materialism that led many to hope the*

*genome would provide the keys for a causal, mechanistic explanation of illness has lost ground, and scientists are looking beyond a simple reductionist approach for new ways to move biology forward. The impact of a new theory will be a new understanding of forces that we do not yet recognize, potentially including phenomenon as diverse as prayer, healing, death, force fields, entrapment and non-locality. While it is too early to know what new theory will emerge, current theories leave so many phenomenon unexplained that a breakthrough grows more likely.*

***A. Systems Theory, Chaos and Complexity***

***B. Grand Unification and Field Theories***

***C. Religion, Science, Morality, Values, and Ethics***

***D. Worldviews and Central Myths***