A Blueprint for A National Bioeconomy

Alan S. Rudolph

There is now common acceptance that the 21st century will be dominated by discoveries and application of life sciences. This aggregate movement is led by the integration of biological sciences with many disciplines from mathematics and physics to materials and chemistry. As these traditional boundaries have come down, the ability to drive new innovation into real technological solutions that offer significant economic US competitive advantage have emerged. Nurtured by over 2 decades of investment in interdisciplinary life sciences research, biotechnology investments in the venture community, new intellectual discovery and emerging markets have been created in health and medicine, education, human performance, energy conversion, and in bioengineering design of new materials. While it took nearly a decade to begin to realize the centuries first disruptive discover, the human genome, the expanse of information technologies and accessibility has increased the rate of movement of interdisciplinary life sciences into realizable contributions to economic gains. This treatise examines select key areas that could provide significant stimulus and grand challenges to enhanced opportunities for economic growth based on advances in interdisciplinary life sciences.

Grand Challenge 1: Advancing the Bioeconomy: A Blueprint for Wellness

Perhaps the largest contribution of biotechnology and medicine could make in the next decade that could dramatically change the economic landscape is in the area of Wellness. Our current system of developing new medicine and the healthcare delivery system that drives current economic liabilities is entirely based on products and services that address disease and dysfunction. Our R&D pipeline and healthcare delivery is primarily geared toward extending life based on a greater understanding of mechanisms and processes that erode with age or genetic or other defects in health introduced by altered growth (cancer) or metabolic (diabetes) mechanisms.

In these endeavors we have learned considerably new information on background status of health across the living complexity from cells, tissues, organs, and animal and human systems. One large contributing factor to these advances has been systems biology tools applied to nutritional inputs to living systems across scale. An example of these advances is the current studies in natural products and their effects on wellness across living scales. Flavinoids such as resveratrol or quecertin are two recent examples of natural products that have been evaluated across living scales from the molecular scale to human clinical trials to examine improvements in boosting immunity and cognitive conditions that could contribute to wellness. Both of these natural produces are making their way to the market in as GRAS compounds (generally accepted as safe) and being used by large populations of people as supplements (e.g. Q-chews). These examples also point out the

motivations in both the academic and private sector as we have seen NIH increase its investments in what historically had been termed 'alternative medicine', and corporations like Nestle invest in large clinical trials to determine how nutraceutical applications could be amplified in their increasing interest in 'probiotics'. Early evidence indicates that quecertin can boost immunity and increase antibody titers when taken in conjunction with flu vaccine. Resevretrol trials indicate increased cognitive function following increased administration. Only a handful of venture firms have focused on wellness. Pioneer examples include Burrill Ventures that has invested in products that increase satiety (or the feeling of fullness), natural sleep aids, probiotics and food products that improve heart health. These trailblazing efforts in biotechnology start-ups have yet to yield significant results primarily because of the challenges in changing consumer behavior and the evidentiary base of science behind product claims.

These examples are brought forward not to promote these products as ready for large scale promotion in wellness treatments, but rather to point out that opportunities to leverage gains in knowledge creation around wellness are ripe and could have broad impact.

Incentivizing Wellness Behavior

It is asserted here that stimulating investments in wellness in the academic and industrial sectors could have profound impact on new knowledge products available for translation into new medicinal practices that could change the paradigm of future medicine dramatically reducing the cost of healthcare delivery. Yet, to ultimately be successful, wellness investments in science and technology development will require change in behavior. The dramatic rise in healthcare costs in this country are driven by people not making educated health decisions during their lifetime. The ability to incent good health behavior and focused wellness decisions will require innovative programs and leadership to drive these innovations into practice.

One proposal offered here would link changing wellness behavior to individual economic incentives. The Progressive Auto Insurance Company has a new program that monitors driver performance in real time and links performance to premiums paid by individual customers. People can decide to drive the within the speed limit or avoid more dangerous driving behavior and reduce their auto insurance premium. Safeway established precedence for a similar strategy in changing individual wellness behavior by linking use of health club facilities to reduced health insurance premiums by employees. Safeway also enjoyed a 30% reduction in healthcare delivery costs as a result of this program. These two examples from two different sectors demonstrates the power of linking changing behaviors to economic incentives.

Consideration of novel additional incentives to promote wellness behavior should be considered. Tying nutritional health and individual weight loss to income tax incentives and insurance premiums could provide a novel way for individuals to actively participate in wellness. Tax incentives for participating in health, wellness, and exercise programs through tax deductions or direct rebates based on confirmed health status. Corporations that are burdened with high healthcare costs should also be incentivized to participate in programs through corporate tax benefits for offering their employees programs that would promote wellness. These programs should extend beyond wellness visits and become more direct in incentivizing weight loss and good health decisions (e.g. smoking cessation).

Stimulating research and development opportunities in wellness should be considered. These include launching new initiatives across academia and federal laboratory system. The use of University Associated Research Centers (UARCs), multi-university research initiatives (MURI) and public private parternships should be used to establish this grand challenge. The DoD operates the largest healthcare system in the world (Tricare) and could be used to explore the intersection of reducing healthcare cost delivery and emerging discovery and technology from these efforts.

Specific Recommendations for Advancing The Wellness Blueprint for a National Bioeconomy.

- Increase federal research and development programs specifically geared toward wellness. Include aspects of nutrition, immune enhancement, and cognitive health. Utilize UARCs, MURIs and public private parterships to stimulate knowledge products in wellness
- Encourage state sponsored loan programs to small business and start up biotechnology companies pursuing products and services in wellness
- Expand education and advertising programs in wellness through consumer product labeling and increased STEM activities directed at good health practices
- Tie economic incentives for individual behavioral changes tied directly to wellness programs including tax credits, rebates, and deductions for participating in nutrition and weight loss programs, physical exercise and smoking cessation programs.

Grand Challenge 2: The Walk Again Project

Many futurists have declared this century the century of the brain. We have made enormous strides in our understanding of information stored and transmitted by the brain in spite of having a fundamental theory for how the brain codes and processes information. Yet, we are poised with an opportunity utilize recent advances in brain assisted devices to create what some would call 'biblical' changes in peoples lives. The cochlear implant that enables the deaf to hear is a powerful example of what can be achieved. Similar efforts are underway with retinal implants to enable the blind to recover sight. The walk again project is a grand challenge that recognizes this potential for stimulating the bioeconomy and mirrors the challenge John Kennedy to our nation that inspired so many people and established the US blueprint for science and technology of that era.

We are poised to launch a new era of brain technology that will have as dramatic an impact on US science and economy as a man walking on the moon. The impact of translating brain science into useful areas of economic impact is driven by the wide application space including learning, entertainment, and in enhanced human performance. In this latter area, the walk again project is an exemplar of the possible, and will crystallize the same power of asking our country to consider a man walking on the moon. The walk again project will challenge our country through public and private sector efforts in brain science and technology to establish the ability of those disabled to walk again on the earth. In doing so, it will stimulate wide investments in new devices that impact multiple areas of economic impact.

We have had the ability to image regions of the brain and denote areas of metabolic activity associated with specific brain functions and dysfunction. In addition, in the last decade new tools have been developed that enable the direct measurement of ensemble of neurons. These new devices enable direct measures of large areas of information coding in the brain from tens to thousands measured simultaneously in real time. This orchestra of neuronal activity has been the subject of recent intense activity in the neuroscience and neurotechnology community and has enabled the grand challenge posed here…..to enable those with lost motor function (quadraplegics, paraplegics, and those that lost limbs to landmines and in military operations) the ability to recover normal mobile function and walk again.

This vision has its roots at DARPA at the turn of this century where the first studies to demonstrate the ability of non-human primates to move objects on a computer were demonstrated at Duke University. That historical "Aurora" project program has advanced to build a prosthetic arm that emulates the high degree of freedom mobility of a real arm. Yet, the ability to interface the complexity of brain signals to these devices is lacking. This grand challenge would create a novel set of devices that would enable for the first time, the extraction of useful brain information for recovering motor functions. This would unlock a trove of useful information and devices that could extend into a number of devices for enhanced communication,

entertainment and learning. Device development would include implantable and non-invasive wearable devices combined with new robotics and prosthetics that result in the recovery of motor functions in different patient populations (military and civilian) including victims of landmines or improvised explosive devices, car accidents, or other motor dysfunctions. This grand challenge would also expand our understanding of brain function and could lead to other developments in neurotechnology. Over the last decade we have seen an expansion of brain devices and their impact in areas such as Parkinson's Disease. Direct brain stimulation is now also being examined in Alzheimer's and other cognitive deficits and mood disorders. With the advent of non-invasive means to extract signals there is great potential to expand applications into communications, learning, and entertainment. The emergence of increasing personal communication and learning devices and entertainment systems that rely on multimedia presentations, this area is rich for economic future impact resulting from translational research and development

This opportunity has been recognized in the global science and technology community. The European commission has recently released a grand challenge project focused on unlocking information in the brain with its center at EPFL Lausanne. This 500 million euro effort spans across Europe and will seek to extract useful brain science and technology over the next 5 years into realizable gains in the public and private sector. The Brazilian government has set a similar grand challenge that combines advances in neuroscience and technology with an educational mission and to enable a paraplegic to walk into the opening ceremony of Olympic stadium in 2016 using a brain assisted device (such as a prosthetic or exoskeleton). The proposed walk again grand challenge would put the US on the global stage of brain competitiveness. This global community also presents a great opportunity to build partnerships in this key area of future growth and potential for mankind.

Specific Recommendations for Advancing A Blueprint for A National Brain Bioeconomy:

- **Establish a Walk Again Grand Challenge project that exploits recent advancements in brain science and technology and sets specific goals for human performance enhancements**
- **Establish public private consortia and research and development institutes that promote discoveries and commercial development of brain assisted devices that can be applied across learning, entertainment, and health applications**
- **Establish an office within NSF, DoD, DoE, and HHS that direct federal investments in Neurotechnology Efforts to promote and execute this grand challenge and related efforts.**
- **Define workforce development and STEM programs in industry and academia to promote neurotechnology**

- **Leverage the US Walk Again Grand Challenge in the Global science and technology community**

Grand Challenge 3: Creating a Bio-based Defense Industrial Base

One of greatest future challenges is to 'rightsize' our defense budget to align with current and future threats. While the current fiscal climate has created an acute process by which the defense department will see cuts, the strategic alignment of defense expenditures with areas that will contribute to mitigating these threats as well as contribute to a blueprint for a national bioeconomy is needed.

Large expenditures in Biodefense and traumatic brain injury are not sufficient. The current approach in investing in biodefense by the defense department has yielded limited results. This has as much to do with the approach as with the contracting and administration of the programs. Directed efforts at acquisition reform and contracting rules are needed if the large defense and federal investments in biodefense and biotechnology are to be realized.

The current expenditures in defense aligned with life sciences and biotechnology also dramatically underestimate the potential for how defense investments could contribute to a bioeconomy much the way our current GDP in defense contributes. We need to establish a new military industrial base that recognizes the potential for life sciences and biotechnology to contribute to the national bioeconomy.

There are ample opportunities in biodesign of materials and new systems that could provide a strong foundation for building and realizing this vision. We have seen microcosms of potential such as the defense investments in force dynamics of winged flight and legged locomotion that have turned into new microair vehicles being developed for military applications in autonomous sensing, decontamination and reconnaissance. Others examples include the bigdog robot that was YouTube's most watched video in 2009 (over 11 million hits). This robot employs simple force dynamic principles of legs and captured the imagination of the public in profound ways. New materials base on gecko feet, infrared and chemical detection from insects, and new production methods utilizing plants are just a few examples of opportunities for defense-based science to emerge as real technology solutions to defense and non-defense problems. Yet, we do not have a concerted well-defined industrial base to support these efforts. We need a concerted effort to develop a broad base of science, technology opportunities and biological products that can contribute to national security. We need a "Bio Boeing".

Essential to these efforts will be to recognize that cost must be a design feature that drives their development. We can no longer support the model that builds high cost defense specific platforms and expect the US economy to support the development.

Specific Recommendations for Advancing a Blueprint for a National Bioeconomy Through a Defense Industrial Base

- **Establish a National BioDesign Institute to exploit advances in Defense investments in biological products for medical and non-medical applications**
- **Launch specific graduate and post-doctoral fellowship programs to recruit and nurture a new workforce dedicated to building a Biobased Industrial Base**
- **Examine acquisition and contract reforms to create flexibility and agility in facilitating growth of a Biotechnology Defense Industrial Base**