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**Center for Agricultural and Pharmaceutical Nanotechnology (CAPN)
at Illinois-Purdue**

Project Brief

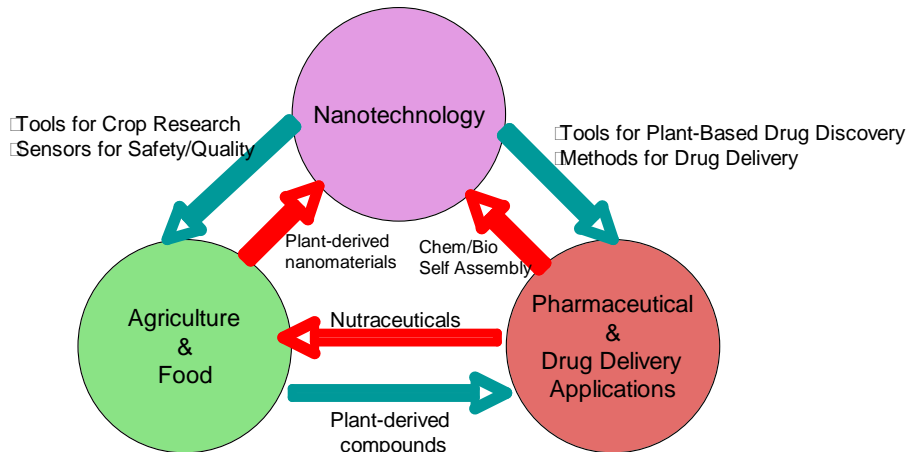
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Vision

A large fraction of the world economy is dependent upon the cultivation and processing of plants for a huge variety of uses. In addition to food products that are consumed by animals or humans, agriculture provides our society with the raw materials that are used in treatment of disease, delivery of medication, and materials used in construction, packaging, and clothing. In the past four decades, we have witnessed (and participated in) the development of a fundamental understanding of photosynthesis, and the ability to genetically engineer plants to possess commercially valuable traits. These fundamental advances in Crop Science make it clear that fundamental properties of plants are controlled at the molecular and cellular level – the realm of nanotechnology.

The ability to develop new tools, materials, and methods that enable detection, actuation, and manipulation of agricultural processes will require new collaborations that will bring crop scientists and nanotechnologists together. Nanotechnology provides an excellent opportunity to bring about scientific breakthroughs as well as tools to realize the potentials of agricultural products for quality, safety, and healthcare benefits. ***By focusing at the intersection of nanotechnology, the agricultural sciences, and pharmaceutical research, our vision is to assemble a diverse and complementary set of researchers and industrial partners that are uniquely suited to address several “grand challenge” types of problems*** in food production, agriculturally-derived materials, and health care. The confluence of these three spaces will provide a rich array of research opportunities where nanotechnology-based tools can be used for plant or human-based life science research, plant-derived materials can be engineered at the nanometer scale for disease treatment, and the tools/methods of chemistry can be applied to confer desired functions to nanostructures. The framework in which the flow of basic science and applications among each of the three technical areas (i.e. nanotechnology-based tools providing benefits to Crop Science research in one project, while in another project engineered plant-based materials provide possibilities for new pharmaceutical products) will provide a cross-disciplinary and translational research environment that will attract top researchers and active industrial participation to the Center, while at the same time it will represent a broad research space that can sustain the Center with new ideas for many years. The figure represents how the flow of technology benefits among the three main technical community pillars can provide a rich research environment for participating academic institutions that will help solve problems facing participating industrial institutions.

Center for Agricultural and Pharmaceutical Nanotechnology (CAPN)



Organization

The initial academic research institutions to be involved in the proposed Center are the University of Illinois at Urbana-Champaign, Illinois and Purdue University, West Lafayette, Indiana. Each campus houses leading capabilities in nanotechnology with applications to agriculture and pharmaceutical research. We feel that a Midwestern "core" of academic institutions will facilitate exchange of information and collaboration on research projects, and translation of technologies to health care and agricultural applications. Several large industrial organizations have expressed interest in participating in the Center, as well as several smaller companies.

The combination of three vastly different research fields into a single research center provides a highly complementary environment that can seed new partnerships to address intractable problems. Nanotechnology, Agriculture, and Pharmaceuticals share many linkages that can be exploited to find solutions to these problems. For example, in the field of tissue engineering, researchers are studying and beginning to understand the mechanisms by which cells interact with their physical surroundings, and how cell behavior – including gene expression and differentiation – is modulated by structural contacts at the nanometer scale. These discoveries are leading to new frontiers in efforts to harness stem cells for creating man-made tissues that more accurately mimic the structure and function of natural tissue. Fundamental advances in this area are expected to support important advances in tissue replacement therapy including spinal injuries, heart valve replacement, and even the development of artificial organs. Nanomaterials derived from plant and animal materials represent new approaches in which biocompatible tissue scaffolds may be inexpensively produced with physical features at the nanometer scale that closely approximate natural tissue. Likewise, nanotechnology is beginning to play a key role in the way that drugs are administered to patients. Nanoparticles constructed from safe, biodegradable materials may be infused with therapeutic compounds, and then functionalized with recognition molecules in such a way as to target their delivery to specific areas within the body, such as at the site of a cancerous tumor or at the site of an arterial blockage. Such methods may revolutionize health care for a large class of diseases, enabling the use of new types of therapeutic compounds that may otherwise prove unfeasible, while reducing the incidence of harmful drug side effects to nontargeted tissue. Many pharmaceutical products are derived from plants, e.g., herbal medicines that have been used by Asians and American Indians for thousands of years. However, due to the complexity of naturally derived herbal medicines, the scientific principles behind the efficacy of them are mostly unknown.

Our proposed Center would leverage the deep expertise in the areas of gene-based and protein-based disease diagnostics. We are approaching an era of "personalized medicine" in which predictions about which individuals will be likely to benefit or suffer harmful side effects from a pharmaceutical compound will be made based upon their gene expression.

Pharmaceutical companies will seek FDA approval for drugs based on safety/efficacy as they do today, but rather than for the entire population of humans, a drug will be approved for patients that satisfy a specific set of genetic preconditions, (or “genetic biomarkers”) or the presence of specific expressed proteins (“protein biomarkers”) that are used to conclusively diagnose a disease. These developments will radically change health care in the future, and nanotechnology will play a key role, as nanosensors can be used to rapidly detect gene and/or protein expression at exceedingly low concentrations, providing the tools that will be used to drive this industry. However, the benefits of gene and protein-based diagnostics are not only applicable to human diseases, but the same type of tools can also be applied to understanding and diagnosing crop diseases. Further, these types of tools can be used to aid the process of crop-based genetic engineering that can confer pest resistance, increase yield, or incorporation of genes from other organisms.

Another research area that ties together all three research areas is the use of nanotechnology-based sensors that can rapidly characterize the interaction of plant-derived materials with a wide array of human cancer cells and healthy tissue cells as a high throughput screening method. Such tools can identify plant extracts that may have applicability for cancer treatment, while also identifying the likelihood of toxic side effects on healthy cells.

In the context of the review criteria for NSF research centers, the Center for Agricultural and Pharmaceutical Nanotechnology would provide a rich interdisciplinary research environment, working in concert with industry to solve industry challenges, that supports projects with broad impact on health care and agriculture – two of the most important areas of our society.

Intellectual Merit:

The focus of the new Center will be to develop different technology platforms that can be applied to three substantially important topics requiring strong academic/industry partnership, which will serve as our core competencies: 1). Nanotechnology, 2). Agriculture, and 3). Pharmaceutical Research. While these application areas are diverse, they share a common thread in which underlying scientific principles all require manipulation and design of materials and energy at the nanometer scale. This unique focus on taking the bio-nanomedical developments from the bench level to the commercial arena will help to transform health care and agriculture in highly significant ways.

Broader Impact:

Significant future advances in health care and agriculture will occur at the confluence of biotechnology and nanotechnology, and are encompassed by the scope of the Center. This convergence of frontiers will provide unprecedented opportunity to revolutionize modern medicine and agriculture. These areas will include biomolecular imaging, cell and tissue engineering, advanced drug and gene delivery, development of plants for pharmaceutical purposes, and biomedical devices. The proposed Center is based on departmental strengths that transcend traditional boundaries, including participation from Bioengineering, Electrical and Computer Engineering, Material Science and Engineering, Agricultural and Biological Engineering, Molecular Genetics, Crop Science, Food Science, Animal Sciences, School of Pharmacy and Pharmaceutical Sciences, and Department of Industrial and Physical Pharmacy, etc. Thus, the Center will help to facilitate collaborative research, education, and preparation of the next generation workforce. The Center will primarily depend on the graduate students for conducting academia-industry relevant research; thus enabling students to become knowledgeable and savvy about industry needs.

The creation of new knowledge will help the US maintain its competitive edge, through the development of novel technology and processes spurring economic growth that help establish sustainable academia-industry relationships in a global context. Technology developed at the Center will also have direct bearing on health care, agriculture, food, and the environment. We will have paradigm-shifting collaborative test-bed projects that harness our industry alliances.