Nanotechnology in bioengineering

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***Abstract*— The area of engineering that has the highest demand on materials' performance is bioengineering. Nanomaterials are important in medical treatment because of their super small size which allow them enter into many biological environments and gives them important nanoproperties and their large surface areas act with complex systems to recognize and respond to diseases and tissue damage. Nanobiology's ability to affect atoms, cells, organs, and the environment gives better way to remove illness. There are many tools like bionanosensors, bio-imaging, biochips, and fluid electrical force microscopy that can help develop this area. At the nanoscale, everything is affected by how small things are. Like floating dust particles, nanoparticles are much less affected by gravity than larger objects. Instead of being affected by gravity, the state of atoms and molecules is constantly impacted by nearby objects. Outside forces such as magnetism, air or water currents, heat, cold, electricity, and other factors affect a nanoparticle's direction and reactions. Atom-to-atom contact among molecules or objects is stronger than gravity's pull. Nanoparticles exist at the size of single atoms, which are about 0.1 nm wide. A particle or object is considered to exist at the nanoscale when one of its dimensions is between 1 and 100 nm in length. Most biological particles have at least one dimension that falls into this range.**

***Index Terms*—Bioengineering, Nanobiology, Nanoproperties.**

I. INTRODUCTION

Nature is versatile in the way it builds everything from the tiniest insects to huge blue whales. Proteins are the foundation of nearly all biomolecular projects. They are composed of a central carbon atom with three attachments: an amino acid group, a carboxyl group, and a side chain of various lengths. Proteins are modular and form long chains of amino acids that fold into specific structures. Amino acids are added through the linkages, in a protein chain. The properties of different linkages makes it possible to work with natural cell mechanisms in biological applications. The extra carbons in a protein chain carry hydrogen and one of 20 different side chains. There are many different ways that proteins bond affects the potential of various new nanostructures and nanomaterials. By moving and exchanging atoms and molecules within basic protein structures, scientists can repair and/or eliminate some diseases. To understand what proteins in cells are actually doing, researchers have to be able to see them. For example, scientists can't know the secrets of biomolecules unless basic structures are also understood. DNA (*deoxyribonucleic acid*) proteins make up the blueprint of life. They encode an organism's development and growth. The knowledge about heredity and hereditary disease was possible after DNA's structure was determined. DNA contains patterns for building body proteins, including the different enzymes. Each DNA molecule is made up of two long strands, twisted around each other, connected by hydrogen bonds, and then coiled into a double helix. The strands are made up of alternating phosphate and sugar groups held together by hydrogen bonds formed between pairs of organic bases. The phosphate and sugar groups are called nucleotides, which are found in three parts: deoxyribose (a five-carbon sugar), a phosphate group, and a nitrogenous base. Four different nitrogenous bases (guanine, cytosine, adenine, and thymine) are the foundation of genetic code. Sometimes written as *G, C, A,* and *T,* these chemicals act as the cell's memory, giving the plan as to how to create enzymes and other proteins. The two DNA chains are held together by purine and pyrimidine bases formed into pairs. Only specific bases pairs can bond. These pairs are adenine (purine) with thymine (pyrimidine), and guanine (purine) with cytosine (pyrimidine). Human DNA contains the plans, or *code*, for building a human being. DNA molecule's structure is built by the nucleic acids A, T, G, and C. These then make a copy and bind to other molecules to provide the body's instructions. A typical DNA strand, for example, might be written like this: *AGCGCAAG*. Its complementary strand in the double helix would then be *TCGCGTTC*. This doesn't change unless the protein strand is somehow damaged. DNA damage can be caused by several factors, such as radiation exposure. If a strand of *GGCAATC* were replicated to *GGGAATC*, it may or may not cause trouble for an individual, depending on what the strand is coding for. One of the great benefits of working with proteins at the nanoscale is the possibility of correcting genetic mistakes/damage. If scientists could move or remove individual, out of position atoms, then medical cures for genetic diseases, such as sickle cell anemia, may be a real possibility. Some DNA sequences are known to provide control centers for turning processes on and off, some build proteins and other biological materials, and some sequences are only understood (Park, 2007).

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II. BIONANOSENSORS

Regular biosensors have been used for many different applications including health care, environmental monitoring, pharmaceutical discovery, food processing, cosmetics, chemical industries, bioterrorism/defense, and bioprocess monitoring/control. Bionanosensors are designed to pick up specific biological signals usually by producing a digital electronic signal associated with a specific biological or chemical compound. New methods such as micro/nanofabrication as well as advanced electronics have made development of much improved biomedical sensors possible. These advanced biosensors have the ability to provide big changes in the medical, pharmaceutical, and environmental industries. Individual monitoring nanodevices such as glucose sensors for diabetics are also in development. Bionanosensors provide scientists with selective identification of toxic chemical compounds at ultra low levels in industrial products, chemical substances, air, soil, and water samples, or in biological systems e.g., bacteria, viruses, cells, or tissues. By combining very specific biomarkers with optical detection and highpowered computer systems, bionanosensors are able to find and differentiate between complex components. Most biosensors work by measuring sample interactions with a reactant as it forms in to a product. The reaction is picked up by a sensor that converts it to an electrical signal. The signal is then displayed/recorded on a computer monitor. Reactions within biological processes can be picked up by transducers in several different ways. The type of sensor used is often determined by the specific biological process. The following characteristics are important components of bionanosensors:

- Able to isolate a specific biological factor with little interference
- Quick response time
- Biocompatible
- Super small (nano) in size
- Super sensitive
- Super accurate
- Tough
- Lower cost on more/different tests per sample

Bionanosensor development faces a few difficulties before it can become the norm in most laboratories and hospitals around the world. First, bionanosensors have to be integrated/ assessed with regard to current clinical methods, as well as developing bioengineering techniques and advanced electronics. For example, the number of times a biosensor can be used during a process is often limited as proteins build up on the biologically active interfaces. Next, electronic and biological interfaces between materials need to be joined with various systems to get high sensitivity, selectivity, and stability.

III. BIOCHIPS

In a DNA sensor, a single-stranded DNA molecule is used to find a complementary sequence among a mixture of other singled-stranded DNA molecules. New biosensors using DNA probes have been developed. A DNA chip or biochip is made by binding many short DNA molecules to a solid surface. This arrangement takes it possible for researchers to analyze thousands of genes at the same time. A biochip is an important tool for discovering how genetic plans are expressed, for measuring biomarker patterns, or for identifying DNA/ RNA nucleotide sequences in a biological sample (Fritzsche, 2002). When nanotechnology is combined with biochip results, repair and/or preventative measures can be started by geneticists or doctors before full-blown problems get a foothold in the body.

IV. BIOSENSORS AND BIOMARKERS

Another recent advance in bionanosensors comes from the area of dentistry. Saliva cleans the mouth, fights tooth decay, and, according to scientists at UCLA's School of Dentistry, acts as a window into the body's overall wellness. Scientists have long known that saliva contains a lot of proteins, hormones, antibodies, and other molecular substances. According to UCLA Professor David Wong, the big advantage of diagnostic saliva tests is that they are non-invasive. Saliva is easy to collect and doesn't have the risks, stresses, or invasiveness of blood tests. Needle sticks are not needed. Dr. Wong and others at UCLA used biosensors to measure elevated levels of four cancer-associated RNA (ribonucleic acid) molecules in saliva and identify between healthy people and those diagnosed with oral cancer with 91% accuracy. With such accurate methods, dental offices may one day be equipped with real-time detectors to diagnose diseases from saliva samples. According to Dr. Wong, extended research into biomarkers for other diseases such as breast, ovarian, and pancreatic cancers; Alzheimer's Disease; AIDS, diabetes and osteoporosis may be diagnosed from saliva samples in the future. The ability to achieve high resolution analysis of biomembranes makes bionanosensors another great tool in the nanotechnologist's toolbox.

V. NANOMEDICINE

Nanomedicine describes the medical field of targeting disease or repairing damaged tissues such as bone, muscle, or nerve at the molecular level. The goal is

A. *search out and destroy early cancer cells,*

B. *remove and replace broken cell parts with nanoscale devices, and*

C. *develop and implant molecular pumps to deliver medicines.*

Nanoscale science can be used to get at medical problems from many different angles, including the following:

- Genetics information storage and retrieval
- Diagnostics, such as the identification of disease
- Detection of overall disease susceptibility, such as Alzheimer's
- Better classification of diseases into different types and subtypes
- Tailor-made drug design based on chromosomal differences
- Gene therapy (e.g., for cystic fibrosis)
- Cell targeting (antibody development that zeroes in on specific cells)

Cancer is still a big killer today. In fact, cancer is not just one disease, but many more are there. Cancers use a whole bag of tricks to avoid detection and invade neighbouring areas in the body. In the long term, nanotechnology and nanoscience may give physicians powerful new tools in the fight against cancer as well as other degenerative diseases even, may be the effects of ageing (de Jong et al., 2005; Ferrari, 2005).

VI. Silicon Nanowires

Harvard University scientists have reported that ultra-thin silicon wires can be used to detect the presence of single viruses electrically. These nanowire detectors can also tell the difference between viruses with great accuracy. If single wires were combined into an array, it is possible that complex arrays could be designed that are able to sense thousands of different viruses. Dr. Charles M. Lieber, Harvard chemistry professor, has made nanoscale silicon wires that turn on or off in the presence of a single virus. By combining nanowires, a current, and antibody receptors, virus detection is possible.

When an individual virus connects with a receptor, it sparks an electrical change that announces its presence. Researchers have found that the detectors can even distinguish between several different viruses with great selectivity. Using nanowire sensors, physicians will soon be able detect viral infections at very early stages. The immune system would still be able to squash small virus populations, but for particularly dangerous viruses, medical intervention would be available long before the infection would normally be detected by traditional methods. With medical possibilities beginning to explode, researchers have begun experiments that take advantage of the many benefits nanotechnology has to offer. Nanotechnology is totally multidisciplinary and includes a huge variety of materials and devices from biology, chemistry, physics, and engineering. These techniques use *nanovectors* (hollow or solid structures) for the targeted delivery of drugs to diseased cells, such as cancer cells, and image contrast agents (e.g., that fluoresce or are opaque under a microscope) (Feynman, 1960). Some of these are described here.

VII. GOLD NANOSHELLS

As the light passes through the tissues, it looks red, but this is not caused just from blood on the inside, but from light passing through the skin. Long wavelength light can pass right through the skin without too much scattering. This method has been used in photodynamic therapy to treat disease within the body. Light can be used in different ways. If it hits metal in the body, the metal can get hot enough to cook surrounding tissue (e.g., a tumor). If light hits a particle, causing it to give off highly reactive oxygen molecules, these oxygen molecules will react with the surrounding tissue and destroy it (dooming tumors again). Researchers Jennifer West and Rebekah Drezek at Rice University's Center for Biological and Environmental Nanotechnology have applied super small particles of gold-coated glass spheres called *nanoshells* created by Rice professor Naomi Halas to improving both the detection and treatment of diseased tissue.

Nanoparticles with a silica (glass) core and gold shell have been designed to absorb light wavelengths in the near-infrared (i.e., in the total spectrum of light) where light's penetration through tissue is greatest. A new kind of cancer therapy is becoming possible using super small gold nanoshells that travel through a tumor's "leaky" vessels and are deposited. The blood vessels that supply tumors with nutrients have tiny gaps in them that allow the nanoshells to get in and collect close to the tumor. This is called the *enhanced permeability and retention,* or EPR, effect. Nanoshells can also be bonded with targeting antibodies and directed, for example, against *oncoproteins* (cancer proteins) or markers, increasing therapy specifi city to the cellular level. Nanoshells can get to the tumor in two ways: by using a targeting antibody or relying on EPR. Not every cancer has a specific known marker for which an antibody can be designed. Fortunately, EPR means treatment with nanoshells is not limited only to those cancers with specifi c markers. To treat breast cancer cells with gold-coated nanoparticles, for example, antibodies are attached to the gold nanoshells, which latch onto the targeted cancer cells. In tests, mouse cancer cells have been treated by shining an infrared laser beam on an affected area. The gold absorbing the infrared light heats up, but the healthy tissues (with no attached gold nanoparticles) keep cool and are not affected. The rising heat (55°C) fries the tumor cells, leaving healthy cells unharmed (Ferrari, 2005).

VIII. PROTEIN ENGINEERING

Biological systems, including the human body, are made up of lots of proteins. Skin, hair, muscle, blood, organs, eyes, and many other body parts contain thousands of proteins that make up their structure and function. Some diseases, such as sickle-cell anaemia and mad cow disease, are caused by damaged protein molecules. For many years, scientists have worked to decode the structure of specific proteins. When the human genome was deciphered a key puzzle piece the process got a lot easier, and more protein structures became known.

Today, artificial proteins can be created by putting together protein building blocks (amino acids) into the long protein strands that have been identified. Researchers and physicians are able to snip a section from a protein and replace it. The protein can then function as nature intended (or in a specifically crafted way) instead of negatively affecting cell development and function. This is known as protein engineering.

IX. Nanotoxicity

Since nanoscale materials often act in ways that differ from their larger bulk sizes, their valuable new traits such as super strength or electrical properties raise questions about whether new products incorporating nanoparticles might be unexpectedly risky. Currently, hundreds of products use nanotechnology. But nanotechnology use is still in its infancy, and nanomaterial production quantities are small. So far, not much is known about the effects of newly invented nanomaterials on humans. The field is pretty wide open and in an information gathering mode. However, nanotechnology toxicologists looking into the risk factors now have a broad roadmap from an Environmental Protection Agency–sponsored panel of experts on how to proceed. An 85-page-long report, along with supporting documents, was published in October 2005 by *Particle and Fiber Toxicology*, an online scientific journal, and was designed to characterize potential health effects related to nanomaterials exposure. It also provides a screening strategy. Although the report focuses on toxic impact from nanoparticles in the body, it doesn't talk much about exposure risk, since few instances are known in which

people have been directly exposed to nanoparticles. The report highlights the need to characterize the particles in several ways, such as structure, form, surface area, electrical properties, and the possibility of forming clumps that interact with the body in ways that differ from individual particles. It also suggests methods for examining nanomaterials' impact on various internal organs as well as ways to test inhalation, consumption, or contact with nanoparticles. The report does not provide methods that could explain why nanoparticles might have biological effects. Detailed information on physiological interactions will have to occur collaboratively between science/medical researchers and clinicians (Feynman, 1960; Goodsell, 2004).

X. Medicine of the Future

Historically, Western medicine has developed advanced technologies to treat acute trauma when time was of the essence. Treating wounds quickly and saving lives are the main goals. Research for finding medicine has also been reactive and geared toward finding therapies for diseases often late in their progression. Focusing on prevention, some methods include acupuncture, acupressure, massage, and meditation. They are fairly low tech compared to the other complex, high-cost instrumentation and chemical therapies used to treat trauma and fight advanced diseases. These technologies will allow people to have their genetic profile assessed as well as have comprehensive molecular testing via blood analysis. Disease and health assessments will be done perhaps as early as birth, allowing physicians to map potential health issues far in advance of their occurrence. Predictive and preventative medicine will become the norm. Personalized medicine will change the foundations of how medicine is viewed by the public. No longer will economics drive the quality of health care around the world. New nanotechnology-based health care advances will change science research, pharmaceutical companies, education, and society for the better (Hood et al., 2004).

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