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A VA Executive's Guide to Nanomedicine

Office of Technology Strategies (TS), Architecture, Strategy & Design (ASD)

Technology Strategies

Defining OI&T's "To Be" Technology Vision

The TS office within OI&T's Architecture, Strategy & Design (ASD) interacts not only with the ASD pillar offices, but also with multiple stakeholders within OI&T and with strategic offices across the enterprise. TS works closely with IT and business owners to capture business rules and provide technical guidance as it relates to Data Sharing across the enterprise, specifically for interagency operability.

Introduction

Nanomedicine, the medical application of nanotechnology, has the potential to revolutionize the prevention and treatment of disease in the human body in the not-so-distant future. This TS Note explores the advancement of nanomedicine from the historical development of nanotechnology. It focuses on the advantages and unresolved issues surrounding the use of nanomedicine applications.

The Evolution of Nanotechnology

In the 1960s, engineers discovered a way to shrink the size of computer components, such as its central processing unit (CPU), the brain of the computer, by using semiconductor materials, namely silicon. This allowed more components to fit on a single microprocessor chip.

Additional space was created by replacing machine parts, such as vacuum tubes, or valves, and relay switches, with a key microprocessor component, the transistor. A transistor functions as a switch, allowing or halting the flow of electrical energy, transforming the computer's operations from mechanical, using moving parts, to electronic (reliant on the flow of electricity).

When transistors were strung together, they produced a binary or machine level sequence of code. The number one was generated when the flow of electricity was on, and when the flow was off, the number zero was generated. So the sequences of numeric code, generated by the on and off switch of electricity, represents computing data. What you might not have thought about is that every single letter, picture, sound, or symbol that you see on your computer screen is really numbers that represent that on/off switch! More transistors mean more electronic signals can be produced, and more signals equates to more processing power.

In 1965, Gordon Moore, the co-founder of Intel, predicted that the number of microprocessor components per chip, especially transistors, would double every two years as these components shrunk in size. Based on his observations, Moore's prediction proved to be fairly accurate over the last 50 years. Now, however, silicon transistors are as small as they physically can be.

The Nanoscale

Most transistors are already on the nanoscale, meaning they are between 1 and 100 nanometers (nm) in length. For size reference, one single nanometer is one billionth of a meter. On the nanoscale, however, silicon transistors can become easily overheated or short-circuit.

Given this impediment, computer developers are working on several solutions: converting transistors into vertical structures called "nanowires" (some of which are as thin as a single nm), producing microprocessors out of new semiconductor materials, or developing microfluids to cool transistors. All of these solutions are enabling the further development of nanotechnology.

Nanotechnology is defined as the process of designing, developing, and implementing technology on the nanoscale. On this scale, nanotechnology will have a profound effect in fields like chemistry, physics, biology, and medicine.

Nanomedecine

When nanotechnology is applied for medical purposes, it is called "nanomedicine". Nanomedicine is the application of nanotechnology the size of human biomolecules to treat sicknesses, perform surgeries, and diagnose diseases, conditions, and disorders.

In terms of its structure, nanotechnology ranges from simple nanoparticle structures, still in its testing stage, but used in simple surgeries, to the more complex nanobots, which are still being conceptualized and developed. Nanobots, as envisioned, are made up of several different material components and shaped to resemble and function as a small machine with the capability to perform multiple functions.

Medical Application

With further research and development, surgeries will be one of the many functions that both nanoparticles and nanobots will be able to perform. This will provide clinicians with several advantages that traditional surgeries cannot. The first main advantage is that surgeries could be performed on the nanoscale, meaning surgeries could be performed inside organs, or even inside cells. The second major advantage is that these surgeries will not impact the surrounding cells, thereby lessening damage to them and increasing recovery

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time.

Pharmacokinetics

Pharmacokinetics, or the movement of medicine through a human body, is another branch of medicine that will be affected by the development of nanomedicine solutions. Researchers are designing nanobots and nanoparticles that will function as nano-vesicles, mimicking the spherical cellular components that transport molecules of nutrients and medicine around a human body. These medicine-carrying nanovesicles will allow clinicians to release a concentrated dose of medicine directly into diseased or infected cells. This will protect against the degradation of the medicine en route and harm to nearby healthy cells.

Nanobots for Diagnosis

Nanobots and nanoparticles can even diagnose infections and diseases in vivo, or inside the body. One form already developed using nanotechnology, though not on the nanoscale, is in vivo medical imaging. For example, when clinicians need to study a patient's digestive tract, they rely on devices like pill cameras or endoscopes. In the near future, these might be replaced by nanobots able to transmit images to a clinician for diagnosis. Similarly, nanobots and nanoparticles are in development that could act as biosensors, devices that monitor, compute, and relay health information to clinicians. When developed, these nanomedical biosensors will allow for faster and more accurate diagnoses, while reducing the need to perform many diagnostic tests.

Nanomedecine Cancer Treatment

All of these possible nanomedicine functions could work in con cert to treat diseases and conditions. In the case of treating cancer, nanovesicles could perform surgery by delivering membrane -destroying medicine, like melittin (a compound isolated from bee venom), through the body to a cancer cell. They then deliver the melittin through the cancer cell's membrane. Once released, the melittin destroys the cancer cell's membrane, thus killing it while sparing surrounding noncancerous cells from radiation or the deleterious effects of traditional cancer surgeries. As clinical trials measuring the effectiveness of melittin-destroying cancer cells have already proven successful, if nanovesicles can be created, this will become a viable solution to treating cancer.

Challenge: Quantum Changes

While nanomedicine has a nearly unlimited potential, many issues currently remain unresolved. One of the effects of working on the nanoscale is that certain nanomaterials experience quantum changes in their structure. Sometimes these nanomaterials can become unstable or even toxic to surrounding biomolecules. If this happens, a patient's immune system could trigger a response and attack nanobots or nanoparticles. More research and development is needed to solve these issues.

Conclusion

As further research and development continues to support the development and viable application of nanomedicine, most hospital systems, including the Veterans Health Administration (VHA), will need to plan how their enterprise will be affected by the adoption of this technology. To this end, VA has identified nanomedicine as a technology trend in its FY 2013-2015 Enterprise Roadmap, noting that this will require the development of interoperability with native VA Information Technology (IT) healthcare systems.

Read more on nanomedicine and related topics in the Office of Technology Strategies' TS Notes and Enterprise Design Patterns. If you have any questions about development operations, don't hesitate to ask TS for assistance or more information.