NANOMEDICINE AND ITS VARIOUS APPLICATIONS

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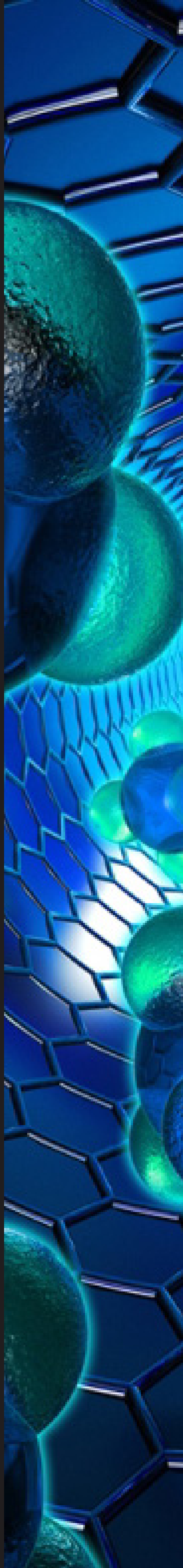
Walking into a drugstore, it is hard to imagine that the medicines filling the seemingly never-ending shelves represent only a small fraction of the possible remedies for existing diseases. In addition to those that are yet to be discovered, others, like nanomedicine, are invisible to the naked eye. Nanotechnology, the uniquely flexible manipulation and application of particles at the nanoscale, has recently been integrated into all aspects of healthcare, from diagnosis to treatment. As our lives become increasingly digitized, nanoparticles allow for a "smart" device within our bodies that is designed to give doctors more information than ever before on medical conditions, without the need for highly invasive procedures.

As with all living organisms, the human body is never in homeostasis, but rather constantly changing. While this ongoing flux proves advantageous for natural injury repair mechanisms, such as in the case of bone fractures, it is difficult for outside treatments to mimic the dynamic nature of the body. Many materials currently used for bone fracture repair are not biocompatible and can trigger immune rejection, a problem common to all foreign objects entering the human body.[4] Additionally, doctors run into the challenge of finding materials that are conducive to movement. However, nanofibers have been synthesized that can mimic the natural extracellular matrix of the cell.[4] These fibers facilitate the healing process by replicating inherent bone structure, helping new bones transition to become fully functional and supportive of full human body weight. Aside from simulating the natural structure of bones, magnetic nanoparticles can also respond to external stimuli while embedded inside an injured area, to enhance therapeutic effects. Bones require stimulation during the repair process to retain functional tissue. Usually very mobile limbs are often restricted during healing by casts and other materials for an extended period of time, and nanotechnology provides stimulating signals without negatively affecting surrounding cells.[4]

Similar advances have been made in dentistry, where nanoparticles are becoming integrated into commonplace procedures. Metal ions have been widely used in treatments, and when combined with nanoparticles, there is an increased antibacterial effect.[3] Together, they disrupt bacterial growth by interfering with signaling pathways or altering the bacterial microenvironment. Nanoparticles can also be integrated into dental fillers, periodically releasing minerals like calcium and fluoride to decrease chances of cavities and maintain dental health.[3]

Other than applications in treatment, nanomaterials can also be applied to the diagnostic process through imaging techniques. Gold nanoparticles can increase the contrast in CT scans without creating more toxicity for the patient.[2] Additionally, the adjustable properties of nanoparticles allow for chemical bonds, or conjugation, with other molecules, creating specific targets for imaging and differentiation between tissues.[2] The specificity of nanoparticles is beneficial for clinical applications as CT scans are often used as a diagnostic tool, and a slightly unclear image could cause a doctor to overlook a potentially threatening disease. Early detection increases the chances of successful treatment, so this serves a very practical purpose. Also, CT scans are often used prior to surgeries to map out the path of entry, so the more distinguishable that different tissue and organ structures can be, the fewer surprises the surgery team will face once in the actual operating room. Imaging techniques take advantage of the "smart" qualities of nanoparticles, using these particles to collect real-time data



about various pathways or target areas of the body. Nanoparticle probes are used with MRIs as they are designed to respond to a certain pH or temperature, which can then pinpoint tumors in contrast to normal healthy tissue.[2] Additionally, these probes can also reflect the internal conditions of identified tumors.

Even after diagnosis aided by nanotechnology, doctors still face the challenge of successful treatment. However, many common diseases currently lack cures or effective treatments. The human body contains many natural barriers against outside harm. These barriers are difficult to breach with traditional medical techniques. The blood-brain barrier, for example, is a semi-permeable membrane that protects the brain from infection while allowing key nutrients to flow through. Many debilitating diseases hide behind this barrier, such as Alzheimer's disease and Parkinson's disease. Scientific consensus is that the accumulation of amyloid-beta plaque between nerve cells partially causes Alzheimer's. Nanogels, which are nanoparticles composed of crosslinked polymers, provide an effective way to prevent the aggregation of the plaque in nerve cells, thus lessening the effects of Alzheimer's.[1] Nanoparticles can also provide the growth factors needed in Parkinson's disease in order to increase dopamine levels and promote overall brain development. Similarly, in multiple sclerosis, the myelin sheath surrounding nerve cells is damaged, but myelin-coated nanoparticles can act as a replacement while the immune system is degrading the naturally occuring myelin. Another barrier present in the body is the blood-labyrinth barrier at the inner ear, which refers to the different chemical compositions of inner ear fluid and blood.[1] In many patients suffering from inner ear disorders, surgery is needed to repair the cochlea, a cavity in the inner ear that converts sound vibrations to neural impulses, but nanotechnology can help bypass surgery and help patients with partial hearing loss.[1]

While these are all promising discoveries, nanotechnology must become more cost-effective before becoming widespread. It is already difficult to provide affordable healthcare for a growing population, and the high cost of nanotechnology only adds to the existing challenges. Many nanotechnology-based medicines are currently marketed by small startups and businesses, and it is difficult for these companies to branch into a market dominated by large pharmaceuticals.[5] Once these obstacles are overcome, nanotechnology and its applications in the clinical field hold great promise for more effective diagnosis and treatment strategies.

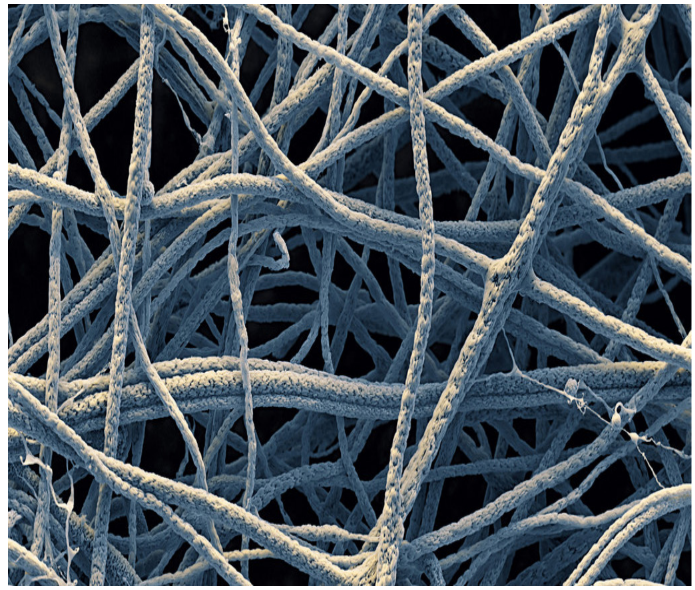


Figure 1. Inorganic nanofibers. Artificial nanofiber matrices can display a similar structure as individual fibers and networks in human bone extracellular matrices, helping to facilitate bone repair during fractures.[4]

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IMAGE REFERENCES

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