Nanocomposites at the Nexus of Sustainability and Healing: A New Paradigm for Medicine

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Abstract : The integration of nanotechnology with sustainability is reshaping modern medicine by enabling innovative approaches in drug delivery, tissue engineering, and wound healing through the use of nanocomposite materials composed of nanoscale components. This review examines the growing importance of these materials as versatile platforms for healthcare applications, with particular focus on the development of biomedical nanomaterials from waste resources, the adoption of environmentally friendly synthesis methods to minimize ecological impact, and the design of multifunctional therapeutic systems that enhance treatment efficiency while reducing systemic toxicity. Based on recent literature from 2024 to 2025, the review highlights how biomass derived from agricultural and industrial waste as well as bio-based polymers can address major limitations in current medical technologies. Key applications discussed include targeted drug delivery, regenerative medicine, antimicrobial therapy, and theranostics, along with an overview of the challenges that limit clinical translation. The review positions nanocomposite research within the framework of circular economy and precision medicine to propose a future of healthcare technologies that are effective, affordable, and environmentally responsible.

***IndexTerms* - Nanocomposites, sustainable medicine, drug delivery, tissue engineering, waste valorization, green synthesis, theranostics.**

1. INTRODUCTION

A contradiction exists between the way therapeutic capabilities have developed over the past twenty years and the challenges faced by existing healthcare infrastructures. The demand for treatment of individuals grows with the global increase in population, longer life expectancies, and chronic illness. Conversely, the world produces at least five billion tons (3.40 billion tons by 2050) of waste, making the environmental and economic costs of providing treatment with traditional modalities untenable. These crises will only become more severe unless there are innovative solutions that connect individual human health and the health of the planet, as they are interdependent. Nanocomposites hold an essential position within this continuum of evolution of materials. Nanocomposites are materials that contain at least one phase of matter in the nanomaterial range (typical nanoscale of 1–100 nm). Nanocomposite materials possess unique attributes based on their inherent nanostructural characteristics that enhance their utility in comparison to all of the components from which they are made. The physical and chemical properties of nanocomposites, such as their large surface area to volume ratios, controllable degradation rates, ability to be functionalized, and potential for use in biological systems at the molecular level, all position nanocomposite materials as key enabling technologies for the creation of next-generation therapeutics. However, current procedures for synthesizing nanomaterials normally employ harsh chemicals, are energy-intensive, or require non-renewable feedstocks, so questions have arisen concerning whether these advanced types of materials will only replace previously identified problems with a new set of problems.

In this review, we examine a major change happening in this field today, that being the purposeful integration of nanocomposite engineering to address the principles of sustainability. Researchers are beginning to see that applying sustainable methods of development (waste valorization; green synthesis; and, biodegradable matrices) will produce materials with a higher level of biomedical performance than traditional methods of engineering. The concept of "sustainable healthy medicine" will not be a compromise between ecological and therapeutic goals, but will be seen as a synergistic relationship where these two types of goals reinforce each other.

2. NANOCOMPOSITES IN BIOMEDICAL CONTEXTS

2.1 Definition and Classification

Nanocomposite materials for biomedical purposes are divided into three categories (based on the matrix material types). Polymer matrix nanocomposites (PMNC) are probably the best studied of these categories and include both natural polymers (such as chitosan, cellulose, collagen, alginate) as well as synthetic polymers (for example, poly(lactic-co-glycolic acid) (PLGA), polycaprolactone (PCL), polyethylene glycol (PEG) with the addition of nanoscale (from 1–100 nm in size) filler materials, respectively. Ceramic matrix nanocomposites (CMNC) typically include materials such as calcium phosphate hydroxyapatite or bioactive glasses that are similar in composition to mineralized tissues and, therefore, provide useful bioactive materials in bone regeneration applications. Comparatively, while metal matrix nanocomposites (MNC) are less frequently used for direct biological applications, they can still provide diagnostics and theranostic platforms due to their unique optical (light) and magnetic properties. The choice of both the matrix and of the filler materials not only defines the mechanical properties of the resulting nanocomposites, but also ultimately determines the biocompatibility of these materials (through various physiological interactions including degradation rate, cellular adhesion, inflammatory potential, and drug release kinetics) resulting from this material selection.

2.2 Synergistic Properties

Nanocomposites have a defining feature called synergy; they combine components that give rise to properties that are found nowhere else but in these two combined materials. In the case of metal nanoparticles that are embedded in polymer matrices, they provide antimicrobial properties and the polymer supplies structural support and allows for controlled hydration, which is especially useful in the case of wound dressings. In addition, cellulose nanocrystals that are incorporated into hydrogel matrices provide mechanical strength and at the same time keep a hydrated, three-dimensional environment that allows for cell proliferation. Nanocomposites also provide the potential for synergy with respect to their therapeutic function. They can be engineered to respond to multiple stimuli including pH, temperature, enzymatic or magnetic fields, thereby enabling the controlled and localized release of therapeutic agents. The ability to co-deliver imaging agents with therapeutic agents enables theranostic platforms to provide the next step toward an integrated and personalized medicine approach.

2.3 Fabrication Methodologies

The translation of nanocomposite technology from the laboratory to the clinic relies heavily on the reproducibility, scalability, and biocompatibility of the techniques used to fabricate these materials . A technique that has become particularly versatile for producing nanofibrous scaffolds that replicate the architecture of the extracellular matrix is electrospinning. Electrospinning provides precise control over numerous parameters such as fiber diameter, alignment, and porosity, which have a direct impact on cell behaviour and tissue integration.

There is another method which can be used for formulating nanocomposites, referred to as in situ polymerisation. This method involves the introduction of nanoparticles into a monomer solution prior to its polymerisation, thereby providing a uniform distribution of nanoparticles throughout the polymer. Other processing techniques; such as solution blending, melt blending, sol-gel processing, and solvent cast processing; each have their own set of advantages depending upon the type of material combination being used as well as the intended application (see Table 1). When determining which technique to select for producing nanocomposite materials, there are several factors that must be considered including, but not limited to, the quality of dispersion, processing parameters, scalability of production, and environmental impact. The sustainability of research is becoming more prominent and therefore incorporating a review of sustainability into the selection process for producing these materials will become increasingly important.

Table 1: Comparative Overview of Nanocomposite Fabrication Techniques

Technique	Process Description	Advantages	Biomedical Applications
Sol-gel method	Precursor mixing followed by gelation and drying	High purity, structural control	Coatings, sensors, drug delivery
In situ polymerization	Nanoparticle dispersion in monomer, then polymerization	Strong matrix-filler interface	Biomedical devices, implants
Melt blending	Nanoparticle mixing into molten polymer	Solvent-free, scalable	Structural biomedical materials
Solution blending	Co-dissolution of components followed by evaporation	Uniform dispersion	Drug delivery, coatings
Electrospinning	Electric field-driven fiber formation	ECM mimicry, high surface area	Tissue scaffolds, wound dressings
Solvent casting	Mold casting with subsequent solvent removal	Simple, cost-effective	Thin films, drug delivery systems

3. THE SUSTAINABILITY IMPERATIVE: FROM WASTE TO WEALTH

3.1 Global Waste Streams as Material Reservoirs

There has been a huge transformative insight in the last few years that has been an underutilized source of valuable material (compounds) for synthesizing nanomaterials in the form of many potential waste streams such as agricultural residues (plant material), industrial byproducts (waste from factories), plastic waste (polymeric waste), and even animal-derived material (biological waste). Agriculture alone has a huge supply of waste in the form of agricultural crop (product) residues (stems, leaves, and fruits), peels from fruits and vegetables, byproducts from the processing of fruits and vegetables and the byproducts of forestry. These provide a valuable source of lignocellulosic biomass that can be converted to cellulose nanocrystals, nanofibers and carbon dots. Additionally, animal waste provides many different sources of biopolymers that can be used to synthesize nanomaterials in the form of shells, bones, hair and fish processing byproducts. These would include chitin, collagen, hydroxyapatite and other biopolymers known to have good biocompatibility.

The extent of this opportunity cannot be overstated. For each ton of waste that we take out of landfill and convert into high-value (biomedical) products we not only create environmental and economic benefits, but also the nanomaterials we produce from waste may differ in terms of properties when compared to nanomaterials that have been produced via traditional routes of synthesis (for example, due to the nature of the surface chemistry being influenced by the nature of the native source material). or hierarchical structure that will be extremely difficult to replicate using traditional synthetic routes.

3.2 Cellulose Nanocrystals: A Paradigm of Waste Valorization

CNCs (cellulose nanocrystals) from lignocellulosic biomass can be produced by acid hydrolysis or enzymatic processes and combine strong mechanical properties with a large surface area and many functionalized hydroxyl groups on the surface. The CNC market is expected to be close to United States one billion dollars by the year 2030, primarily from uses in the biomedical field.

Recent advances in producing CNCs have focused on producing them in a more environmentally friendly manner by looking for hydrolysis methods that require less acid, including an enzymatic pretreatment step prior to acid hydrolysis, and implementing a closed-loop process for recovering reagents and recycling them. In the meantime, surface modification techniques for CNCs have changed dramatically; for example, the use of peptides for targeted cell interactions, polymers to modify the rate of degradation of CNCs, and the addition of a number of different types of antimicrobial agents to create multifunctional materials for preventing infection. CNC hydrogels and aerogels have been used in tissue engineering to provide better adhesion between cells, provide controlled drug release, and prevent infections in vitro and in vivo. Their structure closely resembles that of the native extracellular matrix, and their mechanical properties can be customized for use in a number of different tissue engineering applications such as bone grafts or wound repair.

3.3 Diverse Waste-Derived Nanomaterials

Researchers have been successful in making a variety of nanomaterials from waste streams in addition to cellulose. For example, carbon dots produced from fruit processing waste have photoluminescent properties that can be used for bioimaging. Chitosan obtained from crustacean shells is used to produce nanocomposite wound dressings that possess both antimicrobial and hemostatic properties. Rice bran protein nanoparticles can be used to deliver curcumin and other hydrophobic drugs, thereby converting a significant by product of milling into a functional drug delivery vehicle.

There are also opportunities to use other types of industrial waste streams to produce nanomaterials. The silk industry generates waste that contains fibroin and sericin proteins that have excellent mechanical and biodegradation properties. The metal contents of battery and electronic waste provides an opportunity to capture valuable metals for use in the fabrication of diagnostic nanoparticles despite the toxic nature associated with these wastes. Thus, when waste streams are properly characterized and processed as opposed to being disposed of, they may not only represent a waste disposal problem but also a valuable resource.

3.4 Green Synthesis Approaches

Numerous factors impact the sustainability of the production of nano-composites, making feedstock selection only one aspect of the process. Conventional methods used to create nanoparticles often rely on toxic reducing agents, organic solvents, and energy-intensive conditions; whereas plant-mediated processes through green synthesis provide a new paradigm. Plant-extracted secondary metabolites (e.g., phenolics, flavonoids, terpenoids, and alkaloids) possess the ability to reduce metal ions and stabilize the resulting nanoparticles; therefore, using a phytosynthesis method eliminates the need for harsh chemical reductants. The use of plant-extracted compounds can increase the biocompatibility of the finished nanoparticles since they will be coated with naturally occurring biomolecules extracted from plants (or plant extracts). Examples of the applications of "biogenic" nano-composites include antibacterial, antifungal, anticancer, antidiabetic, and antioxidant agents. The exact mechanisms involved with green synthesis continue to be investigated. The types of metabolites produced by different species of plants (in addition to various tissues in a single plant) directly affect the resulting nanoparticle features (e.g., size, shape, and surface chemistry). This variability presents both challenges with respect to the standardization of nanomaterials as well as opportunities for generating specific nanomaterials tailored for use through careful selection of sources possessing matching bioactivities.

4. THERAPEUTIC APPLICATIONS OF SUSTAINABLE NANOCOMPOSITES

4.1 Drug Delivery Systems

Controlled drug delivery is one of the most established and powerful uses of nanocomposite technology to date. The nanofibrous matrix's high surface area allows a significant amount of drug to be loaded, and the precise rate of degradation can be manipulated by varying polymer type, density of crosslinking, or incorporating nanoparticles — all of which allow for precise and predictable drug-release kinetics.

Nanocomposite drug delivery systems offer specific benefits in difficult to treat therapeutic situations. For example, pH-responsive nanoparticles can be designed to preferentially release their therapeutic agent in an acidic microenvironment (such as that of a tumor) or in an area of inflammation. Also, redox-sensitive systems can be designed to use the glutathione gradient present between intracellular versus extracellular compartments as a mechanism of drug release. Thermoresponsive nanoparticle containing hydrogels will transition from sol to gel state at the normal body temperature allowing for minimally invasive administration methods followed by insitu gelling. They also provide targeted delivery capabilities beyond passive accumulation. Surface functionalization with various types of ligands — antibodies, peptides, aptamers or carbohydrates — will allow for active targeting to a particular cell population or tissue. Furthermore, magnetic nanoparticles within a composite can be directed to the diseased area using an external magnetic field while also acting as contrast agents for Magnetic Resonance Imaging (MRI). This multifunctionality embodies the concept of theragnostic referring to materials which can both diagnose and treat disease, allowing for the ability to monitor the effectiveness of a therapy in real time.

4.2 Tissue Engineering and Regenerative Medicine

The field of engineering tissue to create new, healthy tissue seeks to restore, maintain and improve the function of tissues using combinations of engineered cells, scaffolding, and biologically active molecules. One of the most effective scaffolding systems is the use of engineered nanocomposite scaffolds because they can be designed to closely mimic the mechanical, structural, and chemical characteristics of the native tissue. The use of nanocomposite scaffolds infused with hydroxyapatite nanoparticles in a polymeric matrix system creates a compressive strength required for weight bearing purposes while at the same time supporting osteoblast attachment, growth, and differentiation. When bioactive glass nanoparticles are incorporated into the nanocomposites it can enhance biocompatibility and encourage the formation of blood vessels, which are necessary for the formation of a thick functional tissue constructs. Unique challenges associated with cartilage healing have arisen due to the lack of blood flow and a complex mechanical property of the cartilage. The use of nanocomposite hydrogels with a tunable elasticity and resilience can sustain the compressive and shear forces found in the joints while at the same time maintaining the viability of chondrocytes, the producers of the extracellular matrix (ECM). The use of growth factors or other chondrogenic stimuli can be integrated into the hydrogel matrix creating microenvironments that direct the growth of new cartilage tissue. Neural tissue engineering may be the greatest opportunity for this emerging field. Conductive nanocomposite scaffolding systems, which are composed of carbon nanotubes, graphene, or conductive polymers can facilitate the conduction of electrical signals along repaired nerve pathways. Aligned nanofiber scaffolds may provide topographical cues to guide the extension of axons, while the controlled release of neurotrophic factors stimulates neuronal survival and differentiation.

4.3 Wound Healing and Antimicrobial Applications

Each year, chronic wounds afflict 6.5 million individuals and impose a progressively increasing load on worldwide health care systems. Impairments in wound repair due to diabetes, significant vascular compromise and increasing age, along with complications from antibiotic-resistant bacterial infections, exacerbate chronic wound management issues. Nanocomposite wound dressings offer solutions to multiple aspects of this complex problem at once.

Metal nanoparticles, such as silver, zinc oxide, copper, and gold incorporated into polymer matrices provide continuous antimicrobial activity and also sustain the moist environment required for healing provided by the matrix. Specifically, zinc oxide nanoparticles provide an antimicrobial activity while also promoting angiogenesis and collagen synthesis. Chitosan-based nanocomposites containing essential oils add an additional antimicrobial and anti-inflammatory component, creating a multifunctional dressing with the capability of addressing both infection and the dysregulated inflammatory response commonly observed in chronic wounds. Additionally, to their direct antimicrobial properties, nanoparticles also modulate wound healing via other mechanisms. For example, metal and metal oxide nanoparticles enhance macrophage polarization, shifting the balance from pro-inflammatory (M1) to pro-healing (M2) phenotypes. The immunomodulatory properties of nanoparticles are of particular importance to chronic wound healing because they address the factors that inhibit the progression of the healing process from the inflammatory phase through the proliferative phase and on to the remodeling phase. The ability of nanoparticles to scavenge reactive oxygen species (ROS) also supports the transition to healing.

Polymeric nanoparticles are advantageous for wound healing; natural polymer examples include chitosan, collagen, gelatin, and alginate, all of which exhibit excellent biocompatibility and can be modified to release growth factors, antimicrobial peptides, or nucleic acids. Synthetic polymers such as PLGA and PCL offer the possibility of manipulating their degradation rates and controlling how long drugs are released from them. The synergistic effects of hybrid Nano-composites created by combining metal and polymer components are due to their ability to impart antimicrobial and immunomodulatory properties associated with metal nanoparticles and the ability to deliver drugs and provide structure—both properties of the polymer.

4.4 Cancer Therapy and Theranostics

As demonstrated by nanocomposites' use in oncology, these materials have a role to play in advancing the field of precision medicine. The use of conventional chemotherapy faces limitations such as the systemic toxicity associated with traditional chemotherapy agents, the narrow therapeutic window for many of these agents, and the development of drug resistance to existing agents. By providing new delivery mechanisms for these drugs within a nanocomposite, the limitations presented by conventional chemotherapy may be overcome. Nanoparticles will accumulate preferentially at tumor sites due to the enhanced permeability and retention (EPR) effects of these materials, which is attributable to vascular leakiness and loss of lymphatic drainage from tumor sites. Furthermore, surface-conjugated ligands allow for active targeting of the tumor site while minimizing the exposure of healthy tissue to the drug being delivered. Stimuli-responsive delivery systems can also be developed to release their drugs based on the tumor-specific conditions that will trigger their release (e.g., acidic pH, increased activity of specific enzymes, or external stimuli such as hyperthermia or magnetic fields). Another key advantage of using nanocomposites for theranostic applications in oncology is that imaging agents (such as fluorescent dyes, quantum dots, magnetic nanoparticles, or radionuclides) can also be incorporated in the same platform as the therapeutic agent, allowing for real-time visualization of the distribution of the drug that is being administered, the tumor's response to the drug, and the efficacy of the treatment. This type of feedback will allow for adaptive treatment strategies and an earlier identification of patients who are not responding to therapy so that they may be directed to alternative treatment modalities that may be suitable for them.

Nanocomposites can also be beneficial because they can be used as combination therapies due to their ability to deliver multiple types of treatment using different methods at the same time. This may help reduce the development of resistance mechanisms and create synergistic effects between compounds. Furthermore, through the controlled release of medications, combination treatment plans can be developed through these types of systems.

5. CHALLENGES AND FUTURE DIRECTIONS

5.1 Biocompatibility and Toxicity Concerns

While there is tremendous potential for use of nanocomposites, there are also serious questions about whether or not they will be biocompatible and toxic. Some of the unique characteristics of nanomaterials that make them appealing, such as their high surface area, chemical reactivity and ability to cross biological barriers, create potential safety issues due to unforeseen interactions with living systems. For example, nanoparticles can potentially generate oxidative stress, cause inflammatory responses, be genotoxic or alter chemical signalling pathways in cells. Completely and accurately assessing the safety of nanocomposite materials is even more complicated because safety is based on the characteristics of the nanocomposite created by adding together multiple component materials (rather than the characteristics of the separate component materials). In addition, products resulting from degradation of nanocomposites may not interact with living systems the same way as the corresponding parent materials. The chronic exposure to implanted nanocomposite materials has not been fully studied. Thus, standardized testing methods that consider all of these complexities are needed.

Nanomaterials derived from waste materials have potential advantages and disadvantages in terms of safety, particularly regarding toxicity. First, the potential presence of bioactive residues from the original source materials can enhance their compatibility with living systems. Second, the presence of bioactive residues from original source materials can introduce variability into the evaluation process, complicating the characterization of these materials for safety. Therefore, rigorous and standardized characterization and purification of nanomaterials derived from waste products are needed to ensure that the positive properties provided by these materials are not countered by unexpected toxicological properties of the materials.

5.2 Scalability and Manufacturing Challenges

Translating nanocomposite breakthroughs from the lab to the medical setting necessitates scalable and repeatable methods of preparation. Many techniques developed in academia for preparing nanocomposites are not readily adaptable to commercial quantities, especially those made from waste-derived feedstocks that have considerable variability. The biggest challenge with waste-derived nanocomposites is inconsistent batch-to-batch variation. For example, agricultural waste has an inherent variability due to factors such as type of crop, environmental conditions during growth, time of harvest and the manner in which it is processed post-harvest. Robust characterization protocols and application of statistical process control are critical to ensuring nanocomposite feedstocks meet the requirements of their intended use, regardless of the source variability. Additionally, developing blending strategies that will normalize the feedstock variability may provide further benefit. Although the environmental benefits of green synthesis methods can be substantial, these methods also pose specific challenges when scaling up production. The phytochemical composition of botanical extracts varies based on the growing conditions, species of plant and the extraction processes used to obtain them. Identifying the active phytochemicals (metabolites), responsible for the formation and stabilization of the nanocomposite, would allow for the production of more consistent results by either standardizing plant cultivation and extraction or substituting complex botanical extracts with defined mixtures of bioactive metabolites**.**

5.3 Regulatory Pathways and Clinical Translation

The regulations for considering medical products made from nanocomposite materials can be complicated and are changing as time passes. Most nanomaterials do not easily belong in one specific area of regulation; therefore, there continues to be some confusion whether current safety testing will give an adequate assessment of the safety of nanomaterial-based products. Additionally, when multiple materials are combined to create nanocomposite products, this makes it much more difficult to determine how to effectively regulate nanocomposite-based materials.

The ability to develop worldwide regulatory requirements for nanocomposite-based products could help to foster development globally while also reducing the burden on developers/innovators, particularly when a way has been established for products to be sold on a worldwide basis. The establishment of acceptable ways to determine the characteristics of nanocomposite products, appropriate tests for determining if they are safe, and ways to ensure that they will perform will be one of the key objectives for the development of this new area of medicine. To be moved from development to clinical practice, not only do nanocomposite products have to receive FDA approval, but there must also be data presenting that these products will provide a benefit to the patients that will use them, as well as having an acceptable cost to deliver those benefits. The increased complexity and cost of nanocomposite products will have to be justified by producing a significant improvement in patient outcomes compared with existing alternatives. Therefore, health technology assessment frameworks will be necessary to demonstrate value by assessing both the therapeutic benefits of nanocomposite products and the potential impact that using them may have on the future need for health services i.e., fewer hospitalizations, shorter treatment duration, and so forth.

5.4 Emerging Directions

Numerous new avenues of research are anticipated to enhance both the potential uses and overall effect of sustainable nanocomposites. For example, with respect to 3D bioprinting of nanocomposite hydrogels, new advanced methods will allow 3D printing of tissue constructs designed specifically for a patient with the ability to create spatially controlled property gradients such as mechanical stiffness, growth factor presentation, or pore architecture in order to promote regeneration of complex tissues. New self-healing nanocomposites capable of repairing damage through reversible chemical bonds or regeneration using embedded repair agents may allow for the extension of functional life of implanted devices while decreasing the requirement for revision surgery. Another emerging area of focus is immunomodulatory nanocomposites that can actively control the immune response; this may include the promotion of tolerance for transplanted cells, enhancement of antitumor immunity, or resolution of chronic inflammation. Integration of nanocomposites with other emerging therapeutic modalities, such as gene editing, cell and immunotherapy, offers the potential for synergistic combinations. For example, nanocomposite scaffolds that facilitate a supportive microenvironment for therapeutic cells could improve engraftment and function of the therapeutic cells. Additionally, nanoparticles capable of delivering CRISPR components with both spatial and temporal precision may facilitate clinical application of gene editing.

6. CONCLUSION

Nanocomposite materials are emerging at the intersection of two pivotal movements in contemporary medicine: a move towards precise therapies that can target specific molecular targets and a movement towards sustainable practices that view human health as being interconnected with the health of our planet. The body of research considered in this review supports both a hypothesis that these two objectives, while different in nature, have a synergistic effect on each other. By taking waste products and transforming them into high-performance nanomaterials for biomedical use, we see an excellent example of this synergetic effect. Agricultural wastes, industrial waste products, and animal byproducts were once only considered as problems to dispose of, but are now viewed as abundant sources of high-value chemical compounds, often with higher-levels of performance than traditional virgin materials. Advances in green chemistry and manufacturing further increase the sustainability of the production of these nanocomposite materials while producing high-quality, biocompatible materials. These newly developed nanocomposites are meeting many of the same therapeutic needs that would traditionally have been treated using a conventional approach, such as targeted drug delivery systems, tissue engineering and regeneration, infection prevention and control, and cancer treatment, but with greater levels of therapeutic efficacy. Though we are seeing rapid advancements, challenges remain for any area of science and technology developing at the frontiers. Issues related to long-term safety, scalability of manufacturing, regulatory pathing and clinical acceptance must all be addressed by multidisciplinary teams of scientists representing the areas of materials science, biology and medicine, toxicology and regulatory science on a continuous basis. It is anticipated that the creative and collaborative spirit that has propelled nanocomposites to their current levels will continue to be the driving force for the solutions to the challenges identified above. Nanocomposites have progressed beyond being an objective of research; they now serve as usable products for various real-life healthcare problems. As synthesis methods and our understanding of biological interactions improve, and our clinical experience with them advances, we will see ever-increasing use of nanocomposite materials in healthcare. We are beginning to see a vision being created for sustaining healthy medicine—therapeutic products that are effective, affordable, and environmentally responsible—and that vision continues to slowly come into focus with the advent of each new nanocomposite.

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