



What are biomaterials?

Biomaterials play an integral role in medicine today—restoring function and facilitating healing for people after injury or disease. Biomaterials may be natural or synthetic and are used in medical applications to support, enhance, or replace damaged tissue or a biological function. The first historical use of biomaterials dates to antiquity, when ancient Egyptians used sutures made from animal sinew. The modern field of biomaterials combines medicine, biology, physics, and chemistry, and more recent influences from tissue engineering and materials science. The field has grown significantly in the past decade due to discoveries in tissue engineering, regenerative medicine, and more.

Metals, ceramics, plastic, glass, and even living cells and tissue all can be used in creating a biomaterial. They can be reengineered into molded or machined parts, coatings, fibers, films, foams, and fabrics for use in biomedical products and devices. These may include heart valves, hip joint replacements, dental implants, or contact lenses. They often are biodegradable, and some are bio-absorbable, meaning they are eliminated gradually from the body after fulfilling a function.

How are biomaterials used in current medical practice?

Doctors, researchers, and bioengineers use biomaterials for the following broad range of applications:

- **Medical implants**, including heart valves, stents, and grafts; artificial joints, ligaments, and tendons; hearing loss implants; dental implants; and devices that stimulate nerves.
- **Methods to promote healing of human tissues**, including sutures, clips, and staples for wound closure, and dissolvable dressings.
- **Regenerated human tissues**, using a combination of biomaterial supports or scaffolds, cells, and bioactive molecules. Examples include a bone regenerating hydrogel and a lab-grown human bladder.
- **Molecular probes and nanoparticles** that break through biological barriers and aid in cancer imaging and therapy at the molecular level.
- **Biosensors** to detect the presence and amount of specific substances and to transmit that data. Examples are blood glucose monitoring devices and brain activity sensors.
- **Drug-delivery systems** that carry and/or apply drugs to a disease target. Examples include drug-coated vascular stents and implantable chemotherapy wafers for cancer patients.



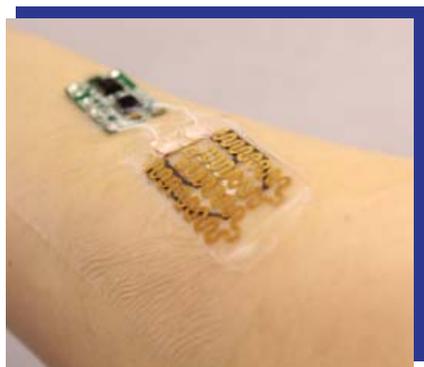
Hydrogel sealants may allow pain-free dressing changes for patients with burns. Grinstaff lab, Boston University

What technologies are NIBIB-funded researchers developing with biomaterials?

NIBIB funds research that aims to address the function and biocompatibility of biomaterials.

Biomaterials designed for function

Bioengineers measure the function of a biomaterial by how well it performs a specific action and how it will be used. A wound healing system must promote skin growth and blood vessel formation. Bone replacement material must support cell attachment and facilitate bone growth.



Smart wound dressing is thin and flexible with an array of pH sensors, thermo-responsive drug carriers, and an onboard controller. Source: Khademhosseini lab, Harvard-MIT.

▶ *A new family of fibrous protein systems*

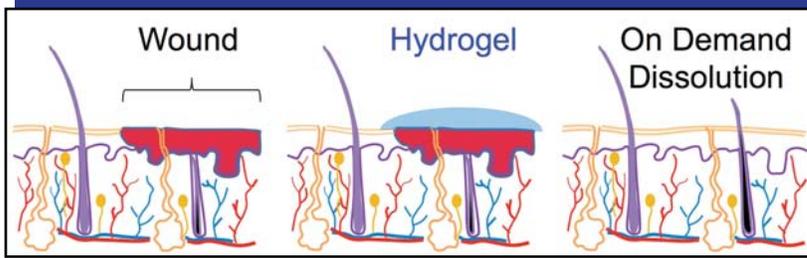
Stem cells are not specialized, so they have the potential to transition into any specific kind of cell under the right conditions. Biomaterials can be used to control stem cell fate and function. NIBIB-funded researchers are working to combine silk with tropoelastin, a highly elastic and dynamic structural protein to construct a panel of protein biomaterials. These materials must mimic the elasticity of diverse tissue structures and, consequently, control biological function, particularly the differentiation of stem cells.

▶ *Smart wound dressing for treating chronic diabetic ulcers*

Patients with diabetic ulcers that don't heal experience decreased quality of life, infections, amputations, and death. NIBIB-funded researchers are developing a smart wound dressing that can deliver oxygen and blood vessel-promoting biochemical factors while monitoring healing. Combining electronics, wound healing, microfabrication, biomaterials, and drug delivery, the dressing integrates sensors and actuators in close contact to skin. It is expected to promote healing while reducing unnecessary dressing replacements and visits to medical facilities.

▶ *Laser welding and repair of ruptured tissues*

One quarter of patients who undergo surgery to rejoin segments of their colon experience subsequent wound site leakage. NIBIB-funded researchers are pursuing a laser-welding technique for colon repair as an alternative to suturing or stapling. The procedure uses photothermal nanocomposites—nano-sized material and gold rods embedded in a matrix that when heated with a laser can fuse with ruptured tissues.



A hydrogel for burns dissolves as it promotes wound healing.
Source: Grinstaff lab, Boston University

▶ *Dissolvable dressing for the treatment of burns*

Burn patients experience acute pain when undergoing dressing removal. Current clinically approved dressings stick to the wound surface, traumatizing newly formed tissue and delaying healing. NIBIB-funded researchers are developing a hydrogel dressing that will automatically dissolve, provide a barrier to infection, and promote healing. By dissolving into safe by-products in a controlled way, the hydrogel will permit on-demand dressing removal and re-exposure of the wound without the need for mechanical debridement and cutting, resulting in easier, less traumatic treatment.

Biomaterials designed for biocompatibility

Biocompatibility is a measure of how a material interacts in the body with the surrounding cells, tissues and other factors. A biomaterial is considered to have good biocompatibility if it does not trigger too strong of an immune response, resists build-up of proteins and other substances on its surface that would hinder its function, and is resistant to infection.

▶ *Dissolvable zinc stents*

Metal stents are commonly used to keep blood vessels open, but stents can cause long-term complications, including re-narrowing of the vessel, blood clots, and bleeding. NIBIB-funded researchers are developing a bio-absorbable zinc stent that harmlessly erodes away over time, minimizing the normal chronic risks associated with permanent stents. Early testing with absorbable zinc stents have been promising.

▶ *Self-sufficient power supply for implantable biomedical devices*

A biomedical device lasts only as long as its battery. NIBIB-funded researchers aim to overcome that limitation by harvesting energy from the human body to power implantable biomedical devices. They are currently exploring innovative nanotechnology to develop ultrathin, lightweight, stretchable, and bio-compatible membranes. The membranes can efficiently and discreetly convert mechanical energy generated within the human body to electrical energy, resulting in a self-sufficient power supply.



Zinc stent is dissolvable and resists corrosion. Photo by Sarah Bird, Michigan Tech.

What are some important areas for future research on biomaterials?

Three fascinating technologies below suggest directions for biomaterials on the horizon:

Immunomodulation is an adjustment of the immune response to a desired level. Immunomodulating biomaterials may help to tackle widespread chronic diseases such as type 1 diabetes, an autoimmune disease where the body's defense destroys insulin-producing cells in the pancreas. Researchers recently developed an injectable, synthetic biomaterial that reversed type 1 diabetes in non-obese diabetic mice—an important step in developing a biodegradable platform to help control the effects of the disease.

Injectable biomaterials are being used increasingly for the delivery of therapeutic agents such as medicine, genetic materials, and proteins. They offer the possibility to treat a variety of conditions by providing targeted delivery while avoiding uptake by the immune system. Research currently underway using both synthetic and naturally derived injectable biomaterials may one day be used to treat bone defects, cancer, and heart attacks.

Supramolecular biomaterials—complexes of molecules that exceed the limits of what molecules can do on their own—have the potential to both sense and respond, making them ideal materials for treating injury or disease. Researchers are exploring the development of supramolecular biomaterials that can be turned on or off in response to physiological cues or that mimic natural biological signaling.

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