

# Healing from within: unlocking the body's capacity for self-repair

Brandon J. Tefft, Ph.D.  
Assistant Professor



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## Engineer



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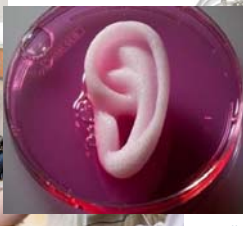
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## Biomedical Engineer



<http://topnews.in>



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### Regenerative Medicine

<http://apexbiologix.com>

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### Cells: Microscopic Tissue Engineers

131 million times per year

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### Outline

- Implantable medical devices
- Regenerative medicine
- Rapidly healing cardiovascular devices

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# IMPLANTABLE MEDICAL DEVICES

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## Top 10 in US

Rank	Device	# per year in US	\$ per year in US
1	Artificial eye lenses	2,582,000	\$8-10 billion
2	Ear tubes	715,000	\$1-2 billion
3	Coronary stents	560,000	\$7.5 billion
4	Artificial knees	543,000	\$12 billion
5	Bone repair hardware	453,000	\$4.5 billion
6	Intra-uterine devices	425,000	\$340 million
7	Spinal fusion hardware	413,000	\$10 billion
8	Breast implants	366,000	\$992 million
9	Cardiac pacemakers	235,567	\$4.5 billion
10	Artificial hips	230,000	\$10.5 billion

<https://www.businessinsider.com>

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## Cardiac Pacemaker

1960

Today

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### Artificial Hip



1962



Today

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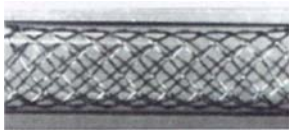
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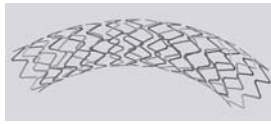
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### Coronary Stent



1986



Today

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### Cochlear Implant



1982



Today

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### Coronary Bypass Graft

1955 Today

Labels: Femoral Vein, Saphenous Vein, Tributaries of Saphenous Vein

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### Lessons from a Splinter

<https://www.tips-and-tricks.co>

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### REGENERATIVE MEDICINE

Logos: BIOMEDICAL ENGINEERING, MARSHFIELD, MCW, ADVANCING A HEALTHIER WISCONSIN ENDOWMENT, Conversation Scientists

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## Salamander Limb



James Monaghan laboratory, Northeastern University

BIO MEDICAL ENGINEERING

MSB 5111H

MSB 5112H



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## Newborn Mouse Heart



Science. 2011; 331(6020):1078-80

BIO MEDICAL ENGINEERING

MSB 5111H

MSB 5112H



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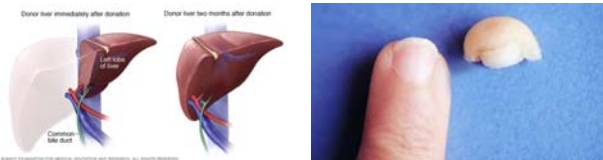
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## Regeneration in Humans



<http://thechart.blogs.cnn.com>

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MSB 5111H

MSB 5112H



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# Heart Regeneration



<http://news.bbc.co.uk/2/hi/health/4904914.stm>



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# Early Days

## ARTICLES

### Tissue Engineering

Robert Langer\* and Joseph P. Vacanti

The loss or failure of an organ or tissue is one of the most frequent, devastating, and costly problems in human health care. A new field, tissue engineering, applies the principles of biology and engineering to the development of functional substitutes for damaged tissue. This article discusses the foundations and challenges of this interdisciplinary field and its attempts to provide solutions to tissue creation and repair.

1993  
1997



Science. 1993; 260(5110):920-6

Plast Reconstr Surg. 1997; 100(2):297-302



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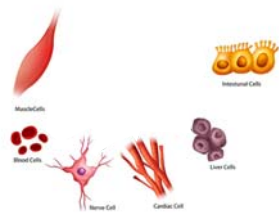
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# Cells Within Us

- 200 types
- 37 trillion cells
- Stem cells



<http://www.equatorias.com/stem-cell-therapy-stem-cell-pluripotent-stem-cells/>



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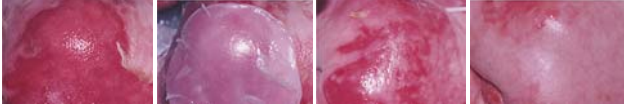
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### Skin



Arch Dermatol. 1999; 135(10):1219-22

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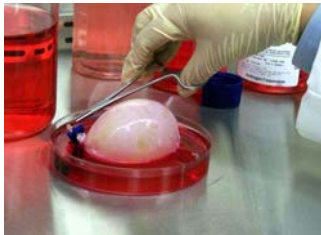
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### Bladder



<https://www.newscientist.com>

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### Cardiovascular Tissues



Humacyte



Xeltis



Miomatrix

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## Musculoskeletal Tissues



Bone



Cartilage



Ligament

PLoS One. 2017; 12(6):e0179249  
<http://meeting.nesps.org/2011/47.cgi>  
<http://tuftsjournal.tufts.edu>



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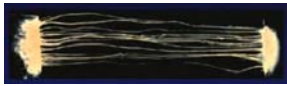
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## Nervous Tissues



Peripheral Nerve



Spinal Cord

Prog Neurobiol. 2009; 89(3):231-9  
PLoS One. 2015; 10(3):e0117709



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## RAPIDLY HEALING CARDIOVASCULAR DEVICES



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### Coronary Stents



www.adventisthealth.org

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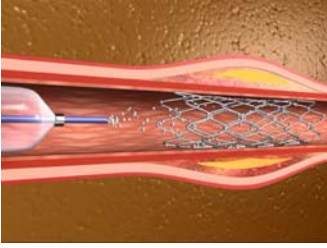
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### Rapid Healing



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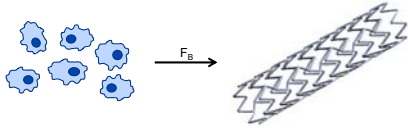
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### Magnetic Cell Capture



US patent #8,465,453 B2  
J Am Coll Cardiol. 2006;48(9):1839-45

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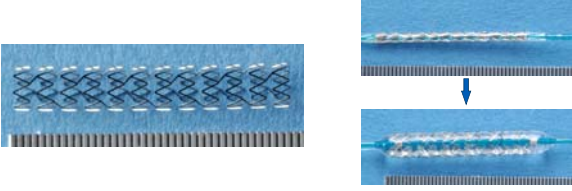
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### Magnetic Stents



The diagram shows a blue braided stent on the left. On the right, two smaller images show the stent's components: a braided mesh and a magnetic coating. A blue arrow points from the top component to the bottom component, indicating the assembly process.

Ann Biomed Eng. 2014;42(12): 2416-24  
J Vis Exp. 2015;103

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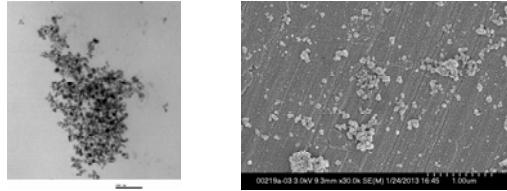
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### Magnetic Nanoparticles



The left micrograph shows dark, irregularly shaped Fe<sub>3</sub>O<sub>4</sub> core nanoparticles. The right micrograph shows larger, more spherical PLGA-coated Fe<sub>3</sub>O<sub>4</sub> nanoparticles. A scale bar of 100nm is visible in the bottom right of the right micrograph.

Fe<sub>3</sub>O<sub>4</sub> core (10 nm) | PLGA-coated Fe<sub>3</sub>O<sub>4</sub> (120 nm)

J Vis Exp. 2015;105

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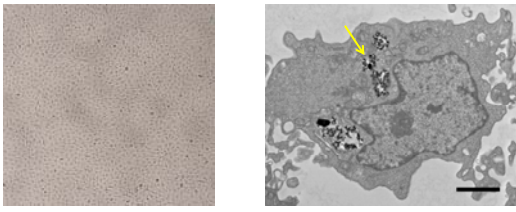
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### Magnetic Cell Labeling



The left image shows a dense culture of blood outgrowth endothelial cells. The right image is a transmission electron micrograph of a single cell with a yellow arrow pointing to dark magnetic nanoparticles within the cytoplasm. A scale bar is present in the bottom right of the micrograph.

Blood outgrowth endothelial cells

Circ Res. 2003;93:1023-1025  
IEEE Trans Magn. 2013;49(1):463-6  
J Vis Exp. 2015;105

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### In Vitro Cell Capture



Tissue Engineering A. 2018;24(13-14):1157-1166

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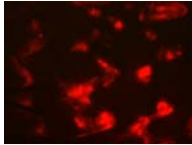
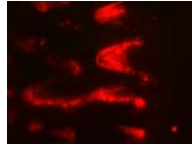
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### Rapid Healing in Pig Model

Distal Magnetic	Middle Magnetic	Proximal Non-Magnetic
		

Tissue Engineering A. 2018;24(13-14):1157-1166

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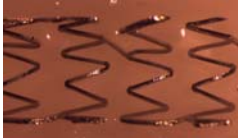

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### Rapid Healing in Pig Model

	
316L stainless steel (non-magnetic)	2205 stainless steel (magnetic)

Tissue Engineering A. 2018;24(13-14):1157-1166

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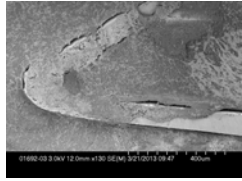
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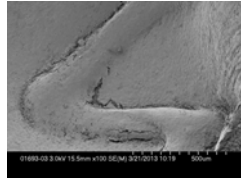
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### Rapid Healing in Pig Model



316L stainless steel (non-magnetic)



2205 stainless steel (magnetic)

Tissue Engineering A. 2018;24(13-14):1157-1166



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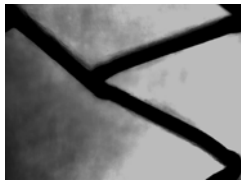
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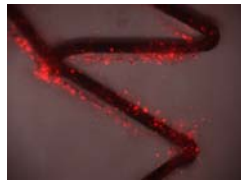
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### Rapid Healing in Pig Model



316L stainless steel (non-magnetic)



2205 stainless steel (magnetic)

Tissue Engineering A. 2018;24(13-14):1157-1166



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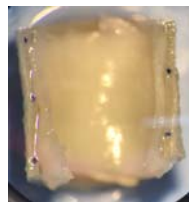
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### Rapidly Healing Vascular Grafts



Non-magnetically cell seeded



Magnetically cell seeded



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## Rapid Healing Heart Valves



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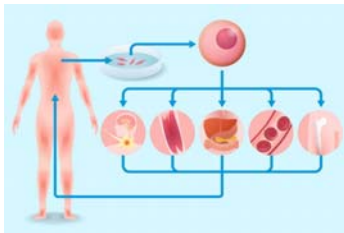
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## Regenerative Medicine



<http://apexbiologix.com>

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## Acknowledgments

- Medical College of Wisconsin
- Marquette University
- Mayo Clinic
- National Institutes of Health

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