

# Johns Hopkins Engineering

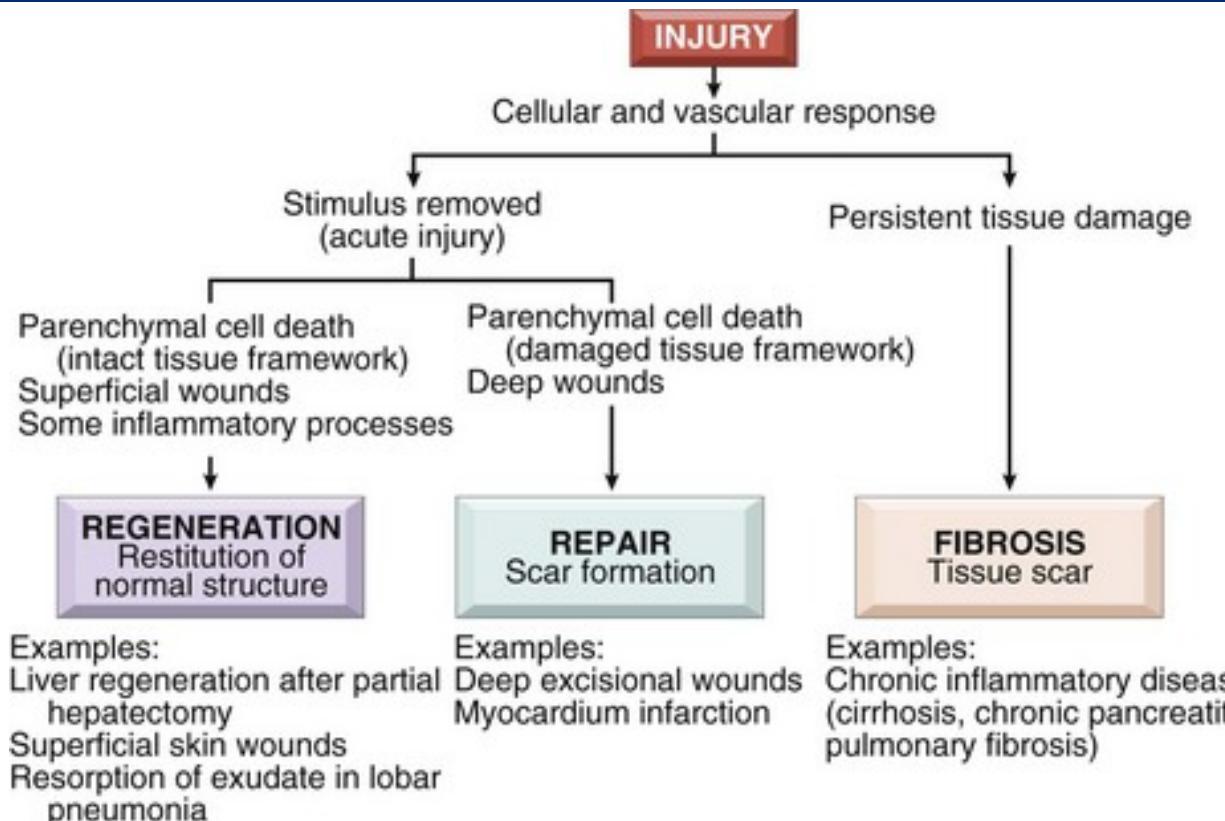
## Immunoengineering

Immune Response to Biomaterials: Foreign Body Reaction

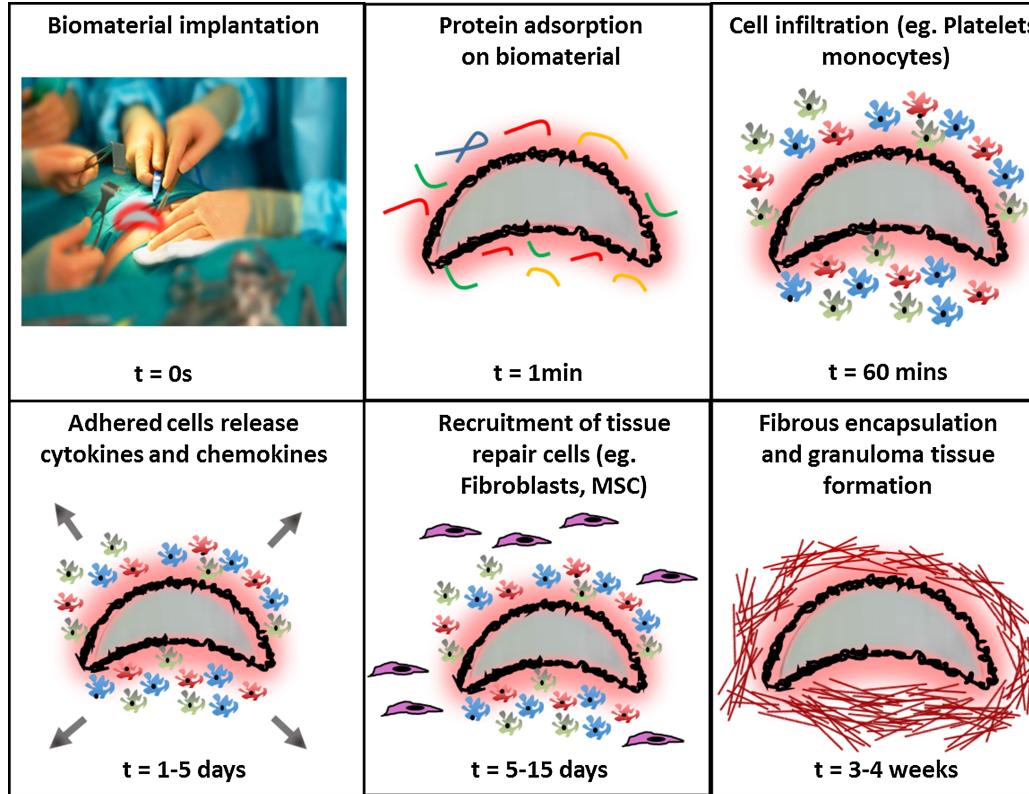


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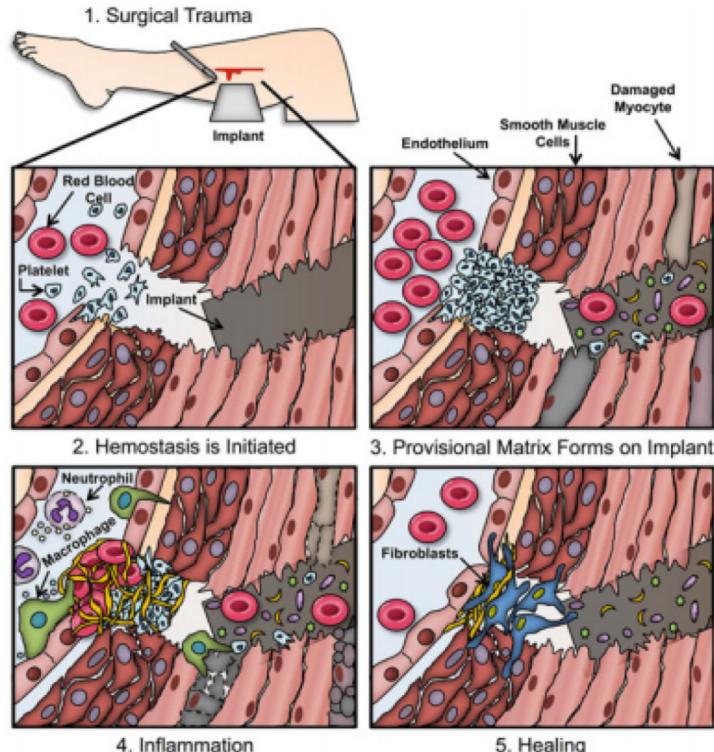
# Chronic Inflammation



# Inflammatory Response to Biomaterials

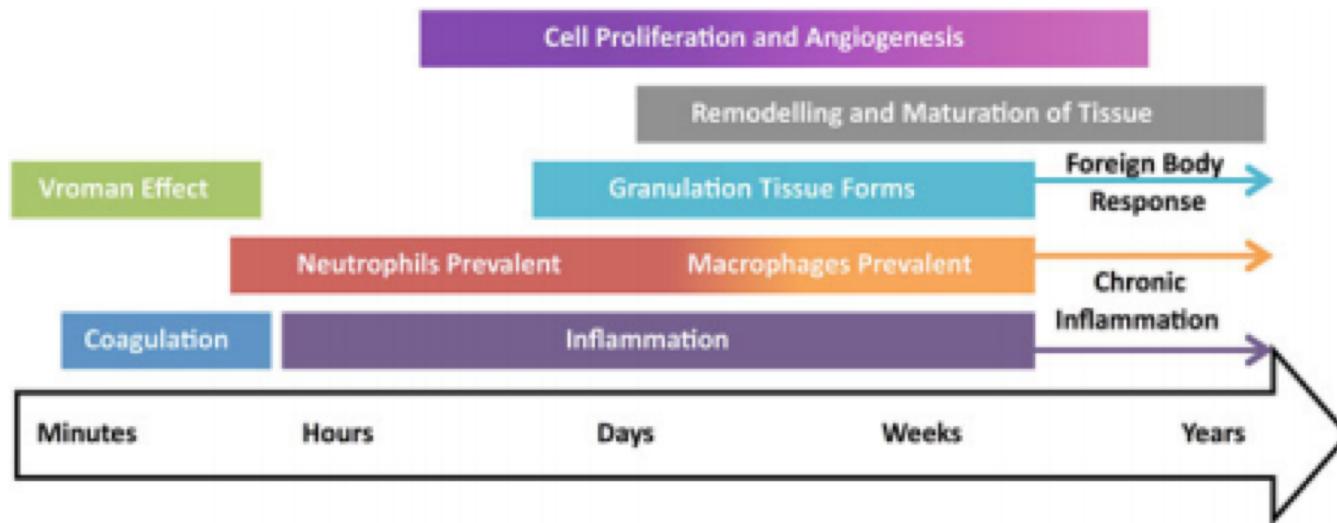


# Response to Implantation of Biomaterial

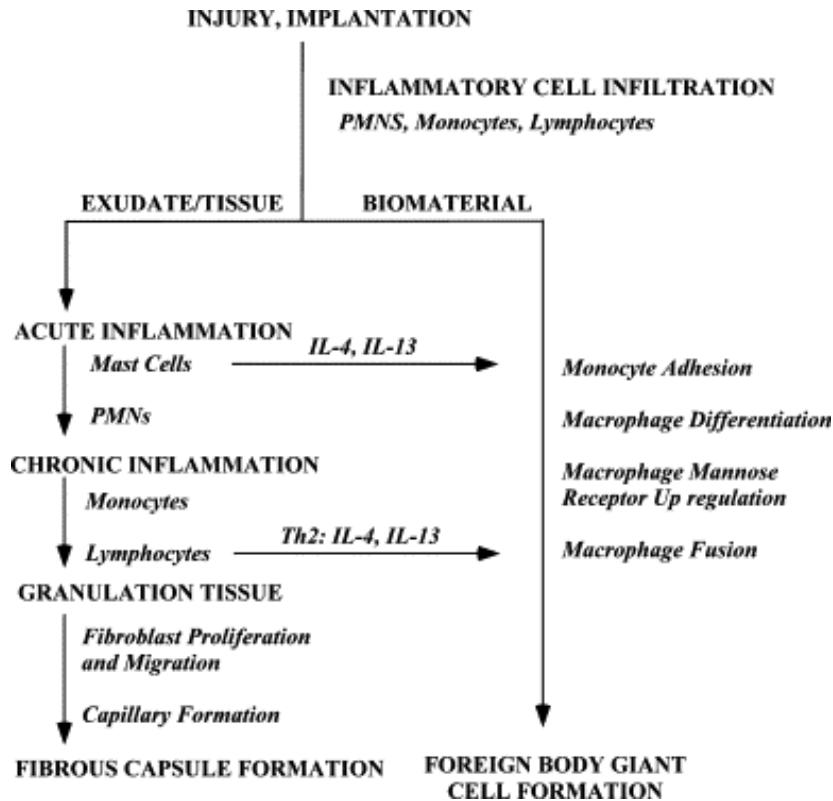


Anderson et al. "Implications of the Acute and Chronic Inflammatory Response and the Foreign Body Reaction to the Immune Response of Implanted Biomaterials". In: Corradetti B. (eds) The Immune Response to Implanted Materials and Devices. Springer, Cham (2017)

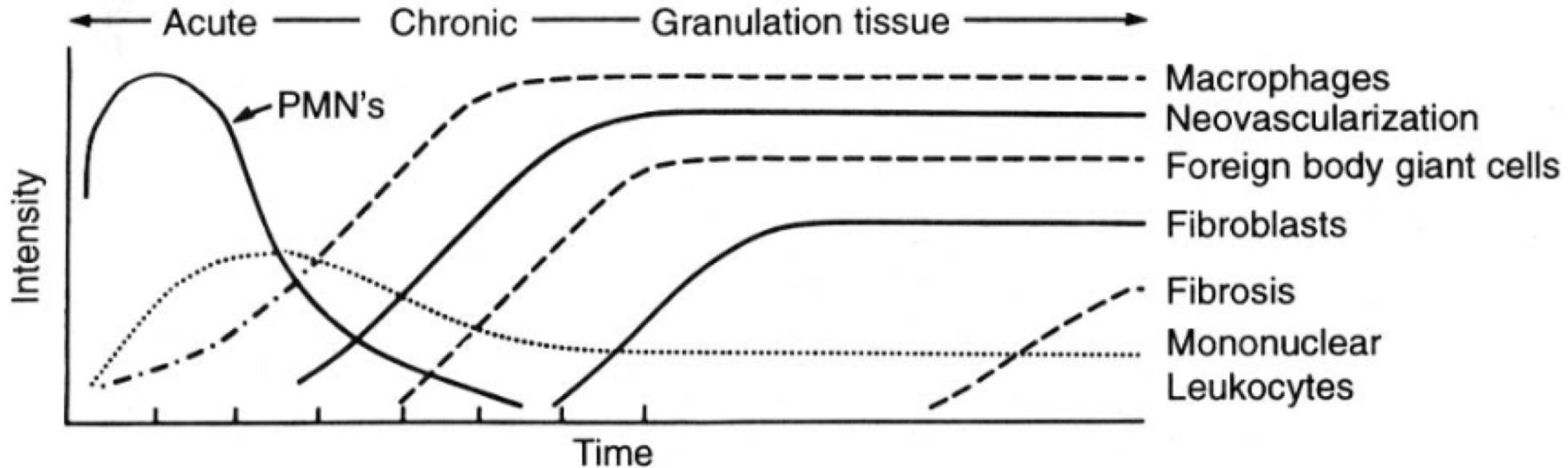
# Timeline of Host Response



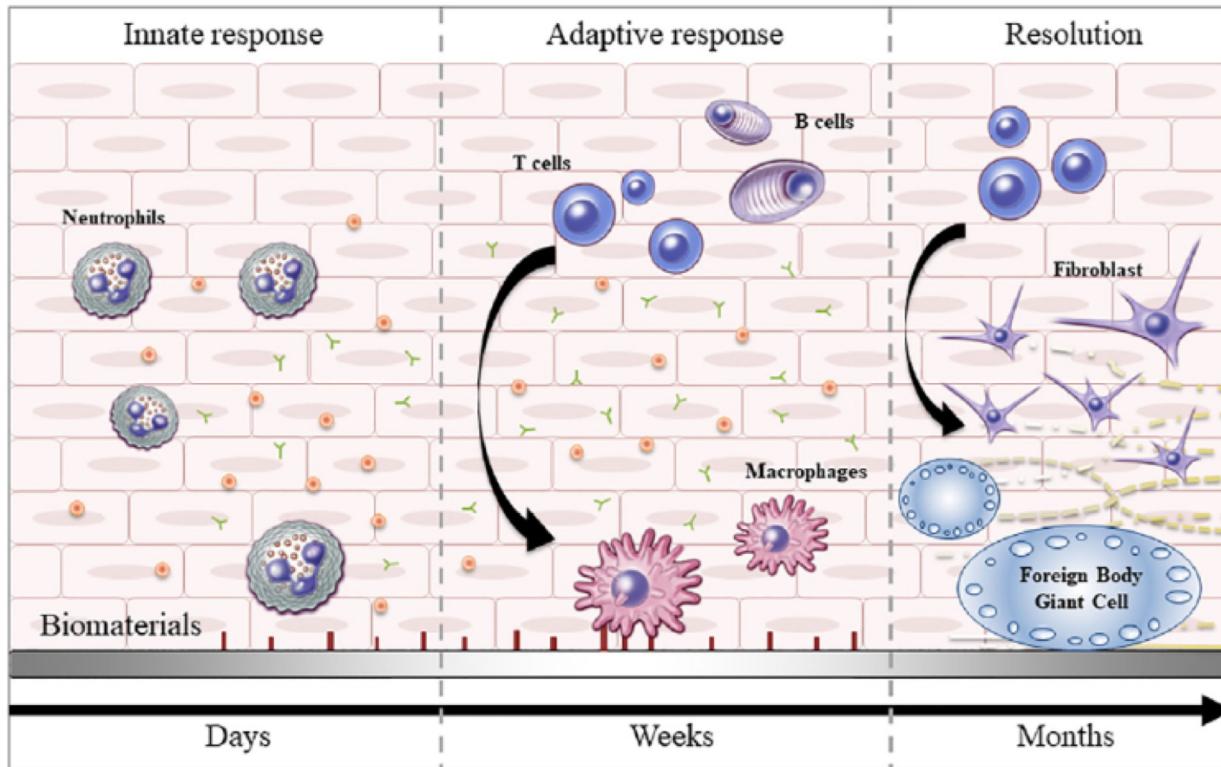
# Foreign Body Response



# Cellular Players



# Cellular Players



Chung et al. "Key players in the immune response to biomaterial scaffolds for regenerative medicine". *Advanced Drug Delivery Reviews*, 114 (2017): 184-192

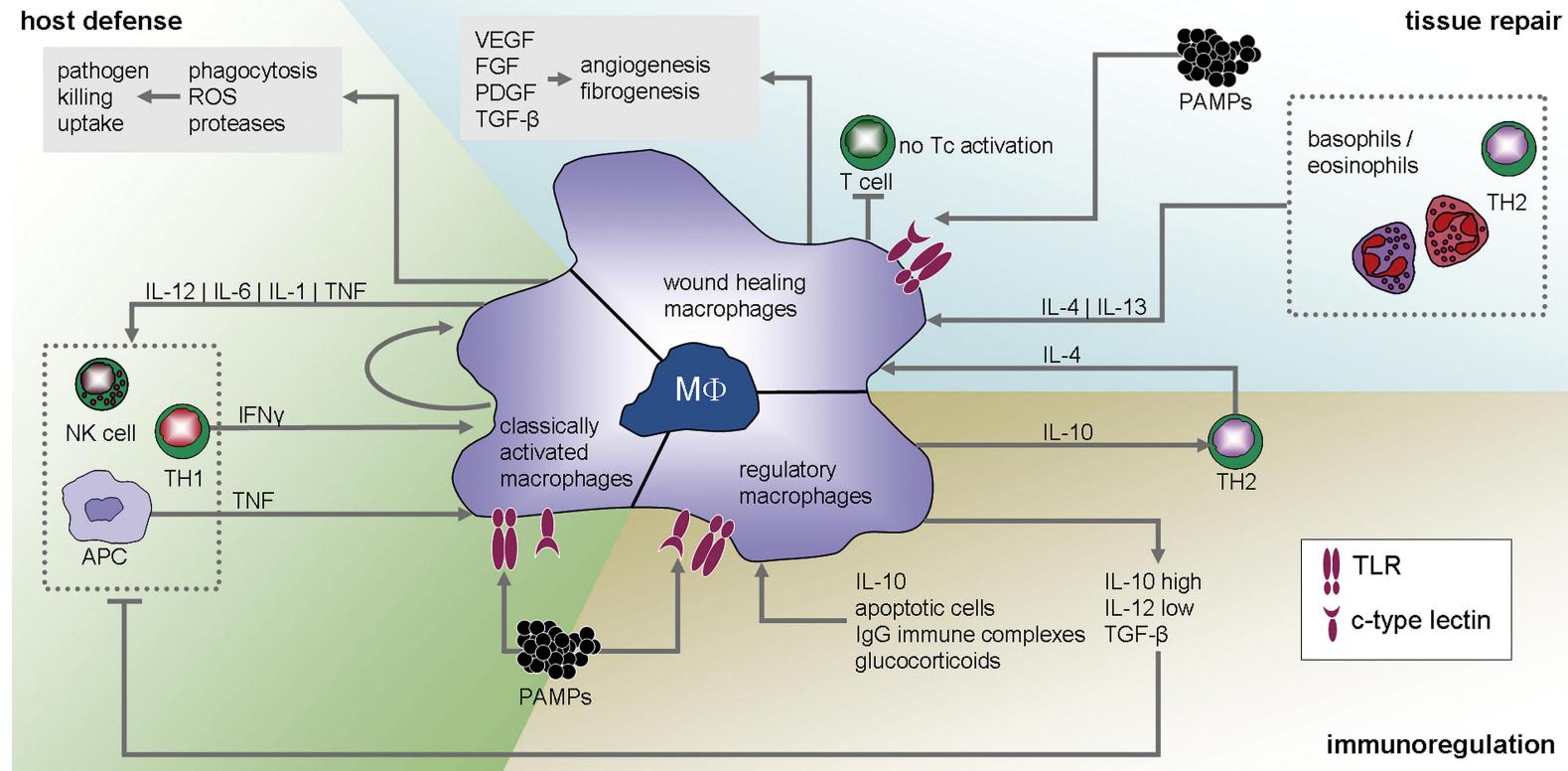
# Acute Inflammation

- Acute
  - Short: resolves within 1 week
  - Neutrophils migrate to implant site
  - Phagocytosis
    - Materials  $> 5 \mu\text{m}$  not phagocytosed
  - Protein adsorption (IgG and C3b) → facilitates neutrophil and macrophage attachment
  - Exudation of fluid and plasma proteins (edema)

# Chronic Inflammation

- Chronic
  - Caused by persistent inflammatory stimuli
  - Can be caused by motion of biomaterial in implant site
  - Monocytes, macrophages, and lymphocytes present
  - Macrophages secrete proteases, chemotactic factors, ROS, complement components, cytokines, growth factors, etc.
  - Proliferation of blood vessels and connective tissue

# Macrophages

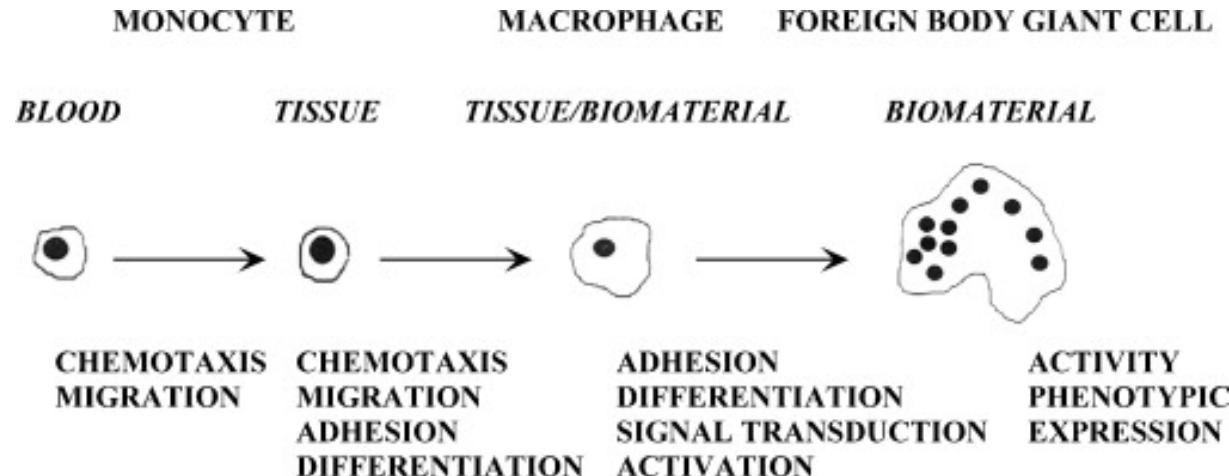


# Granulation Tissue

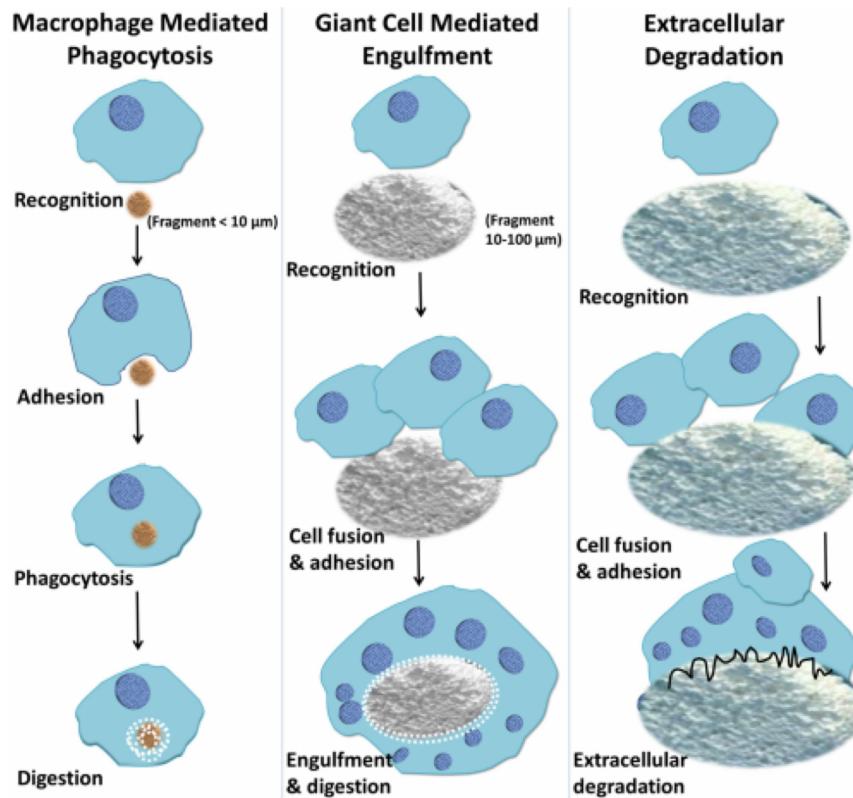
- Formed by proliferation of fibroblasts and endothelial cells
  - Fibroblasts synthesize collagen and proteoglycans, collagen becomes fibrous capsule
  - Vascular ECs undergo angiogenesis, neovascularization
- Pink, soft granular appearance of healing wounds
- Visible 3-5 days post implantation
- Normal wound healing response

# Foreign Body Reaction

- Composed of foreign body giant cells and granulation tissue (macrophages, fibroblasts, capillaries)



# Frustrated Phagocytosis



# Fibrous Encapsulation

- Resolution
- Fibrous capsule composed of connective tissue, mainly collagen
- Typically 50-200 µm in thickness
- Isolates material from rest of body—goal is to minimize interaction of biomaterial with host immune system to protect host
- Failure of biomaterial integration
- Contraction of fibrous capsule

# Biomaterial Properties Influence FBR

- Surface roughness/topography
  - Smooth surfaces have reaction of one layer of macrophages 1-2 cells in thickness
  - Rough surfaces have reaction of macrophages and foreign body giant cells
- Surface chemistry
- Geometry
  - Surface area to volume ratio
- Stiffness



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