BHARATHIDASAN UNIVERSITY

Tiruchirappalli- 620024, Tamil Nadu,
India

Programme: M.Sc., Biomedical Science
(5 Year Integrated Program)

Course Title : **Stem Cell Biology and Regenerative Medicine**
Course Code : **BM59C17**

Unit-V
Tissue Engineering

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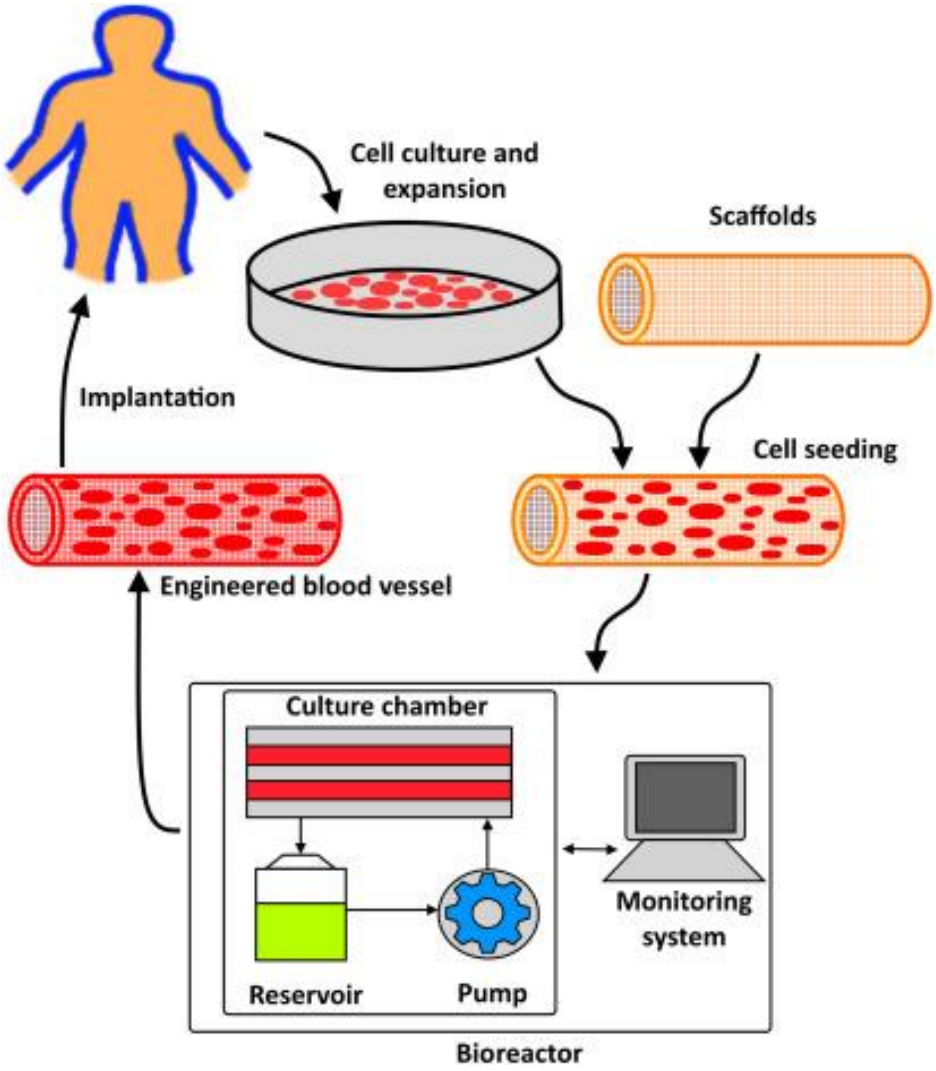
Introduction to Tissue Engineering

Tissue engineering combines biology, engineering, and medicine to restore, maintain, or enhance tissue function.

- **Key Objectives**:
  1. Develop functional tissues for transplantation.
  2. Promote natural tissue regeneration in situ.
  3. Use cells and biomaterials for therapeutic purposes.
- **Example**: Bioengineered skin grafts for burn victims.



Adapted from Ali Ostadfar PhD, in Biofluid Mechanics, 2016

Cells as Therapeutic Agents

- **Therapeutic Cells**:
  1. **Stem Cells**: Pluripotent (e.g., embryonic stem cells) and multipotent (e.g., mesenchymal stem cells).
  2. **Immune Cells**: CAR-T cells for cancer therapy.
  3. **Engineered Cells**: Genetically modified cells to produce insulin in diabetes
- **Applications**:

  Regeneration of damaged tissues, treatment of genetic disorders, and immunotherapy.

- **Example**: Using mesenchymal stem cells to treat osteoarthritis.

Tissue Organization

Hierarchical arrangement of cells within tissues to ensure proper function

- **Levels of Organization**:
  1. **Cellular**: Individual cell types (e.g., fibroblasts, myocytes).
  2. **Tissue**: Groups of similar cells (e.g., epithelial, connective).
  3. **Organ**: Functional units like the heart or liver.
- **Example**: Cardiac tissue consists of cardiomyocytes, blood vessels, and connective tissue.

Tissue Components

- **Main Components**:
  1. **Cells**: Function-specific (e.g., neurons, muscle cells).
  2. **Extracellular Matrix (ECM)**: Structural framework providing biochemical and biomechanical support.
- **ECM Composition**: Collagen, elastin, glycoproteins, and proteoglycans.
- **Example**: Cartilage ECM is rich in collagen type II and proteoglycans for strength and elasticity.

Tissue Types and Dynamics

- **Tissue Types**:
  1. **Epithelial**: Protective layers (e.g., skin).
  2. **Connective**: Support and structure (e.g., bone, blood).
  3. **Muscle**: Contraction and movement.
  4. **Nervous**: Signal transmission.

Tissue Dynamics: Continuous remodeling and adaptation in response to stress and damage

- **Example**: Bone remodeling by osteoblasts and osteoclasts.

Homeostasis in Highly Prolific Tissues

Maintaining balance in rapidly dividing tissues (e.g., skin, gut epithelium).

- **Mechanisms**:
  1. Controlled cell proliferation and apoptosis.
  2. Role of stem cells in renewal.

Example: Intestinal crypts maintain a balance of stem cell proliferation and differentiation.

Tissue Repair

- **Phases of Repair**:
  1. **Inflammation**: Removal of dead cells and pathogens.
  2. **Proliferation**: Formation of granulation tissue.
  3. **Remodeling**: ECM deposition and tissue maturation

Example: Wound healing involves clot formation, angiogenesis, and re-epithelialization

Cell and Extracellular Matrix (ECM) Interactions

- **Binding to ECM**:
  1. Integrins as cell surface receptors.
  2. Focal adhesion complexes.

- **Modifying the ECM**:
  1. Matrix metalloproteinases (MMPs) degrade ECM components.
  2. Example: Tissue remodeling during wound healing.

- **Malfunctions in ECM Signaling**:
  1. Cancer: Abnormal ECM stiffness promotes metastasis.
  2. Fibrosis: Excessive ECM deposition.

Direct Cell-Cell Contact

- **Importance of Cell Junctions**: Coordination, communication, and structural integrity.
- **Types of Cell Junctions**:
  1. **Tight Junctions**: Prevent leakage (e.g., intestinal barrier).
  2. **Adherens Junctions**: Anchor cells together.
  3. **Desmosomes**: Provide mechanical strength (e.g., heart tissue).
  4. **Gap Junctions**: Allow ion and molecule exchange (e.g., cardiac syncytium).
- **Example**: Gap junctions in cardiomyocytes ensure synchronized contraction.

- Tissue engineering bridges science and medicine for regenerative solutions.
- Understanding cell-ECM interactions and cell-cell contacts is key to developing therapeutic strategies.
- Future outlook: 3D bioprinting, personalized tissue constructs, and advances in stem cell research.