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-I
Stem Cells Biology, Stem cell Characteristics

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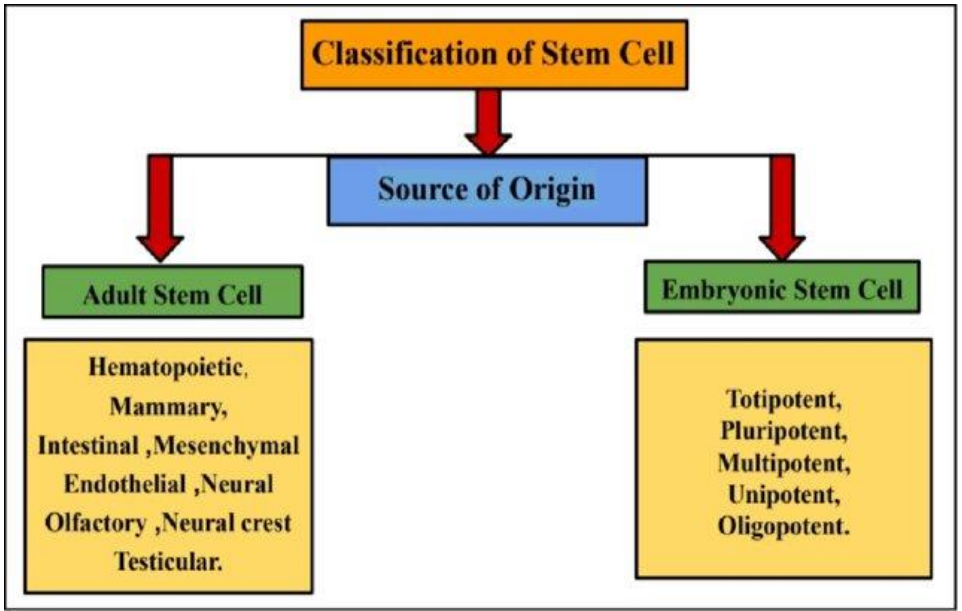
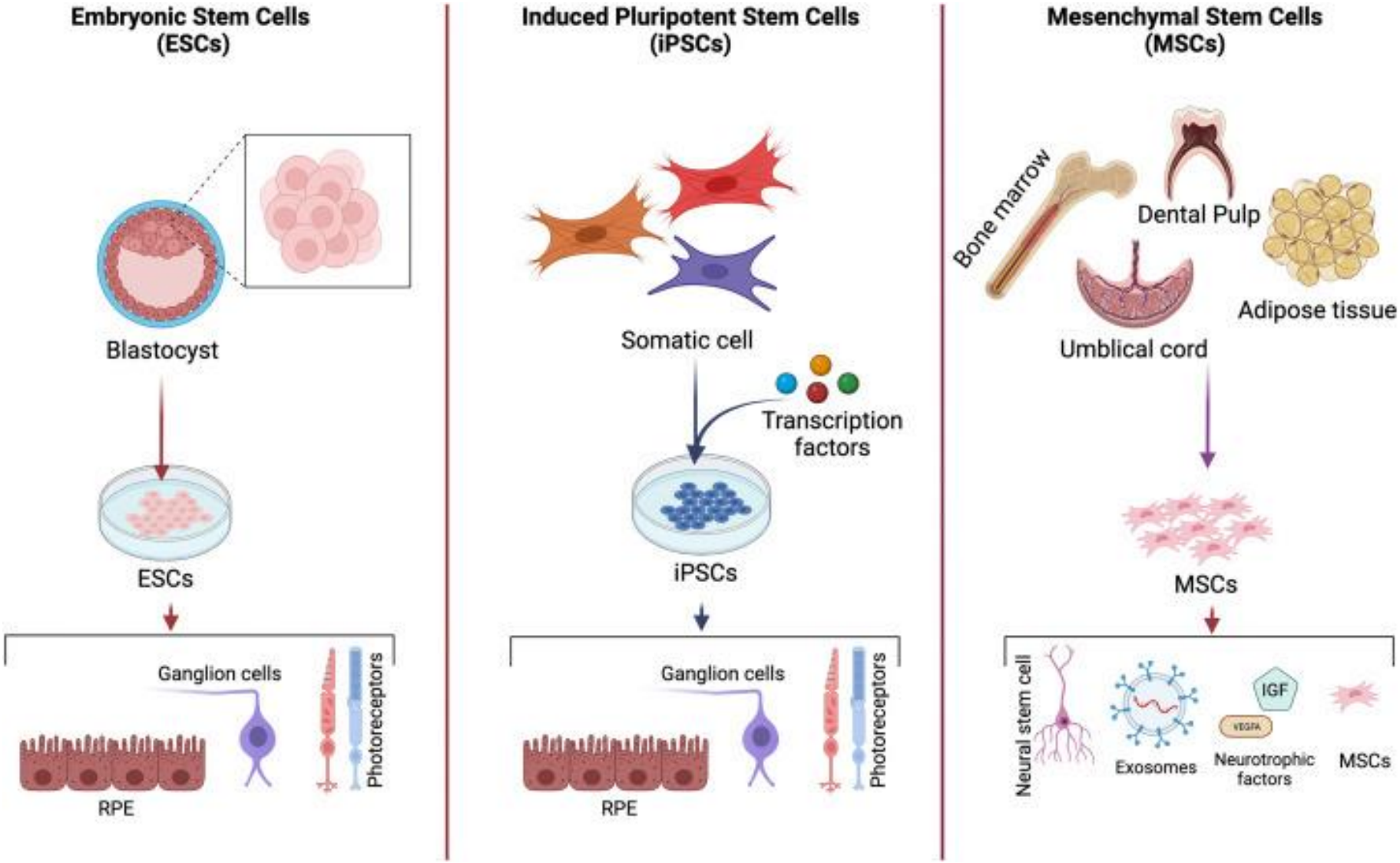
Introduction to Stem Cell Biology

- Stem cells are undifferentiated cells capable of dividing and differentiating into specialized cell types.

- Emphasize their ability for self-renewal and differentiation.
  Example: Hematopoietic stem cells give rise to various blood cells.

- **Classification of Stem Cells (I)**
  Based on Origin:
  - Embryonic stem cells (ESCs)
  - Adult stem cells (ASCs)
  - Induced pluripotent stem cells (iPSCs)




Embryonic Stem Cells
(ESCs)
Blastocyst
ESCs
Ganglion cells
Photoreceptors
RPE
Induced Pluripotent Stem Cells
(iPSCs)
Somatic cell
Transcription
factors
iPSCs
Ganglion cells
Photoreceptors
RPE
Mesenchymal Stem Cells
(MSCs)
Bone marrow
Dental Pulp
Adipose tissue
Umblical cord
MSCs
Neural stem cell
Exosomes
IGF
VEGFA
Neurotrophic
factors
MSCs

Classification of Stem Cells (II)

Based on Potency:

Totipotent : Can form all cell types, including extra-embryonic tissues (e.g., zygote).

Pluripotent : Can form all cell types within the organism (e.g., ESCs).

Multipotent : Can form multiple, but limited, cell types (e.g., mesenchymal stem cells).

Unipotent : Can differentiate into a single cell type (e.g., muscle stem cells).

Sources of Stem Cells

- **Embryonic Stem Cells:** Derived from the inner cell mass of the blastocyst.
- **Adult Stem Cells:** Found in tissues such as bone marrow, adipose tissue, and skin.
- **Perinatal Stem Cells:** From umbilical cord blood and placenta.
- **Induced Pluripotent Stem Cells:** Somatic cells reprogrammed to pluripotency using transcription factors (e.g., OCT4, SOX2).

Properties of Stem Cells

- **Potency** : Ability to differentiate into various cell types.
- **Plasticity** : Capacity to transdifferentiate into other lineages under specific conditions.
- **Self-Renewal :** Ability to undergo numerous cycles of cell division while maintaining an undifferentiated state.
- **Expansion** : Capability to proliferate extensively in culture.

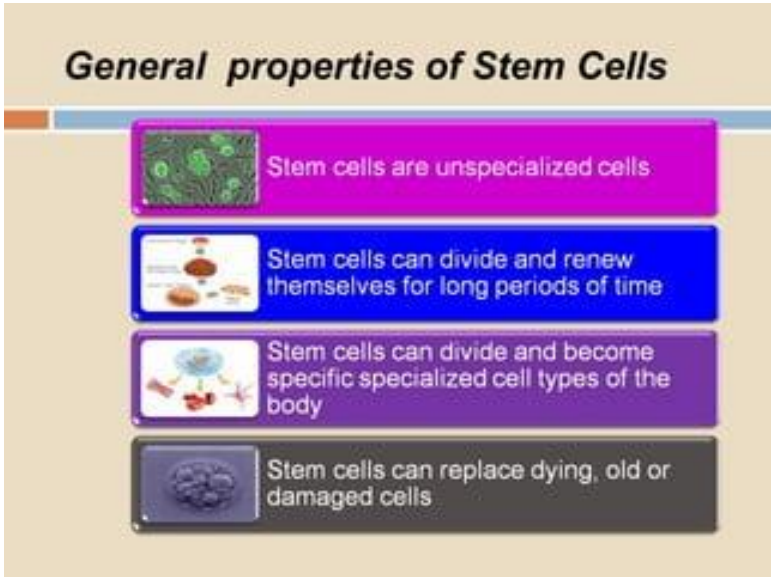
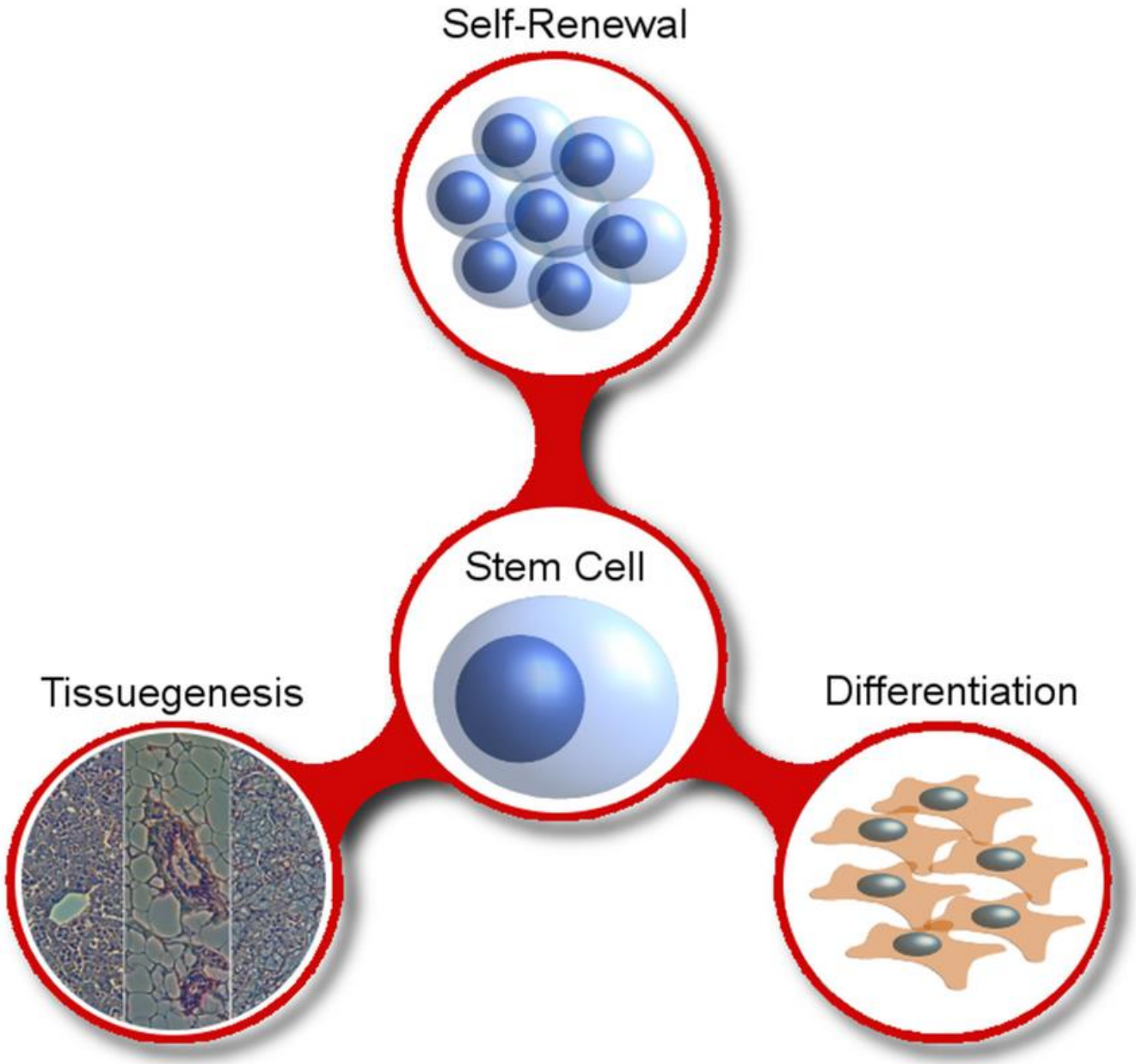


Image adapted from bonvictor.blogspot.com


Self-Renewal
Stem Cell
Tissuegenesis
Differentiation

Stem Cell Culture and Maintenance

- **Culture Environment:**
  - Media supplemented with growth factors (e.g., LIF for mouse ESCs).
  - Sterile and controlled conditions (temperature, CO2 levels).
- **Subcloning:**
  - Isolation of single cells or colonies to ensure uniform populations.
  - Technique: Cloning rings, limiting dilution.
- **Division Control:**
  - Spontaneous Division: Natural division without external cues.
  - Controlled Division: Induced by growth factors or inhibitors to guide differentiation.

Stem Cell Niches

- Definition: Microenvironments regulating stem cell behaviour and fate.
- Examples of Niches:
  - Bone marrow niche for hematopoietic stem cells.
  - Neural niche for neural stem cells in the subventricular zone.
- Components:
  - Cellular: Stromal cells, immune cells.
  - Molecular: Extracellular matrix, signaling molecules.

Molecular Mechanism Pathways

- **Proliferation:**
  - Pathways: Wnt/β-catenin, Notch signaling.

    Example: Wnt signaling promotes ESC proliferation

- **Migration:**
  - Role of chemokines (e.g., SDF-1/CXCL12 in hematopoietic stem cell migration).

- **Differentiation:**
  - Pathways: BMP/Smad, TGF-β, Hedgehog signaling.
  - Example: BMP signaling induces differentiation of mesodermal lineages.

Applications of Stem Cells

- **Regenerative Medicine:**
  - Example: Using iPSCs for cardiac tissue repair.
  - Cartilage and neural tissue regeneration.
- **Drug Screening and Toxicology Testing:**
  - Stem cells as models for testing new pharmaceuticals.
- **Understanding Developmental Biology:**
  - Insights into early embryogenesis and organogenesis.

Challenges in Stem Cell Biology

- Ethical concerns regarding embryonic stem cell research.

  Example: Debate over the use of human embryos for research.

- Risk of teratoma formation from undifferentiated pluripotent cells.
- Difficulty in controlling differentiation and ensuring stability.
- Cost and complexity of stem cell therapies.

Future Prospects of Stem Cell Research

- Advances in gene editing (e.g., CRISPR-Cas9) for stem cell modification.
- Development of organoids for disease modeling.
- Personalized medicine: Patient-specific iPSCs for tailored therapies.