



**BIOM1010**

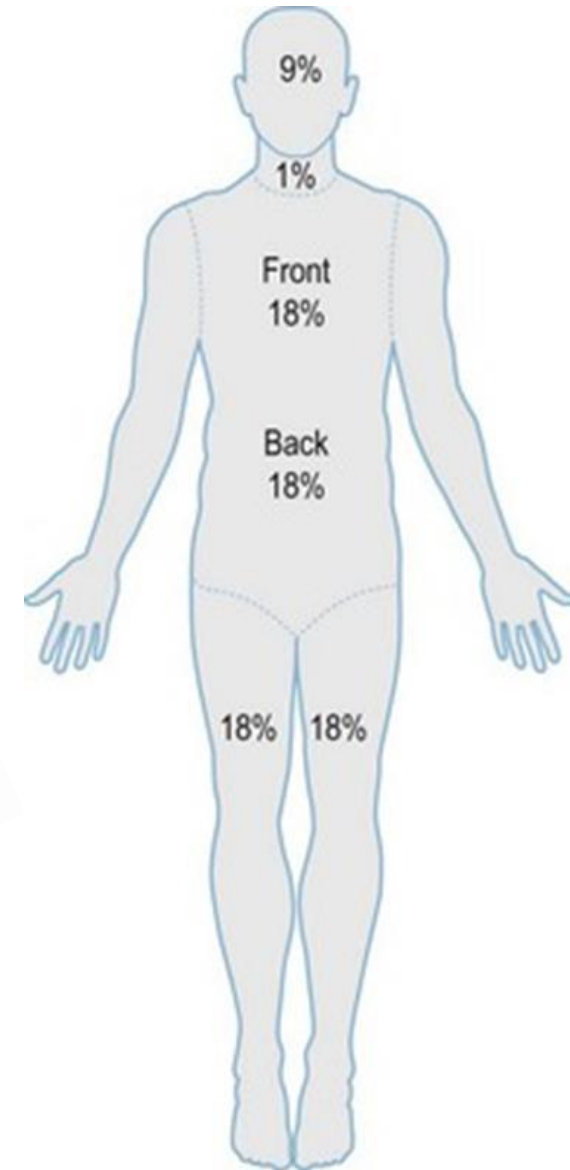
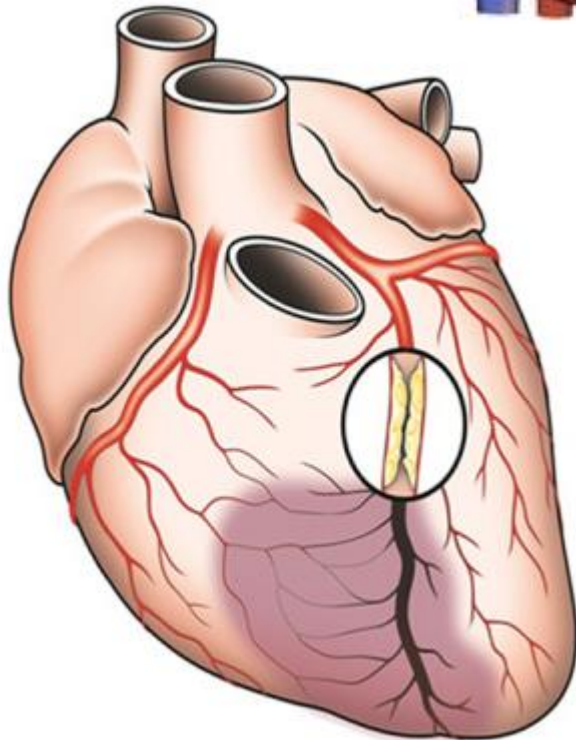
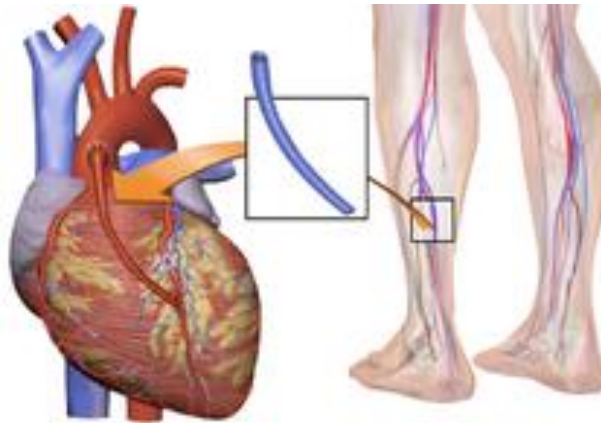
**Engineering in Medicine & Biology  
Semester 2, 2018**

**Week 9**

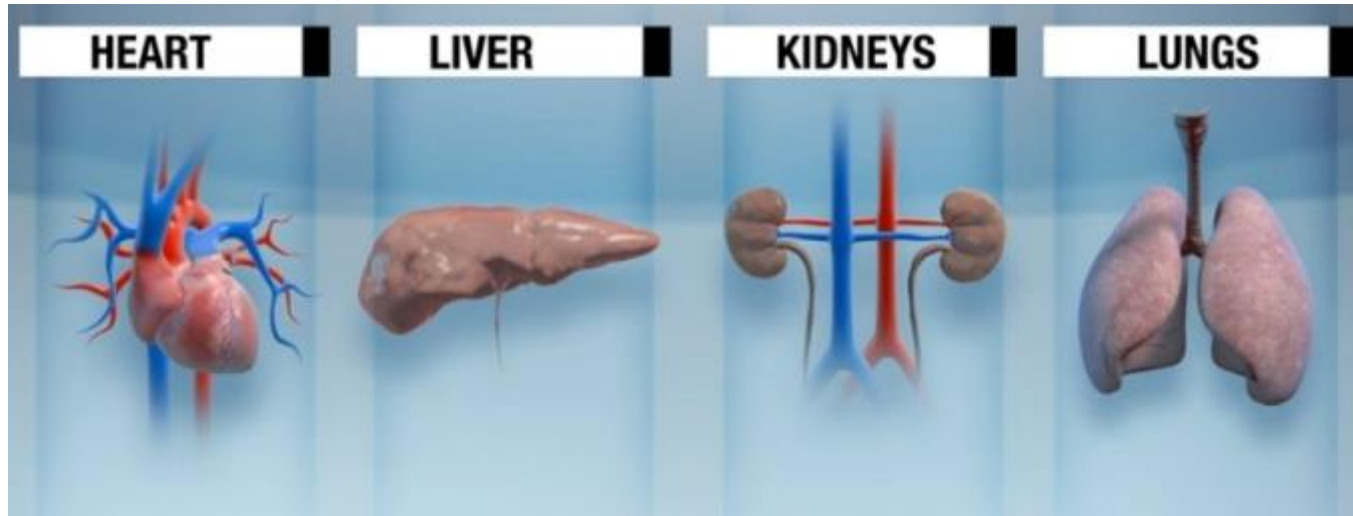
**Biomaterials & Tissue Engineering**

**Dr Jelena Rnjak-Kovacina**

# What if?

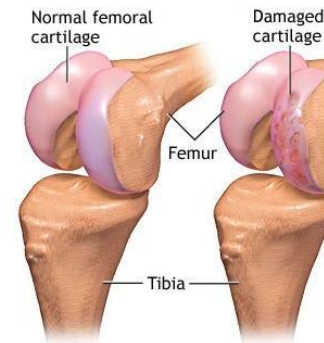
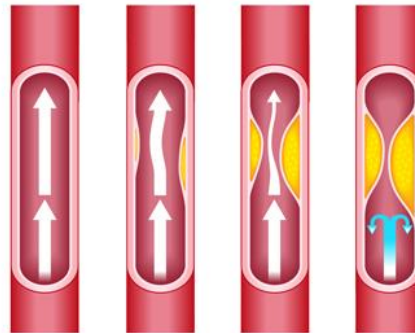
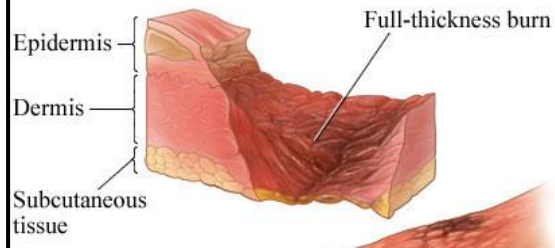
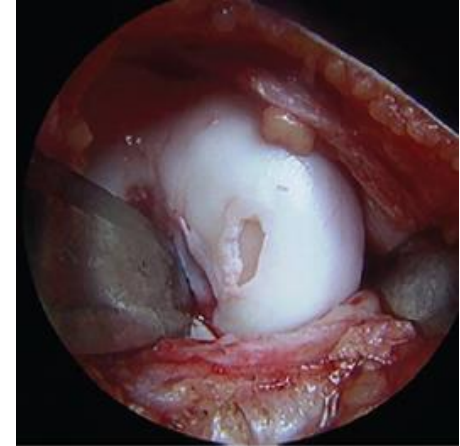
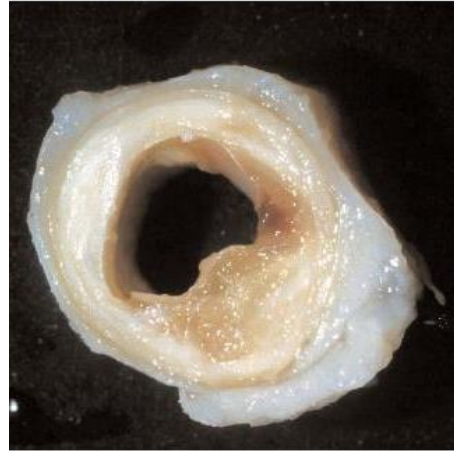


# Organ Transplantation



- In 2010, 8% of the world's population (524 million people) was **aged 65+** and this number is expected to triple to about 1.5 billion people by 2050
- In 2013, 117,733 solid organs were transplanted worldwide, **representing less than 10% of global needs**
- Over half a million Americans undergo tissue transplantation each year
- >100,000 Americans and ~1,500 Australians are on the donor **organ waiting list** at any one time, many of whom will die before a suitable organ can be found

# Tissue transplants



# Imagine...

“Imagine a world where transplant patients do not wait for a donor or a world where burn victims leave the hospital without disfiguring scars. Imagine implant materials that can ‘grow’, reshape themselves, or change their function as the body requires”

-Prof M.V. Sefton

# Is this tissue engineering?



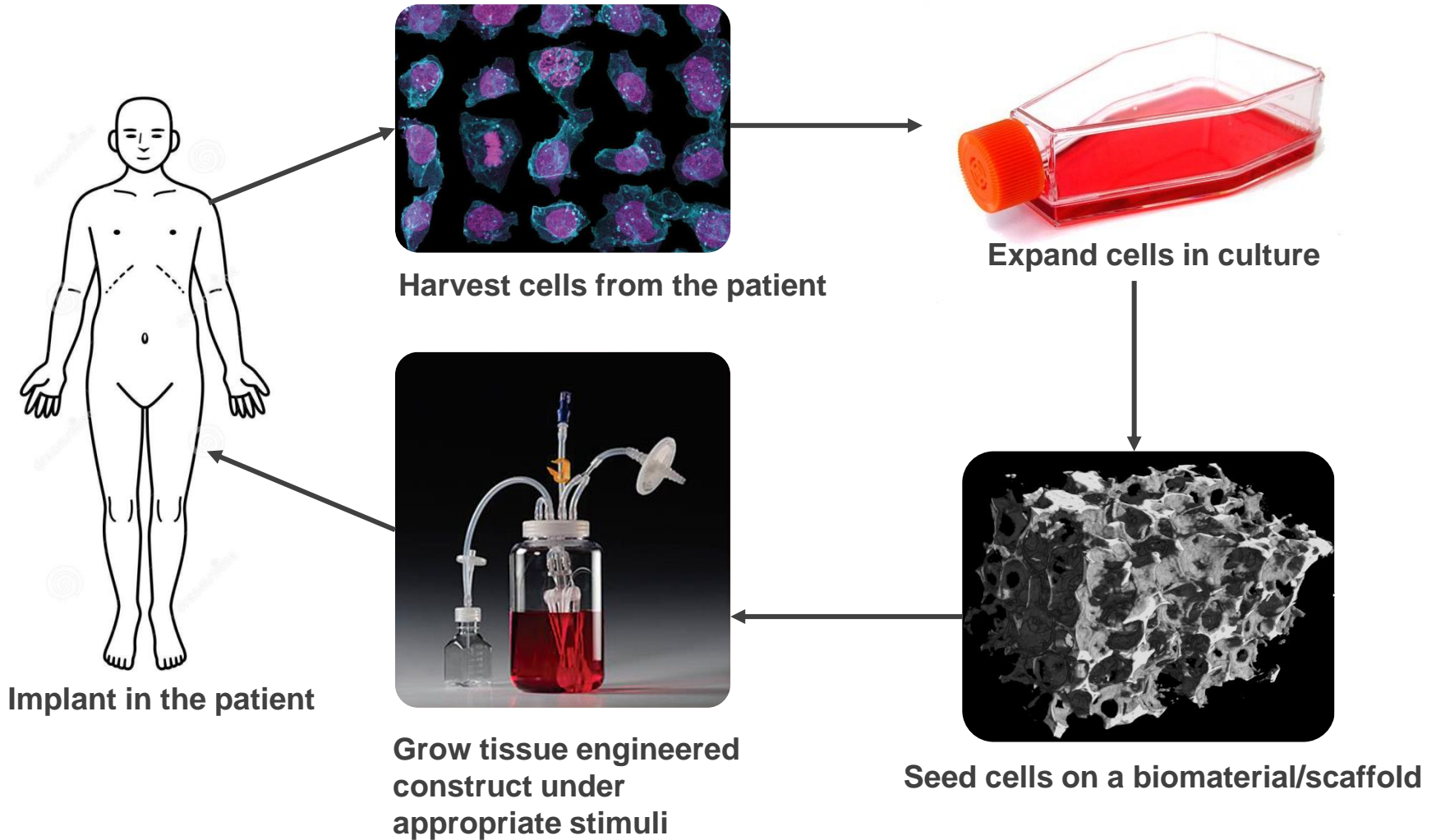
# Tissue engineering

An interdisciplinary field that applies principles of engineering and life sciences toward the development of biological substitutes that **restore, maintain, or improve tissue function or a whole organ** (Langer & Vacanti, 1993, Science 260: 920-6)

Tissue engineering is the **creation of new tissue for the therapeutic reconstruction of the human body**, by the deliberate and controlled stimulation of selected target cells through a systematic combination of molecular and mechanical signals (Williams D.F. To engineer is to create, Trends in Biotechnology, 2006, 24, 4-8)

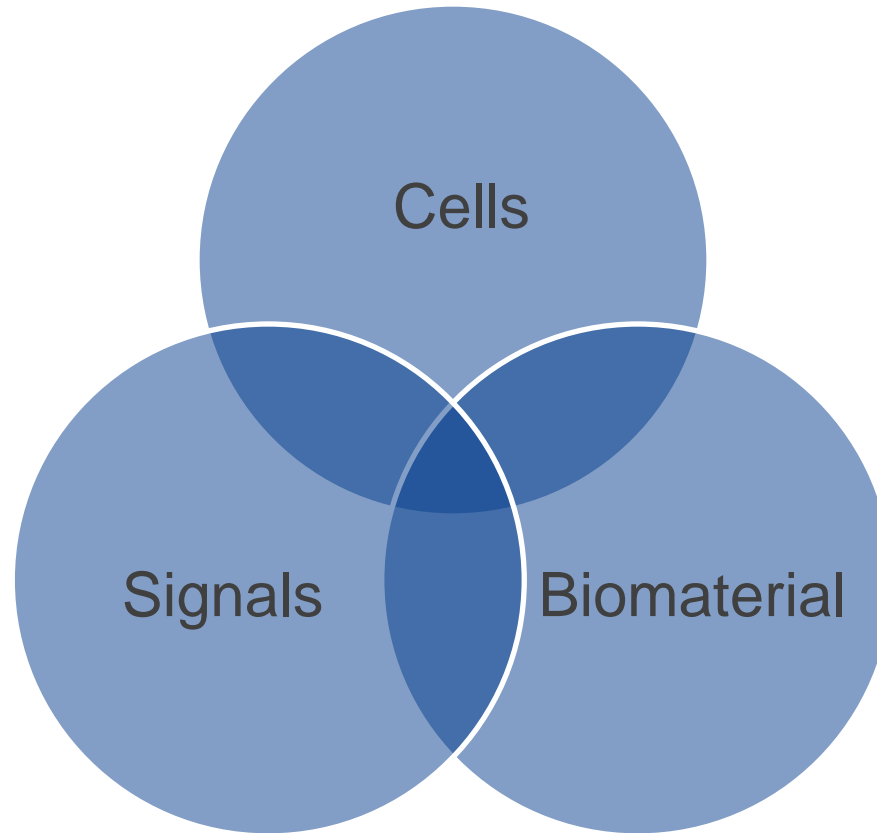


# Tissue engineering: an overview



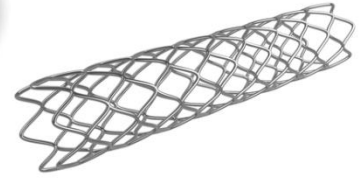
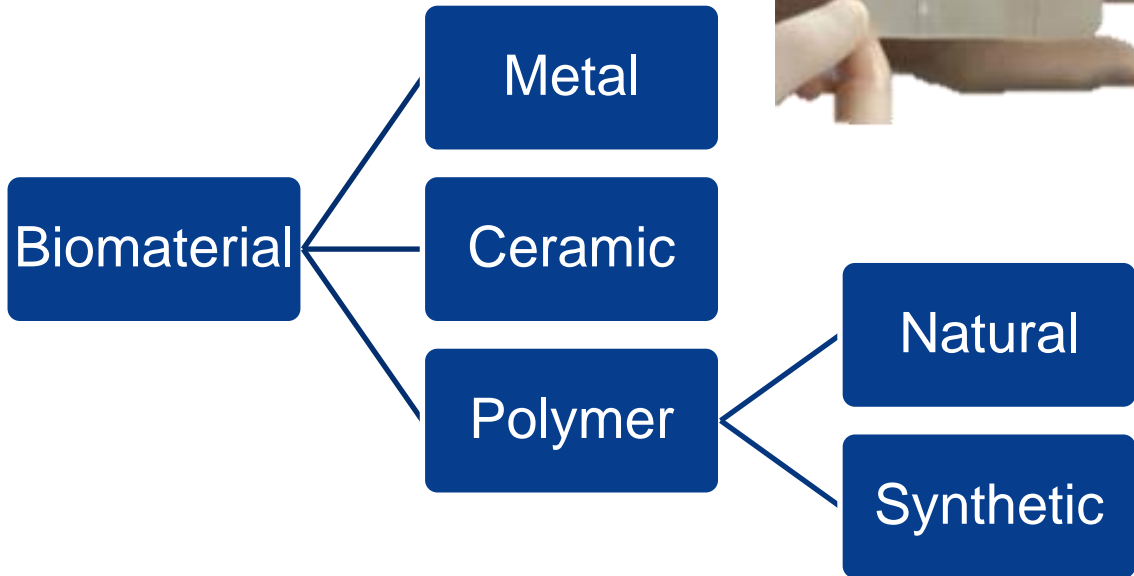


# Tissue engineering: an overview

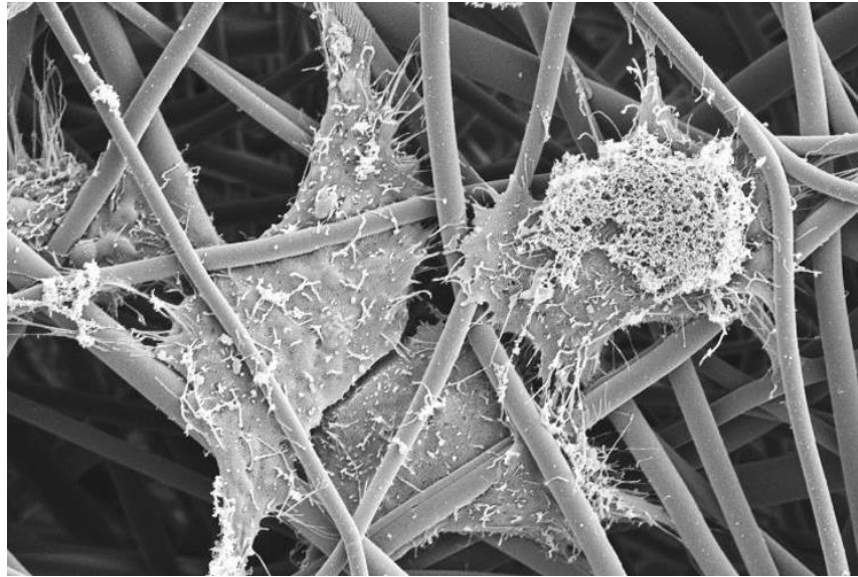
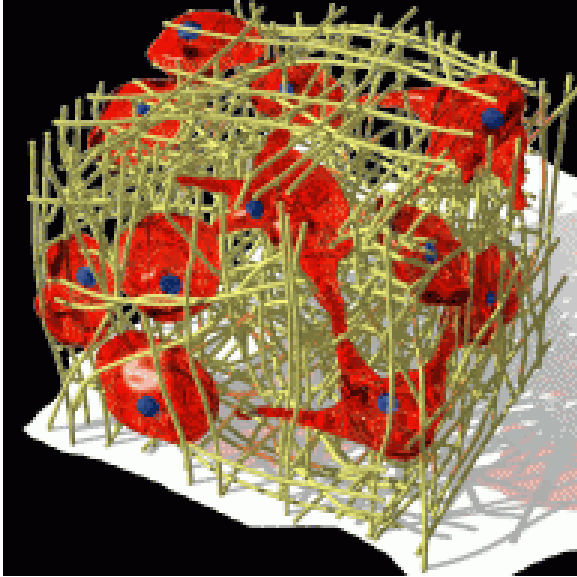


# Biomaterials

‘a material intended to interface with biological systems to evaluate, treat, augment or replace any tissue, organ or function of the body’. (1999)



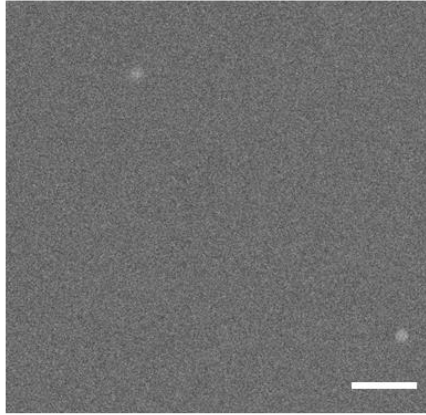
# Biomaterials



# Biomaterials

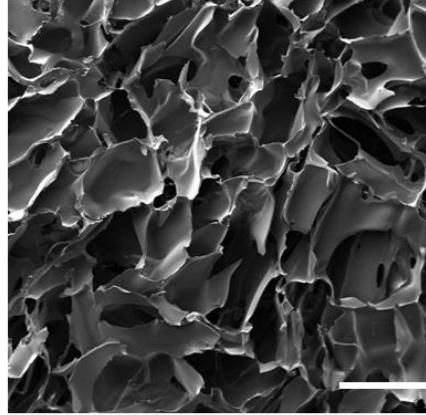
- A few examples of different material formats

**FILMS**



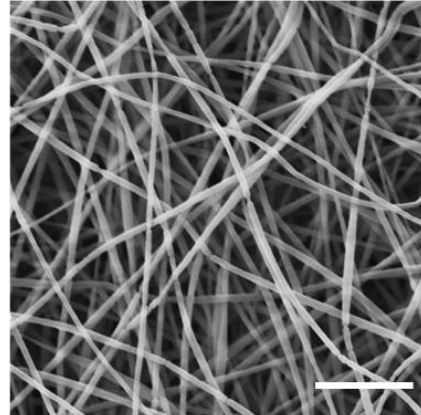
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**SPONGES**



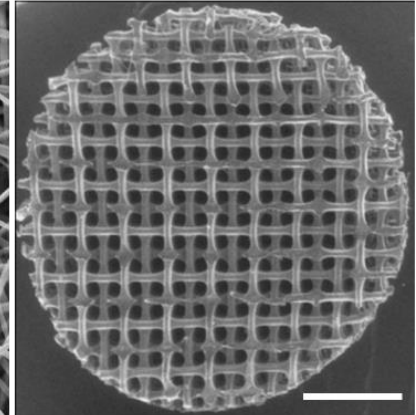
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**FIBRES**



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**3D PRINTED MATERIALS**

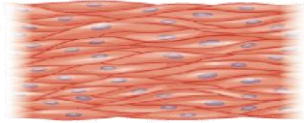


Scale bar=1 mm

# Cells



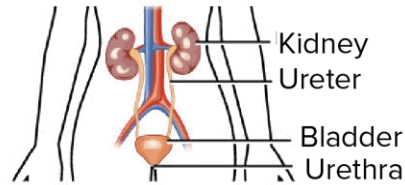
Muscle cell



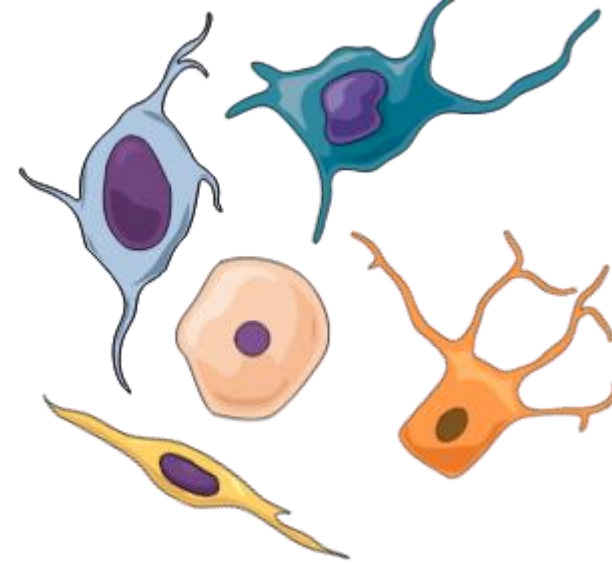
Muscle tissue



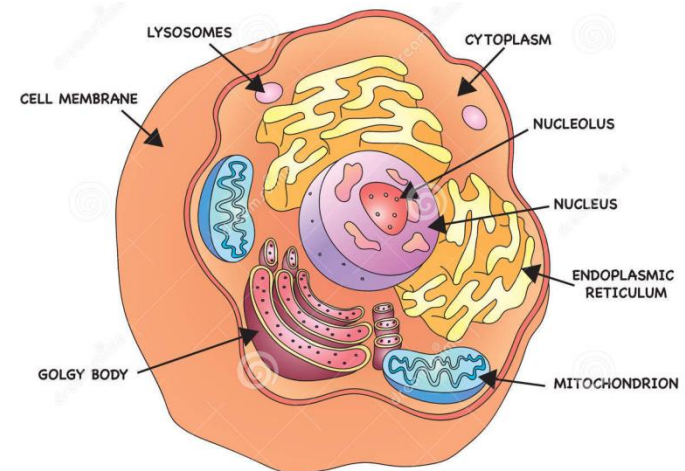
Organ (bladder)



Organ system



- “An autonomous self-replicating unit that may exist as functional independent unit of life (as in the case of unicellular organism), or as sub-unit in a multicellular organism (such as in plants and animals) that is specialised into carrying out particular functions towards the cause of the organism as a whole”



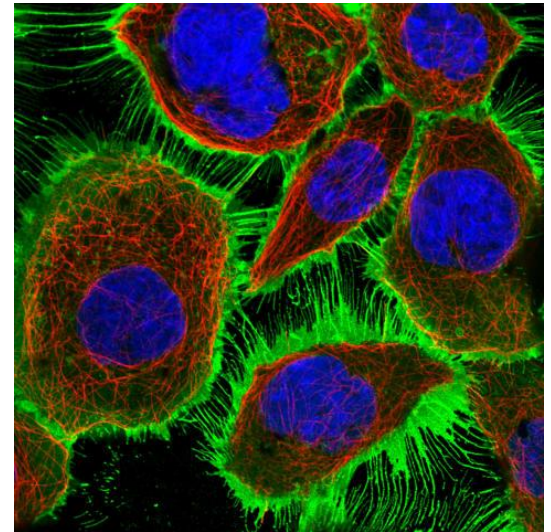
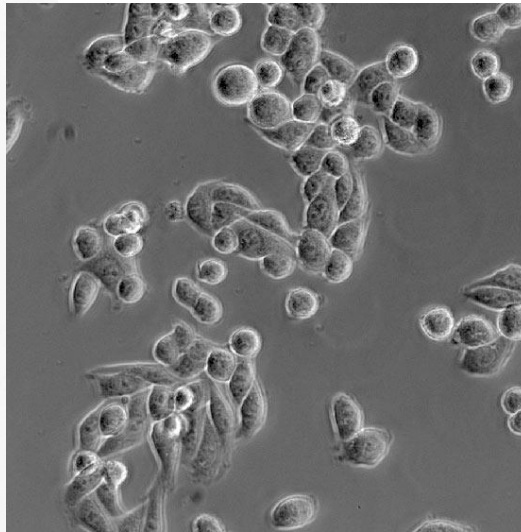
# Cell culture

- Cells from various tissues of plants and animals can be grown and cultured in artificial media outside the body → Cell culture
- Involves the harvesting of individual cells from a specific tissue and maintaining the cells in an incubator at body temperature (37° C) in a plastic or glass flask, covered with a rich medium that mimics that of the internal environment of the human body





# Cell culture

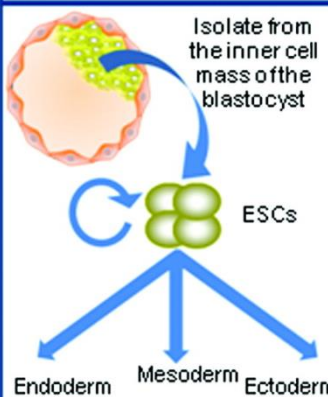
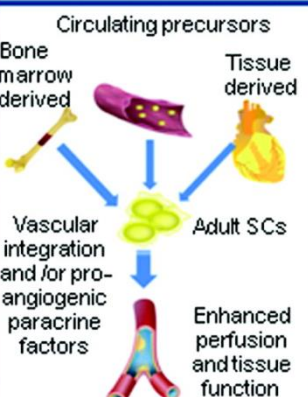
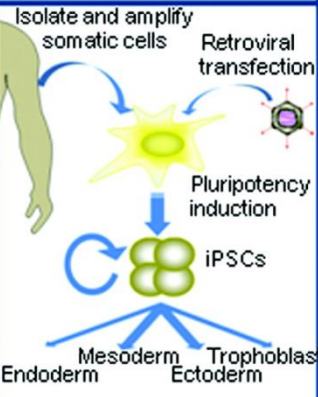




# Cells

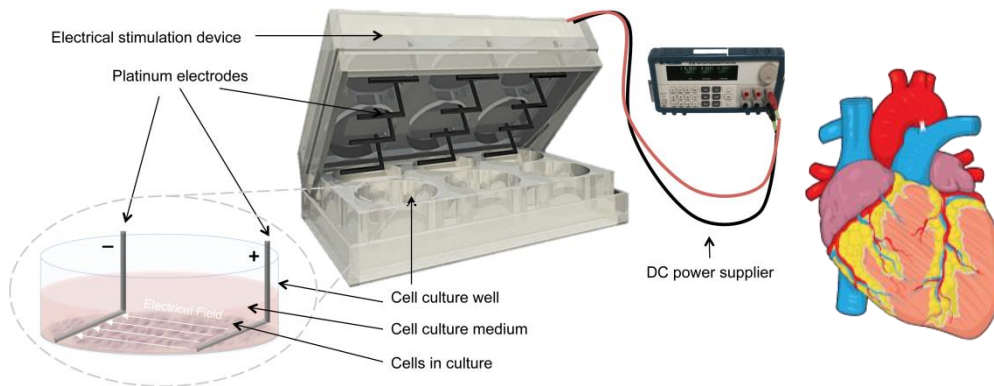
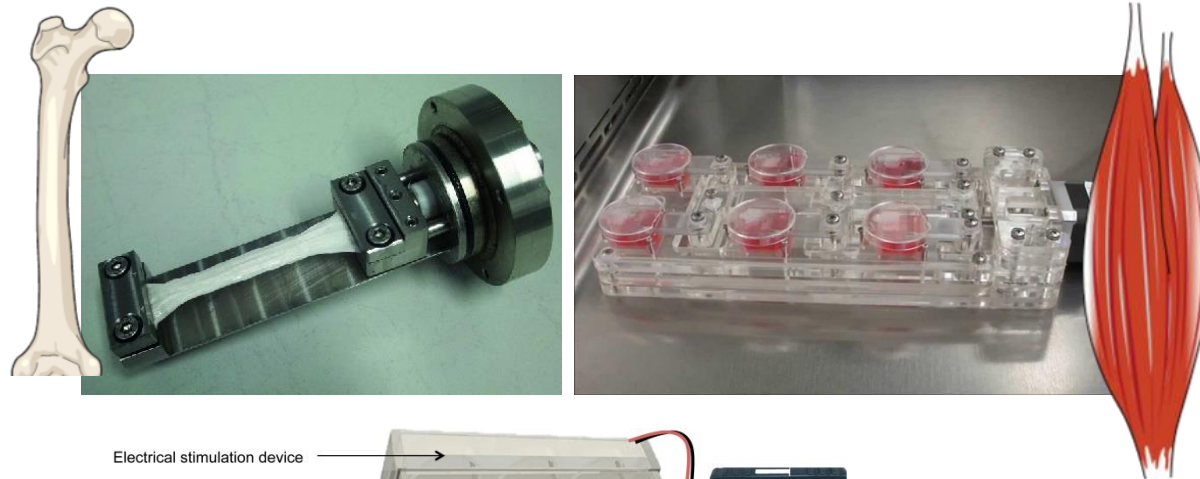
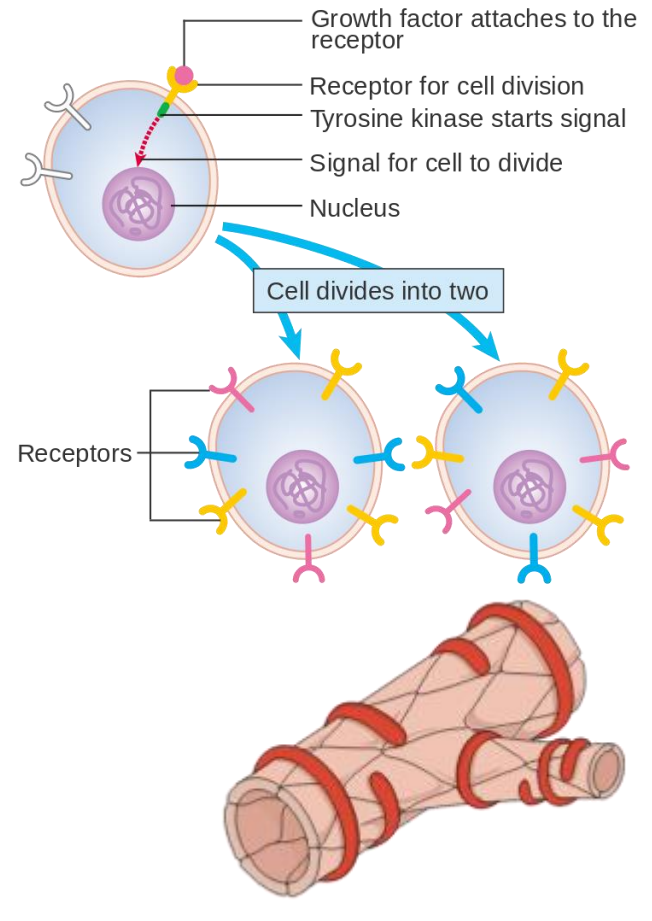
Where do we source cells for tissue engineering applications?

- Source
  - Own- **autologous**
  - Donor- **allogeneic**
- Type
  - Differentiated
  - Stem cells

ESCs	Adult SCs	iPSCs
 <p>Isolate from the inner cell mass of the blastocyst</p> <p>ESCs</p> <p>Endoderm Mesoderm Ectoderm</p>	 <p>Circulating precursors</p> <p>Bone marrow derived Tissue derived</p> <p>Adult SCs</p> <p>Vascular integration and for pro-angiogenic paracrine factors</p> <p>Enhanced perfusion and tissue function</p>	 <p>Isolate and amplify somatic cells</p> <p>Retroviral transfection</p> <p>Pluripotency induction</p> <p>iPSCs</p> <p>Endoderm Mesoderm Ectoderm</p>
<p>Origin:</p> <ul style="list-style-type: none"> <li>• Blastocyst of embryo</li> </ul> <p>Strengths:</p> <ul style="list-style-type: none"> <li>• Pluripotent (3 germ layers)</li> <li>• Self-renewal and high replicative capacity</li> </ul> <p>Weaknesses:</p> <ul style="list-style-type: none"> <li>• Immunological concerns</li> <li>• Subject to ethical debate</li> <li>• Potential for teratoma and teratocarcinoma</li> <li>• Currently no clinical trial data</li> </ul>	<p>Origin:</p> <ul style="list-style-type: none"> <li>• Bone marrow, circulation or resident tissue</li> </ul> <p>Strengths:</p> <ul style="list-style-type: none"> <li>• Autologous</li> <li>• Clinical safety and efficacy data</li> <li>• Typically lineage committed</li> </ul> <p>Weaknesses:</p> <ul style="list-style-type: none"> <li>• Limited number</li> <li>• Limited replicative capacity</li> <li>• Lineage restricted</li> </ul>	<p>Origin:</p> <ul style="list-style-type: none"> <li>• Reprogramming of somatic cells</li> </ul> <p>Strengths:</p> <ul style="list-style-type: none"> <li>• Totipotent (3 germ layers and trophoblast)</li> <li>• Autologous</li> <li>• Large reservoir of cells</li> </ul> <p>Weaknesses:</p> <ul style="list-style-type: none"> <li>• Potential for teratoma and teratocarcinoma</li> <li>• No clinical data</li> </ul>

# Signals

- Biochemical- eg. growth factors
- Mechanical- eg. strain bioreactor
- Electrical- eg. electrical stimulation

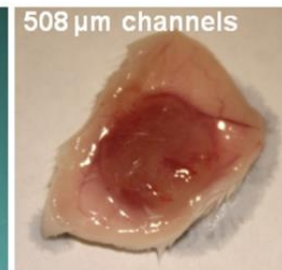
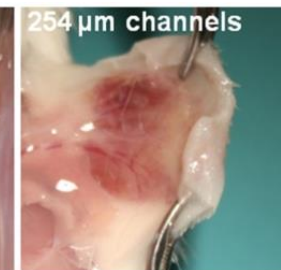
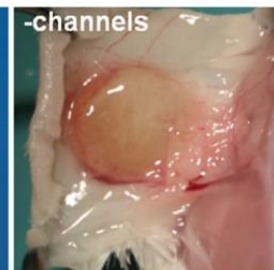
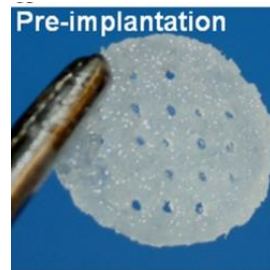
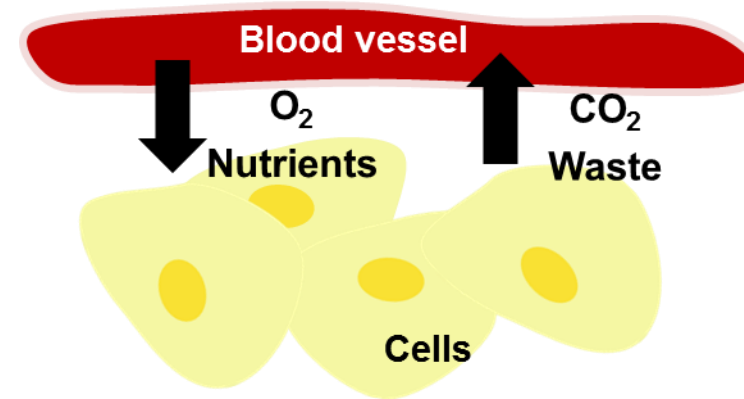


# Challenges

- Source of cells
- Material selection & material source
- Appropriate signals
- Cost
- Ethical issues
- Vascularisation

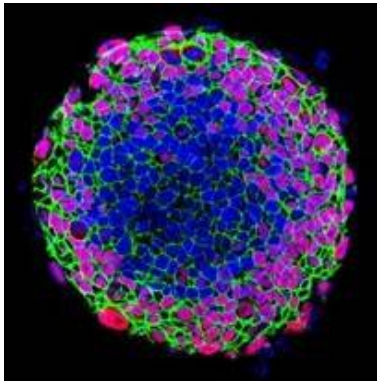


Bodies Exhibit: Circulatory System

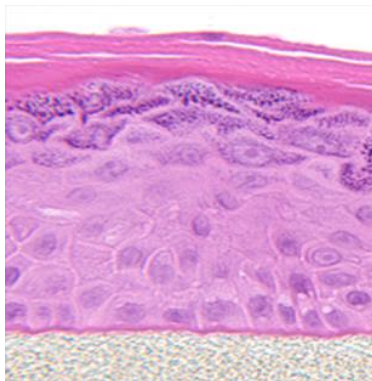


# What else can tissue engineering do?

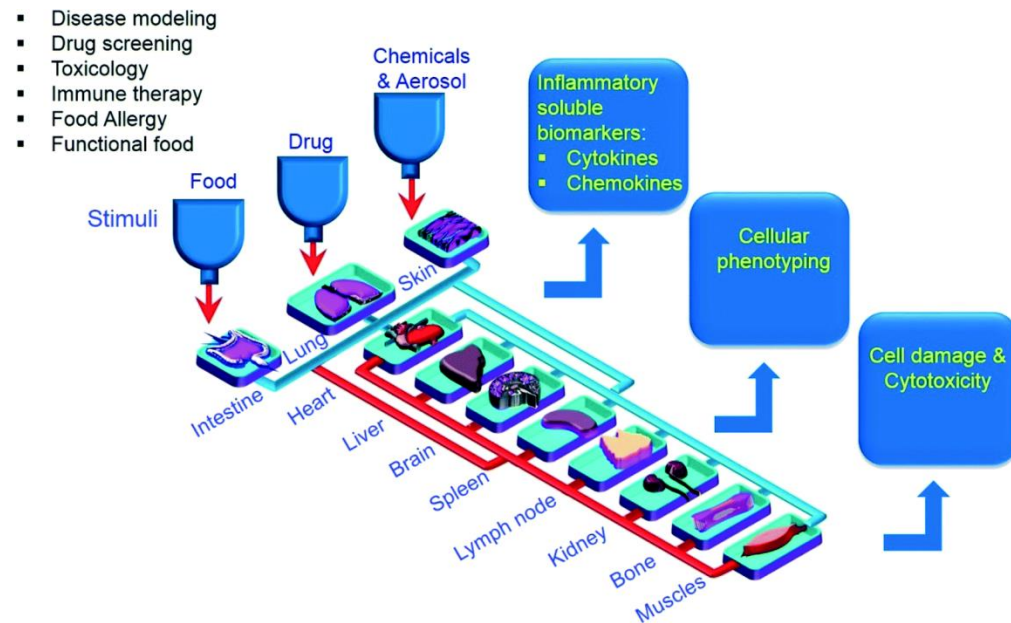
- Replacement and regeneration of damaged, diseased or missing tissues/organs
- *In vitro* tissue models → imagine a world with no animal testing



Heart tissue model



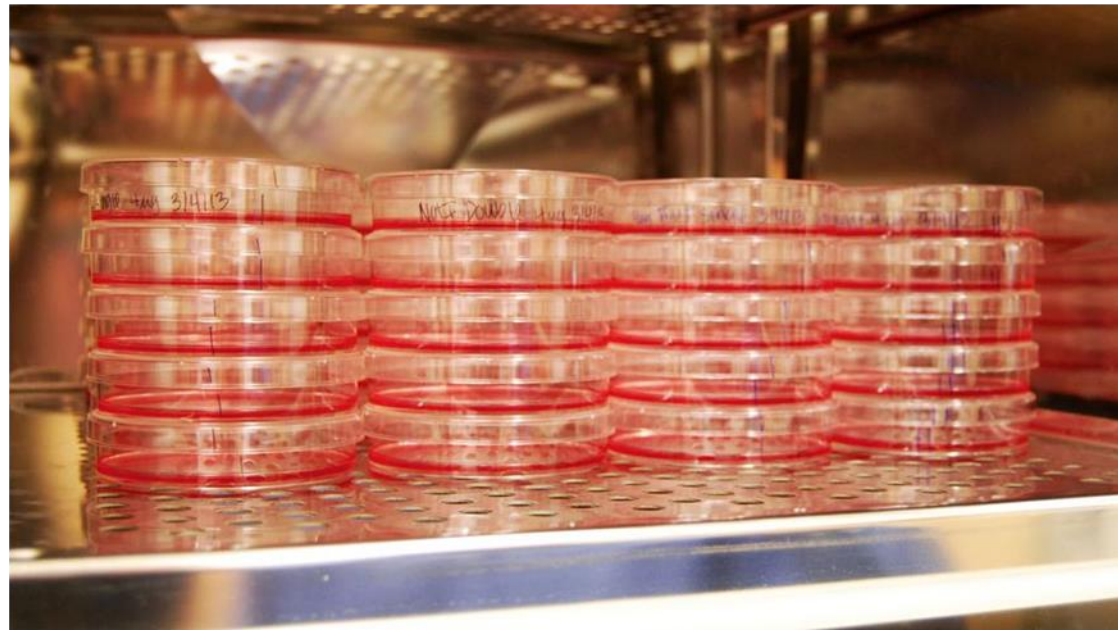
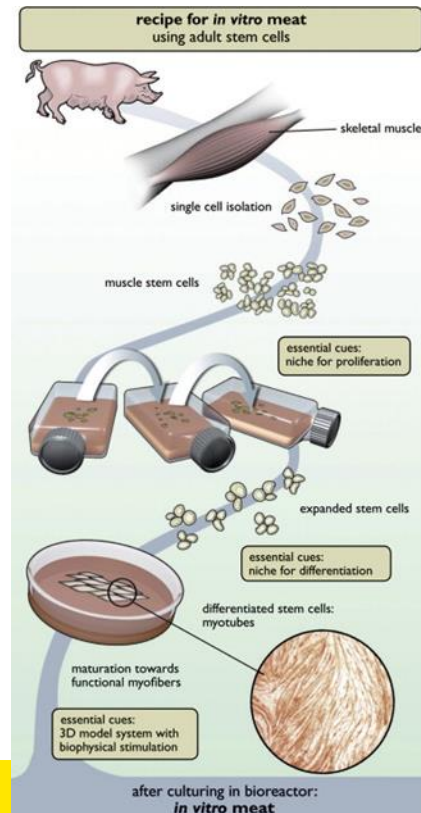
Skin tissue model





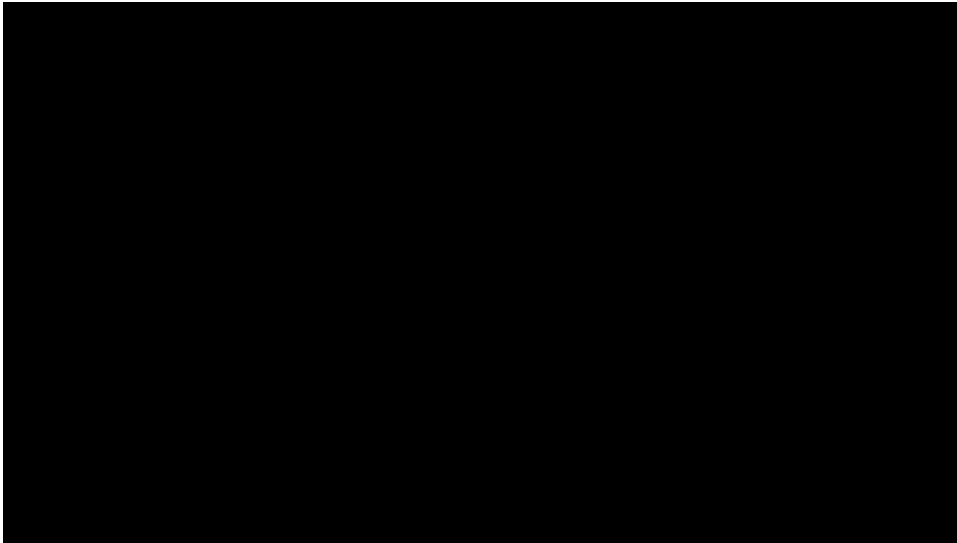
# What else can tissue engineering do?

- Replacement and regeneration of damaged, diseased or missing tissues/organs
- *In vitro* tissue models → imagine a world with no animal testing
- **Artificial meat**



# What else can tissue engineering do?

- Replacement and regeneration of damaged, diseased or missing tissues/organs
- *In vitro* tissue models → imagine a world with no animal testing
- Artificial meat
- **Robotics**



# Questions

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*Thank you!*