An Introduction to 3D Bioprinting
Lesson goals

• Introduce engineering problem ("Bill")
• Define and analyze different types of 3D bioprinters
• Define the basics of tissue engineering
• Identify current applications and limitations of 3D bioprinting
• Start figuring out how to help Bill!
Why do we care about 3D bioprinting?

Watch this video
Bill’s Injuries

- Missing skin on the left arm
- Severely broken femoral shaft
- Ripped rectus femoral muscle
We need your help!

I WANT YOU
TO LEARN ABOUT 3D BIOPRINTING!
What is 3D bioprinting?
We need to learn about the different types of bioprinters!

- **Inkjet Bioprinting**
- **Laser Bioprinting**
- **Extrusion Bioprinting**

Will be used in the activity
Types of bioprinters: **Inkjet**

- **Analogy:** inkjet printer

- **Limitations**
  - Low viscosity
  - Bio-ink must solidify
  - Cell densities

- **Best application** = quickly creating skin grafts
Types of bioprinters: *Inkjet*

*Watch this video*
Types of bioprinters: Laser Assisted

- Analogy: placing polka dots on a dress to create a pattern

- Limitations
  - Low printing speed
  - Cannot print multiple layers easily
  - Wasteful

- Best application = placing cells precisely into solid structures
Types of bioprinters: Laser Assisted

Watch this video
Types of bioprinters: **Extrusion**

- Analogy: squeezing ketchup out of a bottle
- Limitations
  - Lower cellular viability
  - Low resolution
  - Slow print speed
- Best application = creating large 3D structures
Types of bioprinters: Extrusion

Watch this video
Parts of an extrusion bioprinter

- Reservoir 1
- Reservoir 2
- Printing stage
- + Control system
Types of bioprinters: Summary

- **Inkjet Bioprinting**
- **Laser Bioprinting**
- **Extrusion Bioprinting**
Basics of tissue engineering design: 5 Steps

1. Identify function being replaced
2. Determine cell types
3. Determine biomaterial types
4. Determine construction method
5. Construction!
Determine cell types

- Choose cell type for its **function**!

- Constraints:
  - Strength of cells
  - Rejection and immune responses
Determine biomaterial types

- Natural biomaterials:
  - Collagen
  - Elastin

- Synthetic biomaterials:
  - “Polys”
Cell survival during printing

- **oxygen**
- **nutrients**
- **temperature**
Applications of 3D bioprinting

- **Current**
  - Tissue mimics for drug testing and screening
  - Non-transplantable tissues and vessels

- **Near future (~15 years)**
  - Transplantable tissues

- **Far future (~20+ years)**
  - Organs

Images:
- Image 15: Aortic heart valve
- Image 16: Blood vessels
- Image 17: Cartilage
- Image 18: Skin
- Image 19: Kidney
- Image 20: Heart
- Image 21: Kidney
Applications

Watch this video
Limitations

- Vascularization
- Immune rejection
- Biocompatibility
Lesson Goals: Summary

• Introduce engineering problem ("Bill")
• Define and analyze different types of 3D bioprinters
• Define the basics of tissue engineering
• Identify current applications and limitations of 3D bioprinting
• Start figuring out how to help Bill!
Activity Instructions

1. Review your assignments (~5 min)
2. Learn to use your mock bioprinter (~2 min)
3. Engineering sketch of your plan > *get approval* (~10 min)
4. Get biomaterials and print! (~20 min)
5. Present your design and limitations (~2 min for each group)
Mock 3D Bioprinter Instructions for Use

Show this video
Engineering Sketch

- Diagram with labels
- Measurements and scale
- Axes, for reference
Bill’s Injuries

- Missing skin on the left arm
- Severely broken femoral shaft
- Ripped rectus femoral muscle

Images:
1. Diagram of body
2. Photograph of person laying on ground
3. Diagram of femur bone
Image 1: Skin anatomy diagram | File name: skin1.jpg
Source/Rights: 2013 Anatomy Box, Creative Commons Attribution Share License http://www.anatomybox.com/chapters/skin/
Caption: An example of a skin tissue. Bill has injured skin.

Image 2: Muscle anatomy diagram | File name: muscle.jpg
Caption: An example of a muscle. Bill has a ripped femoral muscle.

Image 3: Anatomy of a long bone | Image file name: bone.jpg
Source/Rights: 2016 Carl Fredrick, Wikimedia Commons CC BY-SA 4.0 https://commons.wikimedia.org/wiki/File:603_Anatomy_of_a_Long_Bone.jpg
Caption: An example of a bone and underlying tissue. Bill has a broken femoral shaft.

Image 4: Uncle Sam saying “I want you to learn about 3D bioprinting.” | Image file name: unclesam.jpg
Caption: Some U.S. scientific research funding is going towards 3D bioprinting research.

Image 5: A photograph shows a 3D bioprinter with 4 extrusion heads | Image file name: regenhu.jpg

Image 6: A photograph shows a 3D bioprinted tissue being taken out of growing media. | Image file name: tissue.jpg
Source/Rights: 2016 Anderson, Ojada, Nguyen. Governor’s School of Architecture. All rights reserved. Used with permission. https://govschoolagriculture.com/tag/3d-bioprinting/
Caption: A 3D bioprinted tissue that is kept in media to allow cells to grow.

Image 7: A photograph shows 3D bioprinted structure in the shape of an ear. | Image file name: ear.jpg
Caption: 3D bioprinters can build structures that are in the shape of an ear.

Image 8: Diagram shows a model of an inkjet bioprinter. | Image file name: inkjet.jpg
Caption: Inkjet bioprinters disperse cells over a surface covering much area quickly.
A diagram of a laser-assisted 3D bioprinter. | Image file name: laser.jpg


Caption: A laser-assisted bioprinter uses lasers to force cells onto specific locations of the printing surface.

A diagram of an extrusion 3D bioprinter. | Image file name: extrusion.jpg


Caption: Extrusion bioprinters extrude cells within a filament. The filament/cell mixture forms the structure we see.

A photograph of a 3D bioprinter with 2 extrusion heads printing onto a cell culture plate called a 96-well plate. | Image file name: organovo.jpg


Caption: Extrusion 3D bioprinters have multiple heads to print from. They can also print on different surface. A computer system controls the rate of extrusion, the location, and which material is extruded.

A graphic of a cell having oxygen delivered to it. | Image file name: oxygen.jpg

Source/Rights: 2017 Nick Asby (author), UVA Department of Biomedical Engineering. Caption: Cells need proper oxygen concentrations to survive.

A picture of bottle of cell media | Image file name: media.jpg


Caption: Cells are kept in cell media while they grow. Media provides nutrients, proper pH, water, and other compounds need to make cells grow.

A graphic of a thermometer | Image file name: temperature.jpg

Source/Rights: 2004 Microsoft Corporation, One Microsoft Way, Redmond, WA 98052-6399 USA. All rights reserved

Caption: Cells need to be kept at proper temperatures to replicate and survive.

A picture of 3D bioprinter printing into a cell culture container. The one in this picture is called a 96-well plate. | Image file name: drugTest.jpg


Caption: 3D bioprinters are utilized by companies and researchers to create testing tissue for pharmaceutical research.

A still image taken from an animation/video of beating bioprinted aortic valve. | Image file name: valve.gif


Caption: Researchers use 3D bioprinters to create valves. These are used for research purposes and cannot be placed in humans yet. Original caption: This is still image pulled from a video clip of a living, beating pig heart—aortic valve—that was bioprinted in a lab. The heart was arrested, connected to the perfusion system and restarted. The working fluid was oxygenated balanced saline solution.
Scientists have methods of creating blood vessels with 3D bioprinting methods.

Scientists can bioprint cartilage in the shape of an ear for research purposes. However, it is not safe to use these ears on humans.

Scientists can print human skin for drug testing purposes. The skin does not have the exact structure of human skin, but it is a close replicate.

Scientists are working towards bioprinting hearts.

Incorporating blood vessel structure into tissues and organs requires complicated computer algorithms.

Scientists are working to reduce of immune rejection when implanting a bioprinted tissue or organ into the body.

Biocompatible bioprinted organs have the functionality, longevity, and mechanical properties that the original organ possessed.

Engineering sketches include measurements, scales, dimensions and multiple views of the same design at different angles.