Think, Design, and Build: a Perfect Bone Filler

Texas A&M Chapter

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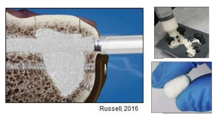
Statement of Purpose

Think: Why do we need a bone filler?

Bone defects are caused by trauma, congenital conditions, surgical resection

Bone fillers currently include several polymeric materials with different advantages

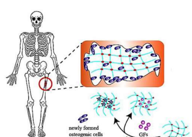


Introduction Lectures

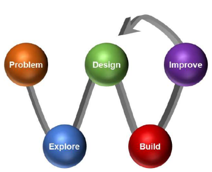
Design: What are important properties for a bone filler?

Integration

Structural Support



Cell Encapsulation



Engineering Design Process

Learning Objectives:

- Understand how bone defects are normally treated
- Explain the important design criteria for bone fillers
- Apply the design process
- Evaluate the pros & cons for given bone fillers
- Remember the safety rules

Materials and Budget

Build: How do we build a model to evaluate bone filler?

"Bone defects"

Straws

Encapsulated "cells/drugs"

Sprinkles

Simple model "*bone fillers*"

Marshmallows (pre-formed bone fillers)

Slime (hydrogel bone fillers)

Hot glue (*in situ* curing bone fillers)

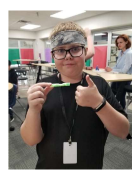
Straw	Marshmallows	Slime	Hot glue	Sprinkles	Mini-Cup	Pop. stick	Total
$1	$1	PVA: $1 BORAX: $5	$5	$2	$4	$3	$22

- All materials can be found at local grocery stores (Walmart) or online (Amazon)
- For one class of ~25 students, the approximate cost is $22
- Materials can last for ~3 classes and can be used for other outreach events

Activities and Discussions

Activity 1: Fill Test for Integration

1. Students break into groups of 3
2. Each team member chooses one material and fills a "fracture"
3. Students rate each material's ability to fill and discuss results with their peers



Fill Test Score Rules	
1	Easy to fill
2	Complicated at first, but I got it
3	I need an adult

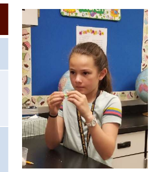
Material	Student Discussions
Slime	Easy to fill, but a bit sticky to work with and "oozed" more than expected
Hot Glue	Harder to fill than expected, glue settled & was too hot to be safe for the body. One student noted this technique would be better to use layer by layer.
Marshmallow	Easier to fill than expected. Many students used several marshmallows and noted that the marshmallow may only work well in certain sized defects.

Activities and Discussions

Activity 2: Snap Test for Structural Support

1. Students attempt to break their filled straw from the previous activity at the defect site
2. Students rate each material's strength and discuss results with their peers

Snap Test Rules	
1	Easy to break
2	Needed some elbow grease
3	Need superman like strength



Material	Student Discussions
Slime	Too weak- most students agreed it was the weakest.
Hot Glue	Definitely the most rigid. Some students went beyond trying to "snap" their fracture to test the strength of the glue (ie. stomping or scissors)
Marshmallow	Weak, but slightly better than the slime.

Activity 3: Encapsulation Test

1. Students fill a new defect with their material and add as many sprinkles as possible
2. They then flip their straw and count the sprinkles still in the defect
3. Students share their results and discuss with peers

Material	Student Discussions
Slime	Definitely the best at encapsulation. Students noted that sprinkles flowing in the slime could be advantageous.
Hot Glue	Better than expected. Optical clarity made counting sprinkles easy. Layer by layer technique worked well.
Marshmallow	Definitely the worst at encapsulation- students agreed.

Feedback

Pros

- Activities were appropriate difficulty for the middle school level.
- Activities were able to lead students thinking independently and learning without noticing.

Cons

- Activities involved food. Safety was mentioned but still hard to keep all students from eating supplies.

Society For Biomaterials

BIOMEDICAL ENGINEERING TEXAS A&M UNIVERSITY

Think, Design, Build: The Perfect Bone Filler

SFB Education Challenge
March 18, 2019

What is SFB Education Challenge?

- Competition to design an educational activity over biomaterials concepts

Goals: improve widespread understanding of biomaterials-related science and careers in the middle school students

Background

- In 2005 there were over 2.1 million fractures in the United States
- Expected to increase to 3 million fractures by 2025
  - Due to our aging population

Causes of Bone Defects:

- Traumatic Incidents (Vehicle Accidents, Falls, Sporting Injuries)
- Osteoporosis
- Bone Cancers
- Birth defects (ex. Cleft palate)

Background

What is a fracture?

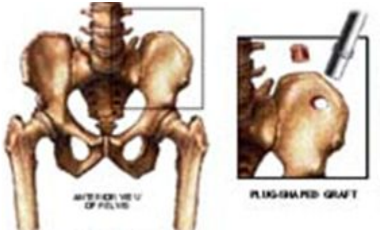
The cracking or breaking of a bone

Types of Fractures:

- Stable (Simple) Fracture: Bones that are broken are barely out of place
- Compound Fracture: Bone may pierce skin
- Transverse Fracture: Horizontal Fracture Line
- Oblique Fracture: Angled Fracture Pattern
- Comminuted Fracture: Bone shatters into multiple pieces
- Non-Union Fracture: Fracture that does not heal

How do we usually heal bones?

Autografts



Pros: -Body recognizes tissue as its own
-No negative host response

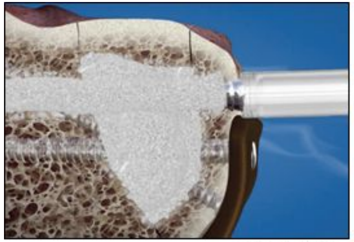
Cons: -Difficult to fit grafts into defects
-Requires 2nd surgery

Metal implants

Pros: -Mechanically robust

Cons: -Host response

Ceramic Injectables

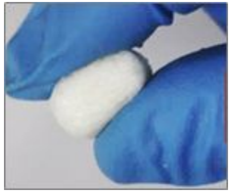


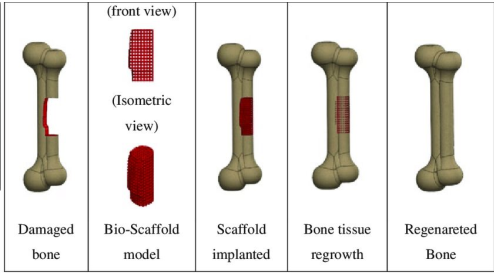
Russell, 2016

Pros: -Integrates well with bone
-Similar to bone makeup

Cons: -Can be too brittle
-*In situ* curing can release heat & damage cells

Polymer Tissue Scaffolds





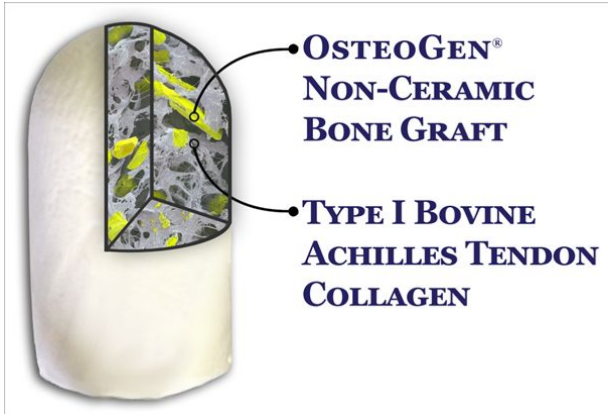
Pros: -Own bone heals as scaffold degrades
-Polymers have tunable properties

Cons: -Mechanically weak

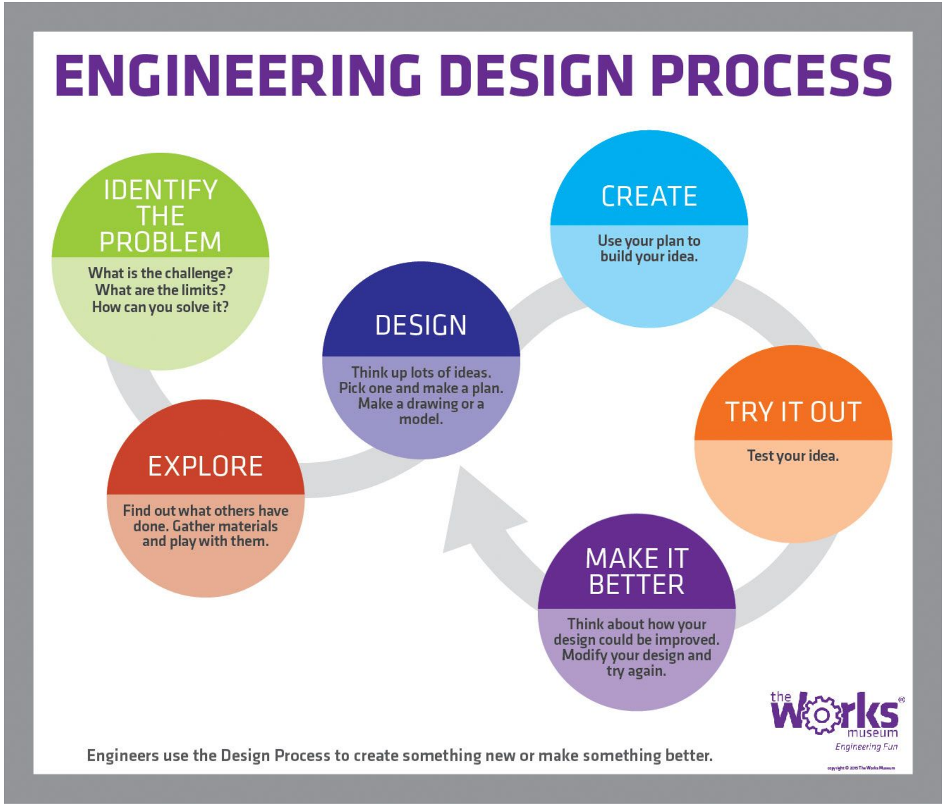
Different Bone Fillers on the Market

Pros and Cons

- PALACOS® from Haraeus Medical
    - Colored green which contrasts with bone
    - Can be formulated with antibiotics
    - High viscosity makes it difficult to work with
- OsteoGen® Plug from Impladent Ltd
    - Does not require mixing of materials
    - Can be difficult to shape
- Surgical Simplex® Radiopaque Bone Cement from Stryker
    - Easily Detectable in X-Ray images
    - Different handling can lead to uncontrollable properties



Quick Review of the Engineering Design Process



Our Problem: A Defect in the Bone

What do we need from a scaffold to make sure that the defect site is completely healed?

- Structural support (rigid)

Integration between implant & bone, includes:

- Contact between scaffold and surrounding bone (good fit)
- Bone cells grow into scaffold to rebuild tissue

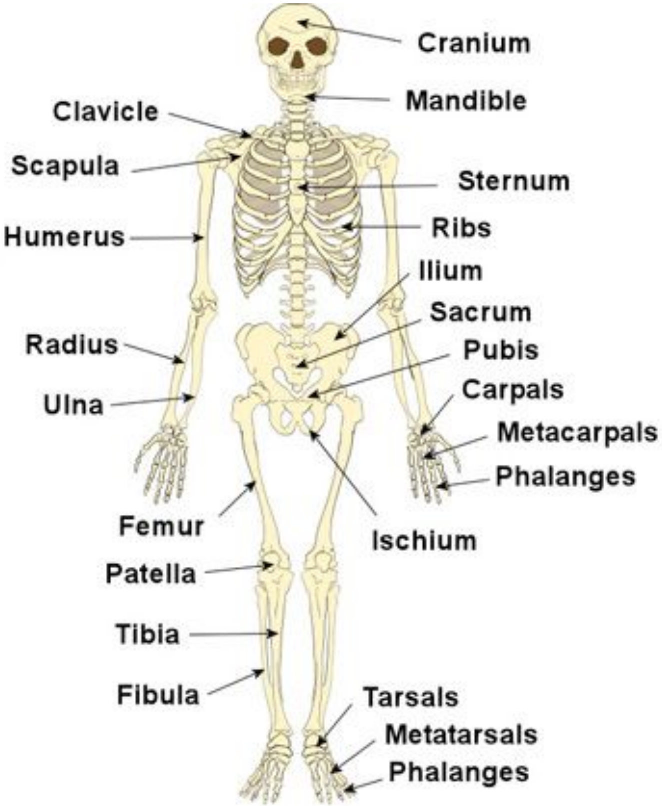
Why do our Bones need to be Rigid?

Rigid: Unable to bend or be forced out of shape; not flexible.

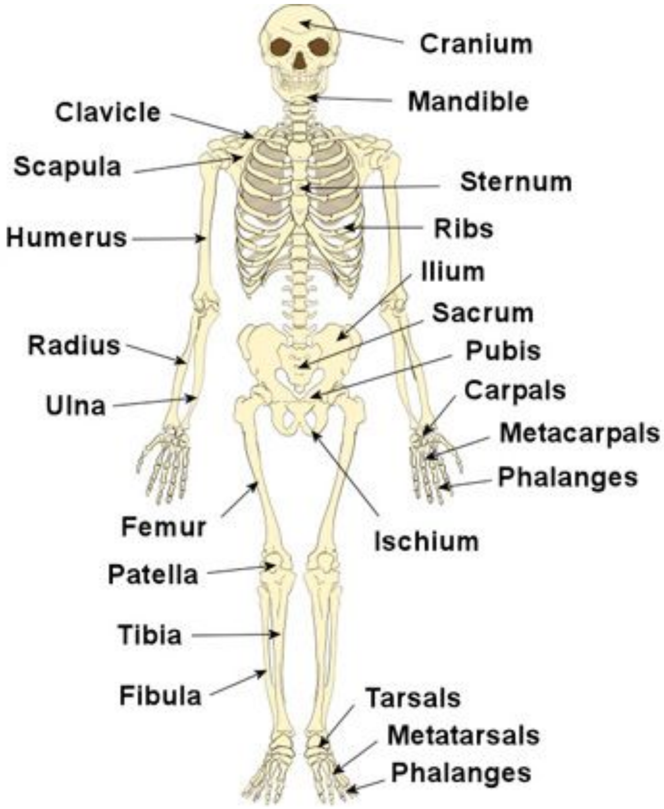
Bones need to be rigid to:

- Hold up our body weight
- Carry and hold objects
- Protect vital organs

As children, we start out with a lot of cartilage which is then replaced by bone as we become adults!



Which Bones Do You Think Need To Be The Most Rigid?

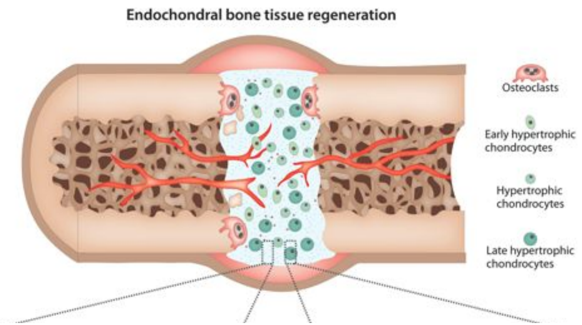


How do the forces on the bone differ between the **cranium** and the **femur**?

Why Do Scaffolds Need to Have Good Contact to Bones?

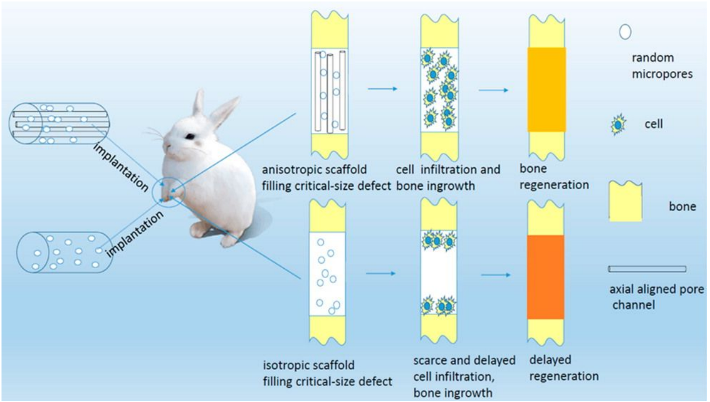
What heals bones?

- Bone cells!
    - Move into defects & lays down new bone!



What happens if scaffolds do not have contact with bones?

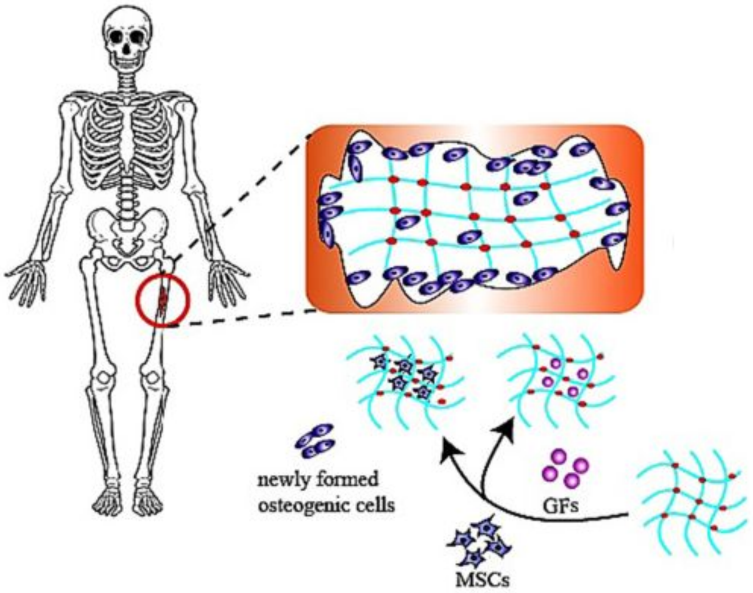
- No bone cells go into scaffolds
    - Delayed healing
- Scaffold may slip out of defect



How Do We Help Bone Growth?

What could you add in with the scaffold?

- Cells
  - Add in helpers to local bone cells
  - **Osteoblasts** build bone
- Growth factors
  - Proteins that cells release that tell each other to grow
  - Can add cells to make growth factors, or add growth factors alone



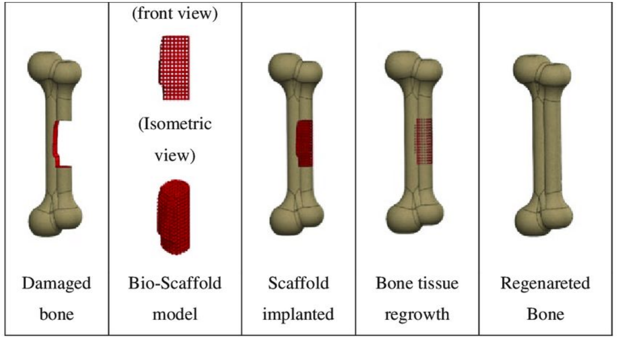
Video of Bone Growth

Other Properties to Think About

Degradation: The condition or process of being broken down

Why would we want bone scaffold to degrade?

- Allow natural healing of the bone
- Release Cells
- Release Growth Factors



Non-degrading bone filler can inhibit healing, which may not be a good option for younger patients who still have the ability to regenerate bone

Our Activity!

- We will be testing out 3 bone fillers
- Our tests will be:
  - Fill Test
  - Snap Test
  - Encapsulation Test
- During our activity we will be:
  - Answering the questions in our packet
  - Following the instructions on the board and in our packet
  - Collaborating with our group to find the best bone cement

Everyone get into groups of 3

Please wait for all of your materials!

Our Bone Model & Material Selection

Smoothie Straws

1. Marshmallow

2. Hot Glue

3. Slime

IMPORTANT LAB SAFETY!

-NO eating any lab supplies
-Handle hot materials with caution & instructor supervision
-Wash hands after handling chemicals

Test 1- Fill Test

- Each group member will choose 1 of the materials
- The materials are:
  - Slime
  - Hot Glue
  - Marshmallows
- Each group member will attempt to place their material in a fracture (a cut open straw)
- You will rate how easy or hard it was to place the material in the fracture site
- **REMEMBER TO ANSWER THE QUESTIONS IN YOUR PACKET**

Fill Test Scoring Scale	
1	Easy to Fill
2	Complicated at first, but I got it
3	I need an adult

Test 2- Snap Test

- Using the straw that you filled with your material, try to break the straw at the fracture site (where the straw was cut)
- Rate how easy or hard it was the break the straw
- **REMEMBER TO ANSWER THE QUESTIONS IN YOUR PACKET**

Snap Test Scoring Scale	
1	Easy to Break
2	Needed some elbow grease
3	Need Superman like strength

Test 3-Encapsulation Test

- Each group member will fill another fracture (straw)
- You can keep the material you have or choose a different one
- As you fill the straw you will pour cells (sprinkles) over the fracture
- After you have filled the straw and added your sprinkles flip the straw so that the fracture side is facing the table
  - Some sprinkles may fall out!
- Count the sprinkles that are still in the fracture site
  - To the best of your ability
- **REMEMBER TO ANSWER THE QUESTIONS IN YOUR PACKET**

What is Biocompatibility?

The ability of a material or medical device to perform with an appropriate response from the body in a specific application

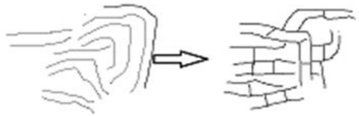
What this means can vary depending on the device and how it is supposed to interact with the body.

For a tissue engineering scaffold, the material must be a placeholder for tissue and help new, functional tissue grow back.

- What functions does bone tissue have that a polymer material can do?
- How does functional tissue grow back in that space?
- What are problems that could occur when cells and tissue start to grow?

*** How do we make a polymer scaffold?

1. Choosing and synthesizing the polymer we need
    a. Chemistry influences hardness, how the cells of the body respond
2. Shaping the polymer into a scaffold
    a. In the lab: create a shape
    b. Put the scaffold into the place it needs to go in the body (*in situ*)
3. Cure the polymer scaffold
    a. 'Sets' the polymer by crosslinking it together
    b. Can be crosslinked over time, with heat, with light, with changes in pH



In situ (in body):
Does the time it takes for the polymer to cure matter? Why?

In the lab:
Does the time it takes for the polymer to cure matter? Why?

Summary of Material Properties

	Hot Glue	**Marshmallow**	**Slime**
Rigidity	Very rigid	Moderately rigid	Not rigid
Biocompatibility	High cell encapsulation (only when the glue is hot)	Low cell encapsulation	High cell encapsulation
Filling	High contact with scaffold	Low contact with scaffold	High contact with scaffold

Reflection

- Which material was the best bone cement?
- Would one material work in a better situation over another?
- What did you like/or not like about the activity? The presentation?

Name: ____________________

Date: ______________________

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Pre-Lab Questions (Answer During the Presentation):

What are three causes of bone defects?

_________________ _____________________ _______________

Bone Treatment (pick one example)	Advantage	Disadvantage

Name one step of the Engineering Design Process

Name a bone that needs to be rigid in order to hold up a person's body weight.

Why do bone scaffolds need to have good contact to bones?

What could you encapsulate in bone scaffold?

Test 1: Fill Test

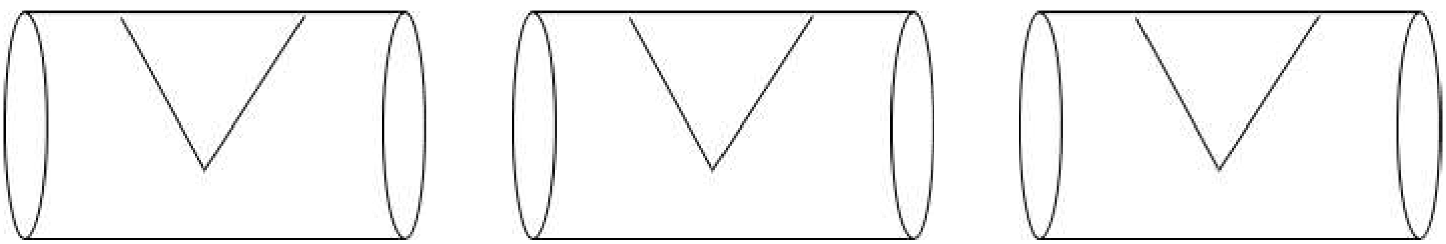
1. *Hypothesize:* *which material will fill the defect best:* ____________

Instructions:

1. Wait for the materials!
2. Teams of 3
   a. Each team member will choose 1 material
3. Fill your fracture.
4. Rate your material.

Draw:

1. Draw how each material fills the fracture site



Slime **Hot Glue** **Marshmallow**

Questions:

1. Which material(s) was the easiest to fill inside the fracture?

2. Would you expect your answer to change if the shape of the defect changed? If yes, how so?

Scoring:

1. **Circle** the score that shows how easy or hard it was to fill each straw with the different bone scaffolds

a. **Remember to talk to your teammates to get their scores**!

Fill Test Score Rule	
1	**Easy to Fill**
2	**Complicated at First, but I got it**
3	**I need an adult**

Name of Material	Filling score
Slime	
Hot Glue	
Marshmallow	

Activity Two: Which Bone scaffold Material Does Not Snap Under Pressure?

Hypothesis (Circle What You Think Will not Snap):

If I add (slime/hot glue/marshmallows) to the fracture site, it will not snap under pressure.

Instructions:

1. Using the straw that you filled with one of the 3 materials, try to break the straw at the defect site
2. **Circle** the score that shows how easy or hard it was to break the defect

Questions:

1. Which material was the hardest to snap?

2. Why would you ***NOT*** want your defect site to snap?

3. What are some other methods to prevent a defect from snapping outside of having the bone scaffold being rigid?

Scoring:

2. **Circle** the score that shows how easy or hard it was to snap each straw with the different bone scaffolds
    a. **Remember to talk to your teammates to get their scores!**

Snap Test Score Rule	
1	**Easy to Break**
2	**Needed some Elbow Grease**
3	**Need Superman like Strength**

Name of Material	**Snapping score**
Slime	
Hot Glue	
Marshmallow	

Activity Three: Which Bone Filler Is the Best at Encapsulating Cells?

Hypothesis (Circle What You Think Will Encapsulate the Cells the Best):

If I add (slime/hot glue/marshmallows) to the fracture site, it will encapsulate the most cells

Instructions:

1. Wait for the materials to be passed out
2. Pick one of the materials to fill your fracture site (straw with)
   a. **Each Team Member Needs to Pick a Different One**
3. Fill your fracture with your material
4. As you fill your fracture add your cells (sprinkles) to the fracture site
5. Once you've filled your fracture and add your sprinkles, flip your straw so that the fracture site is facing the table
   a. Some of the sprinkles will fall out!
6. **Count** how many sprinkles are left in the fracture site

Counts:

1. Fill in the number of sprinkles that were left in each fracture site
   a. **Remember to talk to your teammates to get their scores!**

Number of Sprinkles Left After Flip	
Name of Material	**Number of Sprinkles Left**
Slime	
Hot Glue	
Marshmallow	

Post-Lab Questions (Answer These After Activity Three):

1. From Activity Three, what material had the most sprinkles encapsulated?

2. Why would you want to encapsulate cells inside bone scaffold?

3. Was there one material that was the best at all 3 of the activities? If no, why do you think that is?

4. What are some other features, that we talked about, that you should take into account when designing a bone scaffold?

5. What did you think about the activity? Is there anywhere we could improve?

Name: ____________________

Date: _____________________

Think, Design, Build: The Perfect Bone Filler
ANSWER SHEET

Pre-Lab Questions (Answer During the Presentation):

What are three causes of bone defects?

Traumatic Incidents, Osteoporosis, Bone Cancers, or Birth Defects

Bone Treatment (pick one example)	Advantage	Disadvantage
Autografts	-Body recognizes tissue as its own -No negative host response	-Difficult to fit grafts into defects -Requires 2nd surgery
Metal Implants	-Mechanically robust	-Host response
Ceramic Injectables	-Integrates well with bone -Similar to bone makeup	-Can be too brittle -In situ curing can release heat & damage cells
Polymer Tissue Scaffolds	-Own bone heals as scaffold degrades -Polymers have tunable properties	-Mechanically weak

Name one step of the Engineering Design Process
Identify the problem, Explore, Design, Create, Try it out, Make it Better

Name a bone that needs to be rigid in order to hold up a person's body weight.

Femur, Tibia, Fibula (any bones within the legs)

Why do bone scaffolds need to have good contact to bones?

Allows bone cells to move into defects and lays down new bone

What could you encapsulate in bone scaffold?

Cells, Growth Factors

Test 1: Fill Test

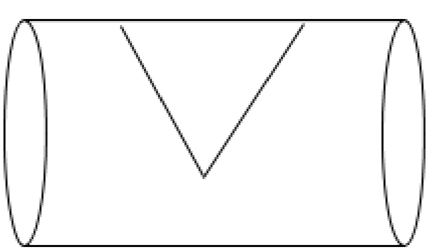
1. *Hypothesize: which material will fill the defect best:* slime or hot glue

Instructions:

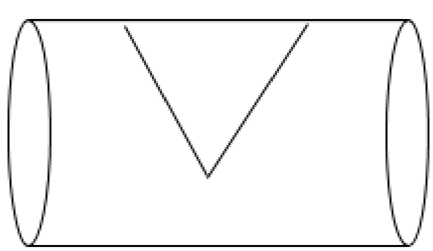
1. Wait for the materials!
2. Teams of 3
    a. Each team member will choose 1 material
3. Fill your fracture.
4. Rate your material.

Draw:

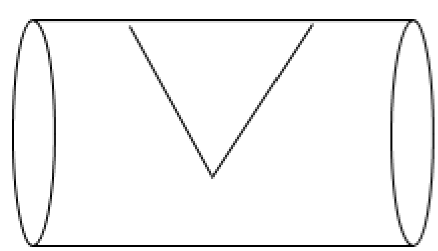
1. Draw how each material fills the fracture site



Slime



Hot Glue



Marshmallow

Questions

1. Which material(s) was the easiest to fill inside the fracture?
   Slime, Hot Glue

2. Would you expect your answer to change if the shape of the defect changed? If yes, how so?
   Yes, defects can be of different sizes and shapes, which can make fitting a bone growth promoting material into the defect easier or harder

Scoring:

1. **Circle** the score that shows how easy or hard it was to fill each straw with the different bone scaffolds
   a. **Remember to talk to your teammates to get their scores**!

Fill Test Score Rule	
1	**Easy to Fill**
2	**Complicated at First, but I got it**
3	**I need an adult**

Name of Material	Filling score
Slime	
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Hypothesis (Circle What You Think Will not Snap):

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Instructions:

1. Using the straw that you filled with one of the 3 materials, try to break the straw at the defect site
2. **Circle** the score that shows how easy or hard it was to break the defect

Questions:

1. Which material was the hardest to snap?
   Hot Glue
2. Why would you ***NOT*** want your defect site to snap?
   Would result in secondary injury followed by a secondary surgery/treatment
3. What are some other methods to prevent a defect from snapping outside of having the bone scaffold being rigid?
   Cast, Bone Plates

Scoring:

2. **Circle** the score that shows how easy or hard it was to snap each straw with the different bone scaffolds
   a. **Remember to talk to your teammates to get their scores!**

Snap Test Score Rule	
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Number of Sprinkles Left After Flip	
Name of Material	**Number of Sprinkles Left**
Slime	
Hot Glue	
Marshmallow	

Post-Lab Questions (Answer These After Activity Three):

1. From Activity Three, what material had the most sprinkles encapsulated?
   Hot glue

2. Why would you want to encapsulate cells inside bone scaffold?
   Promote bone growth

3. Was there one material that was the best at all 3 of the activities? If no, why do you think that is?
   No, each material has its pros and cons. It’s up to doctors to decide what material is going to be best for a patient’s needs.

4. What are some other features, that we talked about, that you should take into account when designing a bone scaffold?
   Degradation

5. What did you think about the activity? Is there anywhere we could improve?