BNG-345 Orthopaedic Biomechanics
Exam 1
October 8, 2013

Name: SOLUTION

This exam is closed book, closed notes. There are 5 section/questions, please write your name on each page.

Grade:

#1 _______/ 20

#2 _______/ 15

#3 _______/ 30

#4 _______/ 20

#5 _______/ 15

Final Grade __________/ 100
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1. Complete the crossword puzzle using the clues. Each answer is worth 2 pt. **Total 20 pts**

**Across**
3. a folding movement where the anterior angle between the two bones is decreased (flexion)
5. Middle region of the long bone (diaphysis)
8. Tissue that connects bone to bone (ligament)
10. A material whose material properties depend on the direction of loading (anisotropic)

**Down**
1. Dense bone (cortical)
2. Plane that divides the body left-right (sagittal)
4. Joint that allows essentially no relative motion (synarthrosis)
6. Bone cell that resorbs bone (osteoclast)
7. In front or before (anterior)
9. Nearest the bottom of the body (distal)
2. **Identify the cell types and describe** their function and the process indicated by the drawing below. **15 pts**

![Diagram of bone cells and processes]

A: Osteocyte: reside in lacunae and connect to other osteocytes with the canaliculi system. Are believed to **sense the strain or other mechanical stimuli** on bone and **translate to a chemical signal for osteoclasts and osteoblasts**.

B: Osteoclast: giant multinucleated cell that **attaches to exposed bone surface and secretes acids to dissolve bone**.

C: Osteoblast: Differentiate from mesenchymal stem cells and **secret osteoid** to re-establish bone matrix.

D: Bone Lining Cell: dormant osteoblast that extend projections to osteocytes. **Sense load** similar to osteocytes.

- First there is activation of the **osteoclasts** which have hematopoietic origins
- The osteoclasts have **ruffled cell membranes** that attached to the bone surface forming a tight seal and **secrete acids to dissolve the bone**
- **Osteoblasts** differentiate from mesenchymal stem cells. They are cuboidal in shape.
- They **secrete osteoid** which is the collagenous matrix that gets mineralized
- Some osteoblasts **get trapped in the osteoid and become osteocytes** where they reside in lacunae that are connected by canaliculi to other osteocytes
3. Analyze the following images.

(a) Label the types of bone indicated in the femur. 4 pts

(b) Name the structures that the letters A, B, C, D, E, and F, are pointing to. 12 pts

A: Trabecular bone, B: Trabecula or strut, C: Osteon, D: Osteocyte, E: Haversian Canal, F: Volkmann’s canal.
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(c) **Identify and describe** the process that generated the injury depicted in these images. 10 pts

These images show **stress fractures**. These are the result of **fatigue which is moderate levels of stress at high cycles**. These types of fractures develop when there is **not sufficient time between the cycles to allow the body time to repair the damage** incurred during the loading.

(d) What does this graph tell you about the mechanical properties of cortical bone as we age? 4 pts

As we age, our cortical bone is **stiffer** meaning that it **cannot deform as much under loading**. In other words, our bone becomes more **brittle as we age** and less resistance to deformations or less **elastic**.
4. The crash test dummy is sitting such that the HAT are at a 90 degree angle with the thighs. The dummy has a lap belt restraining so that the HAT is free to move forward. In a front crash test, the HAT have an angular acceleration of 20 rad/sec\(^2\). The dummy has an overall \(h = 1.4\) m (a 10 year old child) and \(m = 30\) kg. What is the moment generated at the hip?

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Segment} & \text{Segment Weight/ Total Body Weight} & \text{Center of Mass/ Segment Length from Proximal} & \text{Radius of Gyration/ Segment Length at Center of Gravity} \\
\hline
\text{HAT} & 0.678 & 0.696 & 0.496 \\
\hline
\end{array}
\]

\[
\alpha = \frac{\Delta \theta}{\Delta t^2} = \frac{20 \text{ rad/sec}^2}{2} = 10 \text{ rad/sec}^2
\]

\[
\sum \tau = l_{cm} \alpha = I_{cm} \alpha = (I_{cm} + mL_{cm}^2) \alpha
\]

\[
T_H = (I_{cm} + mL_{cm}^2) \alpha = (2.167 m^2 kg + 20.34 \text{ kg})(0.20 \text{ m})^2 \frac{20 \text{ rad/sec}^2}{2} = 59.6 Nm
\]
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5. (a) What is the difference between cortical and cancellous (trabecular) bone? 5 pts

Cortical bone is dense with a porosity of less than 30%. The osteons align along the long axis of the bone making the material properties approximately transversely isotropic. Cancellous bone is porous with a porosity of 50-95%. The trabeculae align along the principal direction of stress. The material properties are anisotropic depending on location, orientation, and age of the specimen.

(b) When testing and reporting the mechanical properties of trabecular bone, what information should be included with the results? 5 pts

When testing and reporting mechanical properties, must state the age and site of the sample.

(c) What does this graph tell us about the mechanical behavior of cortical bone? 5 pts

Cortical bone is stronger in compression than in tension. It is also relatively ductile in the longitudinal direction under tension, but brittle in all other loading and direction.