**Attestation: In typing my name below, I attest that I am in complete compliance with the Marquette University Academic Integrity Policy, and have executed (or agree to comply with) the student honor code and pledge. (**[**Click here to review undergrad**](https://bulletin.marquette.edu/undergrad/academicregulations/#academicintegrity)[**Click here to review grad school**](https://bulletin.marquette.edu/grad/policiesofthegraduateschool/) **policies, if necessary).   
I further attest:**

1. **I understand that I can use any course materials, the course textbook, handouts, PowerPoint slides, my own course notes, (all of these can be accessed electronically or online during the exam period) and that this exam is open book and open notes.**
2. **I agree that I will answer all questions in my own words, and that I will not cut/copy and paste from any electronic source into this examination.**
3. **I agree to complete this exam as an individual assignment and to neither accept nor give unauthorized help, per the student honor code/ pledge.**
4. **I will not use any electronic sources outside of course materials or web engines/browsers for my answers.**
5. **I understand that if I fail to return the completed exam by email to** [**Jeffrey.Toth@marquette.edu**](mailto:Jeffrey.Toth@marquette.edu) **by 6 PM CT on Monday, March 30, the examination absence policy in the course syllabus will apply.**
6. **I understand that unsigned examinations will not be graded.**

**Name: \_\_\_\_**

**Exam #2 BIEN 4420/ 5420, MEEN 4570/ 5570, BIMA 6570**

**Monday, March 30, 2020, 3:45 PM to 6PM**

**Instructor: Prof. Dr. J. M. Toth**

**Highlight grad credit or undergrad below. You must highlight grad credit if you are currently taking this class for grad credit OR will be using this course in the future for grad credit (eg BS/MS).**

**Grad credit (must answer question 57) / 122 pts**

## Undergrad (do not answer question 57) / 114 pts

**Instructions are given in the section headings below. Good Luck! I know you will do well!! 😊**

**Section 1: True or False (Please delete the letter T or F leaving the correct answer.)**

1) (2) T F Increased levels of osteolysis in total joint replacements are correlated with tribology variables, including: small particle size, irregular morphology, and critical particle volume thresholds.

2) (1) T F An *in vivo* epicutaneous testfor immunological responses to materials is more sensitive than an *in vitro* LIF test.

3) (1) T F Screw pullout strength in bone is largely controlled by variables of screw design, including thread, rake, and pitch.

4) (2) T F Hemolysis – destruction of erythrocytes and leukocytes - activates the coagulation cascade by the intrinsic pathway. Altered flow in a medical device and biomaterial surfaces can cause hemolysis.

5) (2) T F Adherent thrombi can decrease patency of a coronary artery stent. Hyperplasia is the excessive growth of reactive tissue which can lead to increased occlusion of a vascular graft.

6) (1) T F A complete carcinogen produces neoplastic transformation by itself. A biochemical reaction within the body can convert a procarcinogen into a carcinogen.

7) (1) T F PMMA (bone cement) provides good short-term fixation. However, it can cause thermal necrosis in bone and can undergo creep. Creep can cause subsequent failure of long-term fixation.

8) (2) T F Some vascular grafts are rough and porous, and are pre-clotted in the patient’s blood prior to implantation. Remodeling of the clot produces a pseudo-intima, similar to the vessel except for the lack of smooth muscle, which makes the vessel segment unable to contract or dilate.

9) (1) T F Press-fit devices might have screws or spikes to provide initial stability. Wolff’s law says that long-term stability requires bone ingrowth on more than 50% of the surface of the device.

10) (2) T F When the rough external surface of a biomaterial comes in contact with blood tissue, the intrinsic (and not extrinsic) pathway of the coagulation cascade may be triggered.

11) (2) T F Nickel has an incidence of antigenicity somewhere between 10% to 20% of the population. The broad statement that Nickel is biocompatible ignores this host-specific response to Nickel.

12) (2) T F In bone, stress shielding can occur due to a mismatch between the elastic modulus of the implant and the elastic modulus of bone. Burstein et al. showed a 70% decrease in torsional energy absorbed by bone after rigid plate removal due to stress shielding.

13) (2) T F The ideal electrochemical series (IES) is performed in water whereas the practical electrochemical series (PES) is performed in seawater. Due to the presence of chloride ion, the PES may better estimate metallic corrosion in the physiologic environment as opposed to the IES.

14) (1) T F Both fretting corrosion and crevice corrosion can occur between the head of the screw and the plate in fracture fixation devices. This might serve as a site for initiation of fatigue failure.

15) (2) T F The total amount of metal ions released from a hip prosthesis is insignificant compared to the normal composition of the body. [1 X 10-6] M of metal ions equates to approximately 50 ppb.

16) (2) T F An ASTM F136 alloy would be in the corrosion region if it had an oxide layer and the Ti ions present were 6 x 10-7 M, the Al ions present were 4 x 10-5 M, and the V ions present were 8 x 10-7 M.

17) (2) T F Aseptic osteolysis has been reported as high as more than 75% of TJA of all implant failures and is the central factor limiting the longevity of current total joint arthroplasties.

18) (1) T F Mechanical motion leading to disruption of local vascular supply surrounding a device that relies on osseointegration for fixation may cause premature device failure.

19) (1) T F Compared to noble metals such as gold and platinum, more reactive base metals such as magnesium and titanium are more likely to be hemocompatible.

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**Section 2: Multiple Choice (Please use the blue highlighter to highlight the best answer.)**

20) The figure at right shows a cross-section through the tip of a self-tapping bone screw.  
Which best describes the screw?

a) Crest > thread d) Small pitch

(2) b) Lawn rake e) Neutral rake

c) Negative rake f) Positive rake

21) For internal fracture fixation in long bones, devices designed to withstand **bending forces** and **torsional forces**, respectively are:

a) Harrington rod, Bone plate with screws

(1) b) Unlocked Intramedullary nail, Bone plate with screws

c) Bone plate with screws, Unlocked Intramedullary nail

d) Kirschner wires, Steinman pins

e) Bone plate with screws, Locked Intramedullary nail

22) Which of the following correlates best with carcinogenicity? That is, if a material is \_\_\_\_\_\_\_\_\_\_, it may be carcinogenic. (Basis for the Ames Test).

a) Pathogenic d) Toxic

(1) b) Immunogenic e) Corrosive

c) Mutagenic f) Allergenic

23) Which of the following are most likely to be present in patients’ tissues adjacent to knee implants made of cobalt-chromium-molybdenum based alloys - ASTM F75?

a) Macrophages d) Foreign body giant cells g) All of these (a-f)

(1) b) Lymphocytes e) Wear debris h) only a), b), d), and e)

c) Eosinophils f) Plasma Cells i) only b), c), and f)

24) Fretting corrosion limits the use of these alloys for articulating components of knee and hip prostheses. Poor shear strength limits these alloys from being used as bone screws for large fracture fixation plates.

a) Cobalt-based alloys d) Stainless steels

(2) b) Tantalum alloys e) Platinum alloys

c) Titanium alloys f) Nickel Alloys

25) What is the typical outcome of an immune response to a synthetic biomaterial?

a) A humoral immune response

(2) b) Production of an antibody in response to the material

c) Rejection of the device

d) Significant pain and swelling at the site necessitating device removal

e) A cell-mediated immune response resulting in the accumulation of macrophages and T-lymphocytes surrounding the biomaterial

f) All of the above

26) As the surface hardness of an articulating device increases, which of the following are true?

a) Volume of wear debris produced decreases

(2) b) Wear debris particle size increases

c) Both a) and b)

d) None of the above

27) Which of the following refers to a dental implant that is a metal framework that rests on the bony ridge, but does not penetrate it?

a) Superosteal d) Subperiosteal

(2) b) Transosteal e) Endosseous

c) Allogeneic f) None of the above

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**Section 2: Multiple Choice; continued (Please use the blue highlighter to highlight the best answer.)**

28) Present in a humoral immune response to a natural biomaterial.

a) Lymphocytes d) Antibody g) All of these (a-f)

(2) b) Antigen e) Epitope h) only a), b), and e)

c) Eosinophils f) Plasma Cells i) only b) and e)

29) Bone is made up of a mineral phase composed primarily of \_\_\_\_\_\_\_\_\_\_\_\_ and an organic matrix composed primarily of \_\_\_\_\_\_\_\_\_\_\_\_\_?

a) Sodium phosphate, Collagen d) Calcium phosphate, Glycosaminoglycans

(2) b) Calcium carbonate, Glycoproteins e) Calcium phosphate, Glycoproteins

c) Calcium phosphate, Collagen f) Calcium carbonate, Collagen

30) Which theory for Materials-Induced carcinogenicity is used to explain the phenomenon that the implant capsule may provide for a unique environment favorable for the development of a tumor?

a) Degradation products

(1) b) Chemical leachables and surface procarcinogens

c) Physical contact with materials

d) Maturation or proliferation of preneoplastic cells

e) All of the above

**Section 3: Short Answer (Please start typing your answer after ANS) )**

31) (1) Explain how the design of a compression bone plate is different than a standard bone plate?

ANS)

32) (2) **Identify** and **describe** the two principle requirements for odontocompatibility.

ANS)

33) (2) Describe a test (1) **and** evaluation method (1) to evaluate osseointegration of a medical device.

ANS)

34) (2) What is platelet consumption? Give an example of a medical device in which platelet consumption would be an important hemocompatibility requirement/concern.

ANS)

35) (2) With respect to a medical device, what is leaching? Give a medical device example of leaching.

ANS)

36) (3) Dimes produced a 60% incidence of tumors when implanted into rat subcutaneous tissues. Does this mean that Ni and Cu in dimes are carcinogenic? Identify and explain this phenomenon.

ANS)

37) (1) Diameter that separates K-wires from Steinman pins? ANS) \_\_\_\_\_\_\_\_\_

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**Section 3: Short Answer (Please start typing your answer after ANS))**

38) (2) Besides preventing blood coagulation (non-thrombogenic), **identify and define** 2 other requirements for hemocompatibility.

ANS)

39) (5) What are three specific scenarios for BMIs (and consequences) that may occur when a synthetic vascular graft comes in contact with blood? What do these scenarios tell us about the hemocompatibility of the material?

ANS)

40) (3) Identify and define 2 cardiovascular functional tests used to evaluate these scenarios?

ANS)

41) (2) Differentiate the terms arthrodesis and arthroplasty. Elucidate two of the six design requirements for spine arthroplasty devices.

ANS)

42) (3) Neoplastic transformation in response to carcinogens is thought to be a three-step process**. Identify and briefly explain** these three steps.

1)

2)

3)

43) (2) Oxidation, one of the four major types of corrosion reactions, may produce a metal oxide surface  
 film on a biomaterial. This oxide layer is a passivating layer if....

a)

b)

44) (2) **Identify and define/explain** the two mechanisms that are responsible for the estimated 0.05 to 0.5 mm/year decrease in thickness of metal components in total hip and total knee arthroplasty.

ANS)

45) (1) Name one thing that can cause radiolysis of a polymeric medical device. \_\_\_

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**Section 3: Short Answer (Please start typing your answer after ANS))**

46) (2) Explain stress cracking in poly(ether urethane) elastomers in pacemaker or AICD (defibrillator) leads. How can this material response adversely affect the performance of a pacemaker or AICD lead?

ANS)

47) (2) Write an equation to calculate the interfacial strength for a cylindrical specimen from an intramedullary test.

ANS)

48) (3) Galvanic corrosion can occur between two metals implanted in the body. **Identify and elucidate** three requirements for galvanic corrosion that should be avoided in the design of medical devices.

ANS)

49) Wolff’s law indicates that bone tries to maintain a steady state with respect to strain. In the following, highlight the correct way in which bone tries to maintain a steady strain state adjacent to an implant.

(2) Decreased strain around a prosthesis  Osteocyte Osteoclast Osteoblast Activity  
 Bone Apposition / Resorption Bone Atrophy/ Hypertrophy  
  decreased / increased strain due to remodeling

(2) Stresses seen by bone are thought to cause strain-generated potentials. How is this electrical phenomenon used in the design of medical devices to cause bone fracture healing?

ANS)

50) (2) What is a hapten? How can a hapten induce an immune response?

ANS)

51) (2) The release of chemicals (O2-) and products secreted by macrophages is called? \_\_\_

52) (2) What are the axes on a Pourbaix Diagram? What are the three regions on a Pourbaix Diagram?

Axes: Abcissa (x): \_\_\_\_ Ordinate (y): \_\_\_ (1)

3 Regions: \_\_\_\_ \_\_\_\_ \_\_\_\_\_ (1)

53) (2) Explain the LIF test. What does the LIF test tell us about a biomaterial?

ANS)

54) (2) Explain the Ames test. What does the Ames test tell us about a biomaterial?

ANS)

EC ( 1 ) Attendance quiz on Wednesday, March 04, 2020 (I will enter, JT) \_\_\_\_

EC ( 1 ) Name of the glenoid component of a reverse total shoulder? \_\_

EC ( 1 ) Network of tubules connecting osteocytes to blood vessels? \_\_\_

EC ( 1 ) Concentration of titanium in human body in ppb (± 15)? \_\_\_\_\_\_\_\_\_\_

EC ( 1 ) Represents about 85% of the bone found in the human body? \_\_\_

EC ( 1 ) Smallest size wound that will not completely heal without intervention? \_\_\_\_\_\_\_

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**Section 4: Essay Questions (55 and 56) Please start typing your answer after ANS)**

55) (6) Preclinical safety data are needed to assure the FDA that patients will not be exposed to unreasonable risk associated with a new medical device. You are a research associate working for a medical device company. The director of research wants you to design and perform an *in vivo* preclinical study to determine if the company’s newest biomaterial is carcinogenic. Include details of your model and groups to be studied. Discuss your assumptions.

ANS)

56) (6) Wear debris (from metals and polymers) is often produced in articulating orthopaedic prostheses. What happens to this debris? Why is it hypothesized that the **debris** can cause loosening of metal components? What are some engineering solutions to solve this problem?

ANS)

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**Graduate Student Essay Question [Choose One, not both!] Please start typing your answer after ANS)**

57) (8) You are a research associate working for a medical device company. The director of research wants you to perform a ***rapid screening test*** on 5 new surface coatings on your company’s polyurethane for hemocompatibility assessment. What will you tell him? Design a study that will evaluate the surfaces. Include your methodological details and assumptions. ***OR***

57) (8) You are a research associate working for a medical device company. The director of research wants you to test a new surface to stimulate bone ingrowth. Your company has two such surfaces already and a competitor has an ingrowth surface that is the gold standard in the field. Design a study that will evaluate the surface(s), including all details (study model, implant shapes/sizes, location of implants, time points, measurement methods, and outcomes).

ANS)

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