Recommended Prerequisite Knowledge for ME 482

The only formal coursework prerequisite for ME 482 is TAM 251. However, besides this material, it is recommended/ expected for you to be familiar with a few key aspects of sophomore/junior level mechanics (ME 330, TAM 324) and freshmen level biology.

For **Mechanics**, you should be familiar with the mechanical behavior described in a stress-strain curve. You should understand how stress and strain are related, how microstructure influences mechanical behavior, and how you may choose to use a certain material based on its mechanical behavior. In ME 482, we will see the interplay between biological microstructure, mechanics, and tissue function. For more information, here are 2 helpful videos:
Introduction to stress-strain behavior.
How to analyze force-displacement data (helpful during Prelab 1).

For **Biology**¸ there is no biology prerequisite for ME 482; however, in the past, several students have found some basic biology terminology helpful for class readings and discussion. If you do not have a college freshmen biology background, we recommend you read these biology notes, and follow up any questions with some light Wikipedia reading. You do not have to memorize any of this material or go into too much detail; we are recommending this material so that you have seen it at least once before we discuss it in class.

Overview: Before we advance in this course, you should recognize that tissues have a hierarchical structure, which we will explore more in class. You should know the main function of bone, cartilage, ligaments, tendon, and muscle in layman's terms. You should be aware that cells come in various shapes, sizes, and connections – specifically, some cells rely on cell-cell interactions and some rely on cell-matrix interactions. You should be familiar with the four major macromolecules – proteins, carbohydrates, lipids, and nucleic acids. You know their general structure and purpose; you do not need to know exact chemical formulas. Read the following segments on tissues, cells, and macromolecules; **if you read and understand these paragraphs, you will likely have a sufficient biology background for this course. While we encourage you to study as much as you would like, DO NOT feel compelled by us or the course to spend more time learning beyond these paragraphs, as these paragraphs describe the essentials you need to know for the course. Spend your time wisely!**

Tissue Level

In this class, we will talk about the different length scales and hierarchical of biological tissues. You do not need to know these structures yet, but you can begin to think about what we mean by hierarchical structures. When we say "bone," do we mean a whole bone, like a femur? Do we mean A small volume of bone mineral? Actual bone cells? Are there different types of bone cells? Is the structure of bone different in the center compared to the outside?

The following are brief descriptions of the tissues we will focus on in this course:

Bones are the main structural unit of the body, carrying the weight of the rest of our body. Relative to other biological tissues, bone is very stiff and much less ductile. Although bones are

mainly loaded in compression, they are capable of tensile, bending, and torsional loads, albeit to a lesser extent. Some bones are more load-bearing than others (think legs vs arms, bipedal vs quadrupedal creatures); how might the loading change the structure of bone?

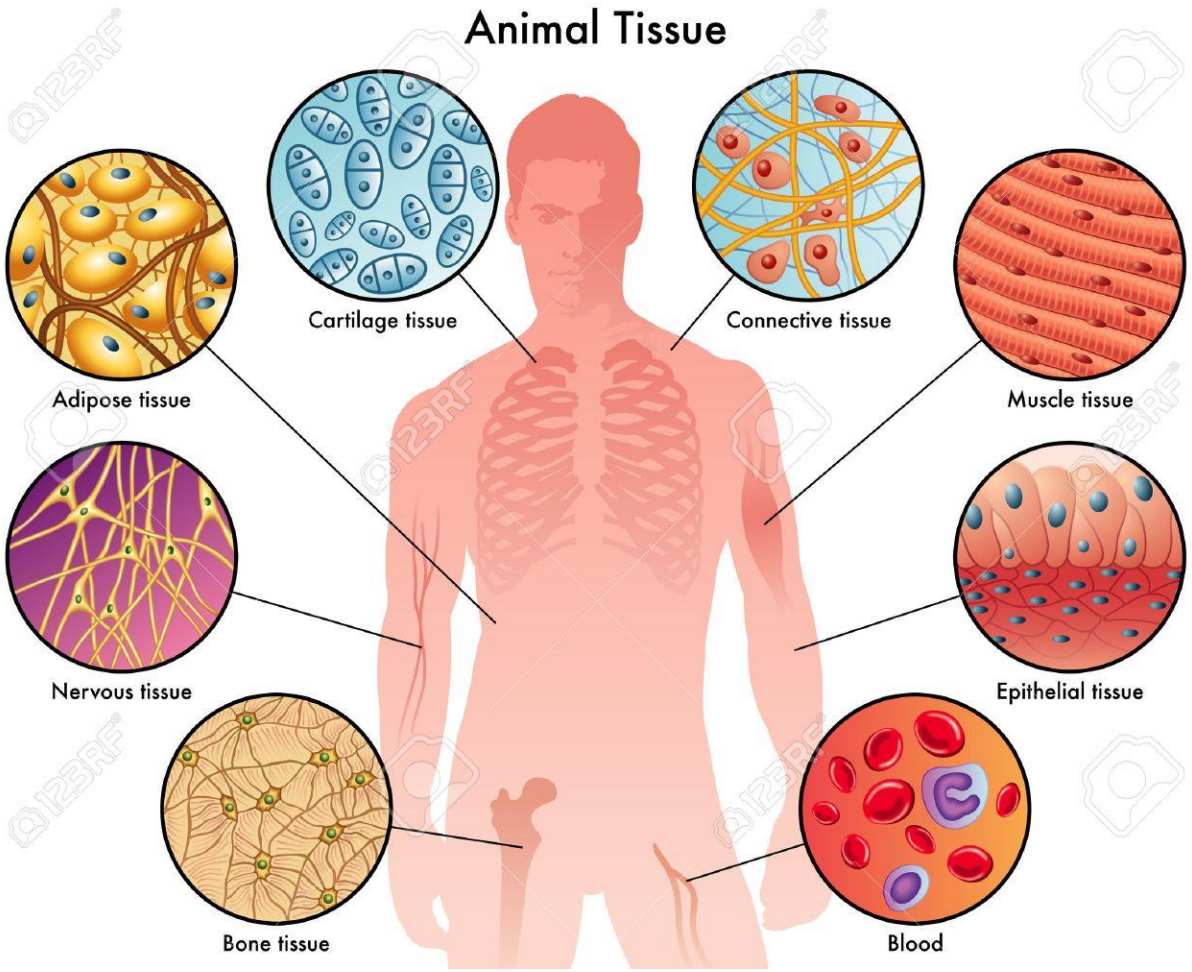
There are three types of **Cartilage**: elastic cartilage (more flexible, cartilage in outer ear), hyaline cartilage (covers joints and bones), and fibrocartilage (in joints, at the bone-tendon interface). Cartilage is less stiff than bone, but stiffer than other tissues; it is more ductile than bone. This course will focus on articular cartilage, a subset of hyaline cartilage that covers the surface of bone.

Ligaments connect bone to bone. **Tendons** connect bone to muscle. These two tissues have similar structures and primarily loaded in tension. What might be different between bone-to-bone connections than muscle-to-bone connections?

There are skeletal, smooth, and cardiac muscles. We do not spend much time on muscle, but if we do, we will focus on skeletal muscles. **Skeletal Muscles** generate force in tension. Muscle fibers are all aligned parallel to each other, so they are strong in one direction.

Cellular Level

We will not discuss cellular or subcellular structures in much detail in this course. You should know that in some tissues, cells are tightly packed together and have many cell-cell interactions (e.g. epithelial cells, like skin, in the figure below), and other cells are more isolated, exist in the extracellular matrix (ECM), and have cell-ECM interactions (e.g. adipose, bone cells in the figure below), and some cells are suspended (e.g. blood cells in the figure below). You do not need to know about these connections or cell types – we will discuss the important ones in class. We are just pointing out that cells come in various shapes and sizes. Some cells are only a few microns, and some, like neurons, can be meters long to connect your brain to your lower limbs.



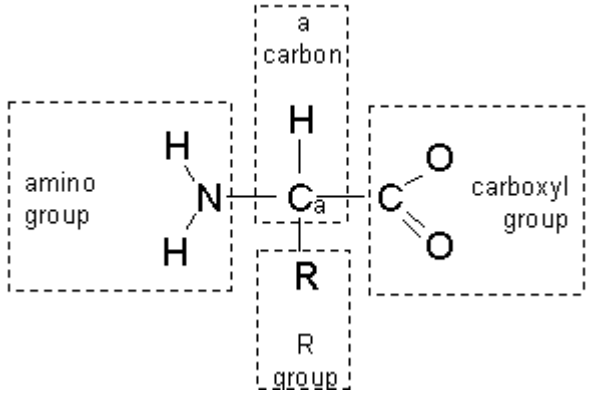
It might be helpful to be familiar with the common features of a cell, like the nucleus, cytoplasm, mitochondria, and cell membrane, in case they come up in readings, but these will not be the focus of the course.

Major Macromolecules

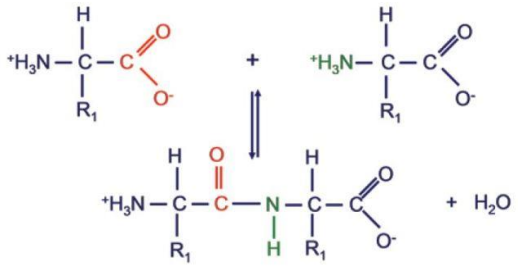
Proteins

Proteins are responsible for most cellular functions. For us, proteins may function as a structural element (e.g. collagen and elastin providing structure in the ECM), a catalyst for reactions (enzymes), or a signal relay (send/receive signals from a cell to another cell, from a cell to the ECM, or from the ECM to the cell).

Proteins are made up of Amino Acids. An Amino Acid has the general structure of an amino group, a carbon, carboxyl group, and an R group (also called the side chain).



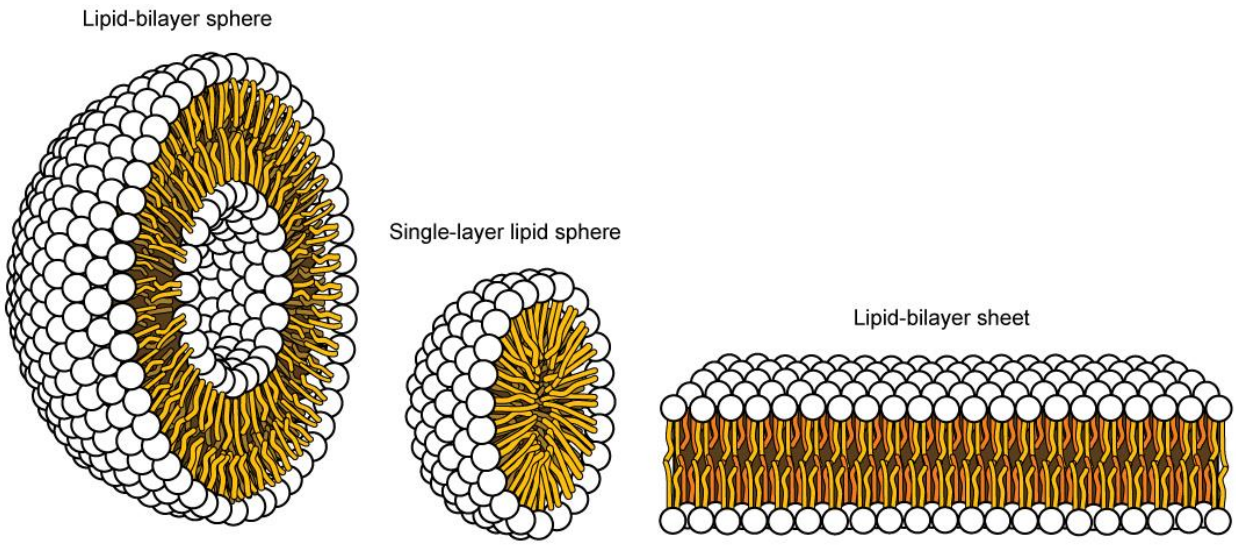
There are 20 different amino acids, eacg with a different R group. The R groups are commonly classified as being positively/negatively charged or uncharged, hydrophobic/hydrophilic (nonpolar/polar), and small/large in size. The amino acids bind as shown below to create a protein. Proteins can be several to several thousands of amino acids in length; the average protein is about 200 amino acids in length.



The arrangement of the amino acids determine the protein shape and function. Proteins that go through a lipid membrane (transmembrane proteins), will have different hydrophobic and hydrophilic domains that interact with the different hydrophobic and hydrophilic domains of the lipid membrane.

Lipids (fats)

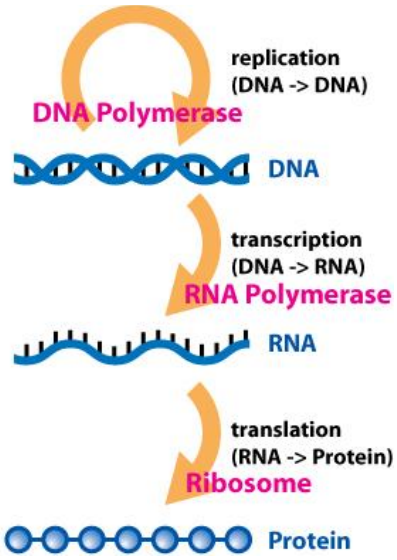
Lipids make up membranes in the cell. Some membranes, like the cell membrane, are a bilayer, and some are a single-layer. Lipids consist of a hydrophilic head (white in the diagram below) and a hydrophobic tail (yellow).



Carbohydrates (Saccharides)
For this course, you should know that carbohydrates are one of the major macromolecules, and generally have the formula $C_m(H_2O)_n$, where *m* and *n* are integers.

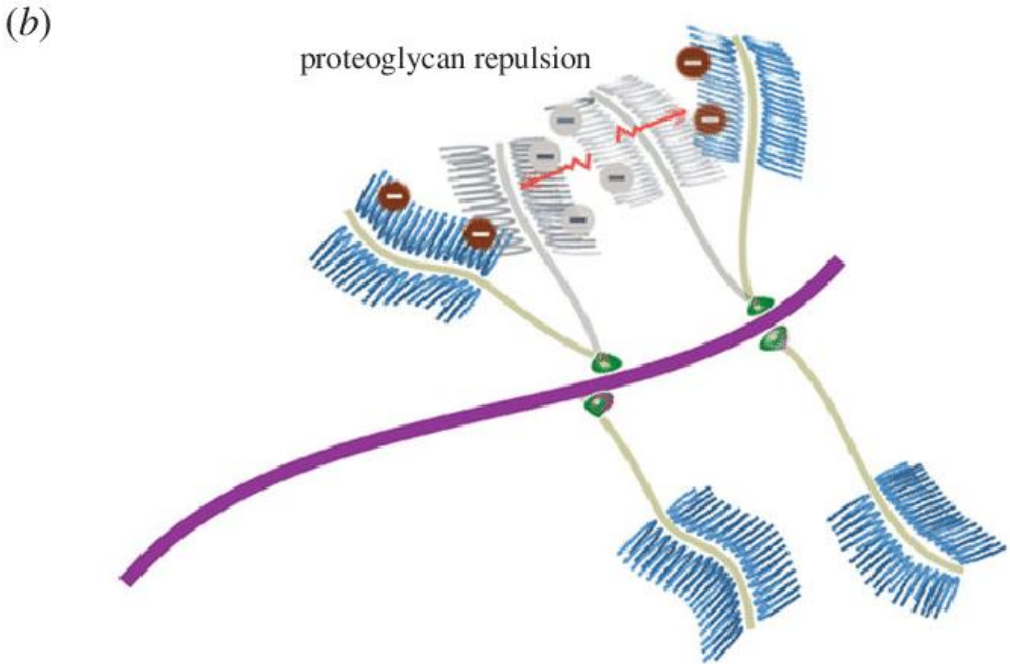
Nucleic Acids (DNA and RNA)
DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) We will not talk about DNA and RNA too much in this course.

You may want to be briefly familiar with the Central Dogma of Biology. In short, in replication, DNA copies itself for more DNA; in transcription, DNA makes RNA; and in translation, this RNA makes proteins.



Complex Macromolecules

These macromolecules work together for various functions. For example, there are many transmembrane proteins in the cell lipid bilayer membrane to connect to the extracellular matrix or transport molecules into/out of the cell. Proteoglycans are a negatively-charged protein and carbohydrate molecule that helps resist compressive loads. From the figure below, how does the negative charge resist compressive loads?



Source: Altered swelling and ion fluxes in articular cartilage as a biomarker in osteoarthritis and joint immobilization: a computational analysis. Sara Manzano, Raquel Manzano, Manuel Doblaré, Mohamed Hamdy Doweidar. J. R. Soc. Interface 2015 12 20141090; DOI: 10.1098/rsif.2014.1090. Published 12 November 2014