Questions for repetition and application – *answers in italics*

1. Most tissues and biological structures adapt to mechanical loading/usage. One of them has very limited adaptational capacities at best. Which one is it and why?

   **Joint cartilage (also named hyaline cartilage).** The main reason for the limited/slow adaptation seems to be its avascularity. There is not blood supply in cartilage tissue. This is most likely due to the fact that stress/pressure experienced within the tissue is much higher than blood pressure. Therefore, the function and integrity of blood vessels would be limited.

   Additional info:

   When injured in a full thickness defect, it has also been described that any clotting occurs due to bleeding from subchondral bone is not permanent. Clotting will disappear after 6 months or one year and a hole will remain. This may not be painful or immediately problematic but it is most likely that over years osteoarthritis will be the result.

   **Joint cartilage contains collagen type II as the main collagen type.** There is also fibro-cartilage found in some joints, i.e., the intervertebral discs and the menisci. Menisci are fibro-cartilage (similar composites as hyaline cartilage but collagen type I, therefore, showing a more fibrous structure and the not so highly loaded areas at the perimeter of the knee joint contain blood vessels; this is somewhat an exception. Extra figure on right:

2. Name the type of collagen mainly found in bone, cartilage, fibro-cartilage, ligament and tendon and characterize briefly the geometric organization. Give an example and describe briefly the function for one example for each.

   See table: fibro-cartilage see question 1. bone: circular and parallel, cartilage: mixed (Figure below), fibro-cartilage: crossed, ligament & tendon: parallel.

   **Joint Cartilage**

   - superficial layer: parallel, horizontal
   - transitional: irregular
   - deep: parallel, vertical
3. Tendons are often affected by overuse injuries. How can this be treated conservatively (without chirurgical intervention) and what can be said about the adaptational capacities of tendon tissue?

A group from Norway has demonstrated clearly that high intensity excentric exercise (calf muscle training) will alleviate symptoms in many patients with tendinopathies. A group from Germany showed that to induce changes in tendon thickness very high loads are required, minimum 90% of maximum isometric muscle force. This fits well with the general adaptation model of Frost – tissue strain needs to be higher than physiological level and for tendon this seems to be close to the maximum isometric force of the muscle. Viewed together, these approaches explain the effectiveness of the excentric training programs.

4. What is microdamage and how is it believed that it may lead to overuse injuries of tissues?

Microdamage are microscopic distortions in tissue which are small enough to NOT compromise the macroscopic integrity of the material. These can occur in bone due to high loading or loading rates (impact in running) or during high level excentric contractions. They may affect tendon-bone insertions, e.g., shin splints, medial tibial stress syndrome.

Some researchers believe that a certain amount of microdamage is needed to regulate tissue adaptation. It may therefore be that either the amount of microdamage or the weakening of the material due to microdamage triggers material fatigue (e.g., stress fractures, tendon inflammation, …). The result is the same and it is not yet clarified if which of these mechanisms rules; especially not if it is the same for all tissues.
5. Calculate the stress acting on the biceps (humeris) tendon when doing a biceps curl.

 mass: 20 kg
 weight’s lever arm: 38 cm
 muscle lever arm: 6 cm
 tendon cross sectional area: 0.6 cm²

Calculate this for a horizontal forearm position.

(Calculate the muscle force first.)

To do this properly we should use clear acronyms and symbols for formulae and sketches.

\[ \text{mass } M_w = 20 \text{ kg} \rightarrow \text{The force exerted by the mass } M_w \text{ is the weight of the dumb bell, } F_w. \]

\[ F_w = M_w \times g; \text{ with } g \text{ being the gravitational acceleration (} g = -9.81 \text{ m/s}^2 \) \]

with \( l_w = 0.38 \text{ m} \) we calculate

\[ T_w = l_w \times F_w; \text{ } T_w \text{ is the torque produced by the dumb bell’s weight. } \]

\[ T_w \text{ should be the same magnitude but opposite direction as the torque created by the muscle force, } T_m. \]

\[ T_m = F_m \times l_m; \]

and \( T_m = -T_w. \)

Inserting the above formulae

\( (1), (2), (3), (4) \rightarrow F_m \times l_m = -(F_w \times l_w) \)

\[ \Rightarrow F_m = - \frac{M_w \times g \times l_w}{l_m} \]

inserting values: \( F_m = 20 \times 9.81 \times 0.38 \div 0.06 \text{ kg m/s}^2 \text{ m} / \text{ m} = 1242.6 \text{ N} \)

As discussed will the whole muscle force act (be transferred to the tendon). Stress is the ration of force per area. So we simply divide the muscle force by tendon cross sectional area.
\[ \sigma_t = \frac{F_m}{A_t}, \text{ with } A_t = \text{area of the tendon, } \sigma_t = \text{stress in tendon.} \quad \ldots (5) \]

Inserting values:
\[ \sigma_t = \frac{1242.6}{0.00006 \text{ m}^2} \quad \text{(remember: } 1 \text{ cm}^2 = 0.0001 \text{ m}^2) \]
\[ = 20710000 \text{ N/m}^2 = 20.7 \text{ MPa} \]

6. a) What happens if the arm/weight (in question 5) is going further down? Describe/discuss.

\[ \text{In the drawing on the left it can be seen that the lever arm of the muscle gets shorter but similarly the lever arm of the weight. From the sketch in Question 5 it is not exactly the same, but the offset is rather small so the tendency is, that both change by relatively the same range such that the muscle force required would be roughly the same (in the static case).} \]

b) Take the horizontal as the end/lowest position. What is the effect of lowering the arm fast and turning around quickly? Describe/discuss, possibly estimate how much lower or higher the stress will be.

\[ \text{Ok, sorry the wording of that question is not ideal. I was interested to hear how the situation changes in a dynamic case where you start at an almost flexed elbow (dumbbell almost touching the shoulder, given in the sketch above on the right) then move the weight down until the forearm is horizontal and then quickly up again.} \]

\[ \text{While the weight moves down the force in the muscle is lower than that caused by the weight in the static case. Then there is one point where the forearm is quiet, since it has a downward velocity before and an upward after reaching this point there is an additional acceleration due to the change in velocity. If the downward velocity would be } 1 \text{ m/s and the upward also, the difference is } 2 \text{ m/s. Assuming that this would happen within } 0.3 \text{ s (as one repetition might take } 1 - 2 \text{ seconds) this would give an average acceleration (due to change in movement) of } a_{ccm} = 2 \text{ m/s} / 0.3 \text{ s} = 6.7 \text{ m/s}^2 \text{.} \]
As we are only estimating we may say that the force in the muscle would be roughly 2 (1.67) times as high. It is also likely that the peak acceleration is higher, up to 3 times the force would be my guess.

If we then go back to the first calculation in Question 5 we may say that the stress in the tendon might be up to 60 MPa. This is not critical for the tendon but not much is missing if we increase the weight. However, with a higher weight we will not be able to accelerate that much. Still, keeping this estimate in mind it becomes reasonable to suffer a biceps tendon rupture during highly dynamic catch or throwing movements.

c) What class of lever resembles this?

This last one is easy (take from lecture 4). It’s a 2nd class lever.