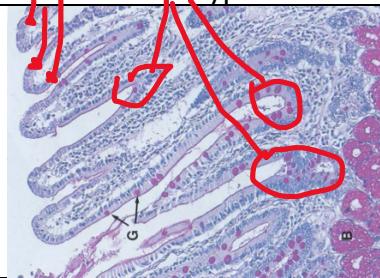
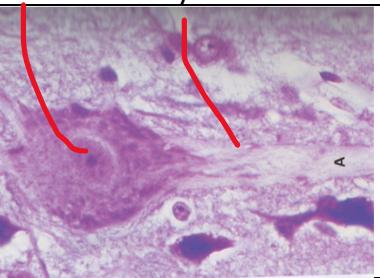
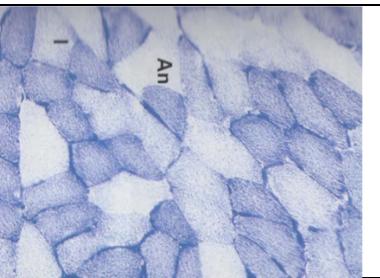
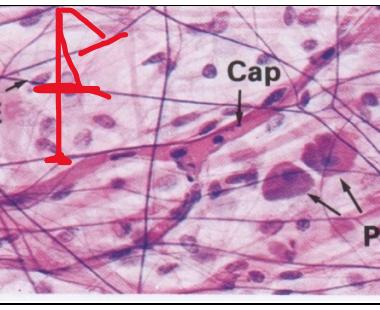
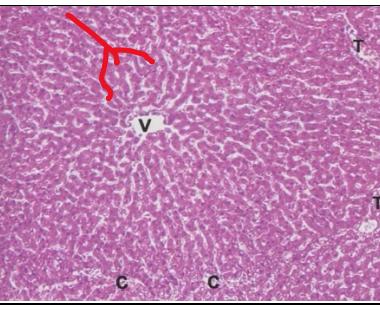
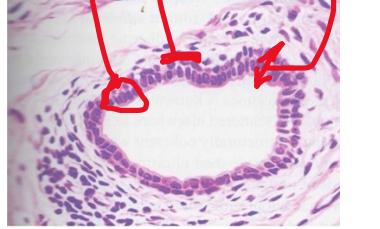
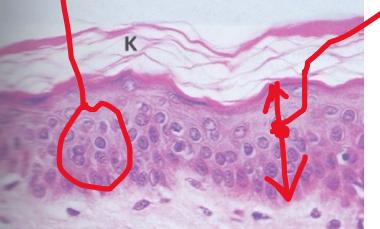
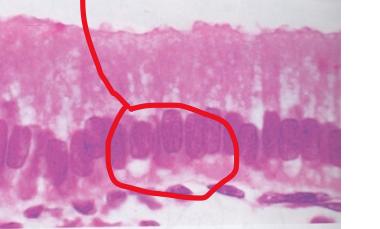


Assignment 4: Tissue Organization and Dynamics

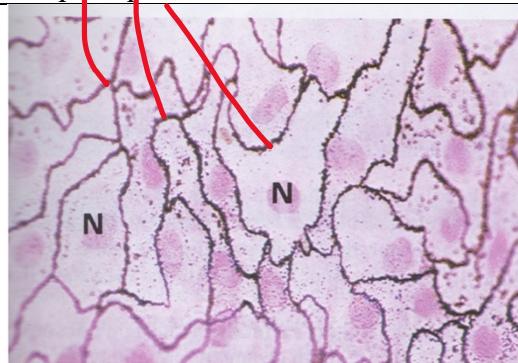
Cell and Tissue Engineering

1. Name that tissue and structure! Assign every word from the word bank below to an image or structure within an image. Please use arrows and circles to point to the structure you are labeling when necessary. Note there are 2 bonus images. Correct identification of the structure/tissue is worth 1.5 bonus points each.

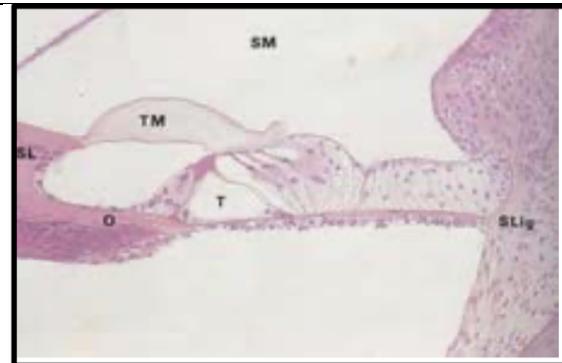
Cilia Microvilli Skeletal muscle Columnar epithelium Liver sinusoid Myelin	Neuron Simple squamous epithelium Stratified squamous epithelium	Stratified cuboidal epithelium Elastin Cryptus Basement membrane
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Microvilli and cryptus	Neuron and myelin	Skeletal muscle
		
Cilia and epithelium	Elastin	Liver sinusoid
		
Stratified cuboidal Basement membrane epithelium	Stratified squamous, epithelium	Columnar epithelium
		

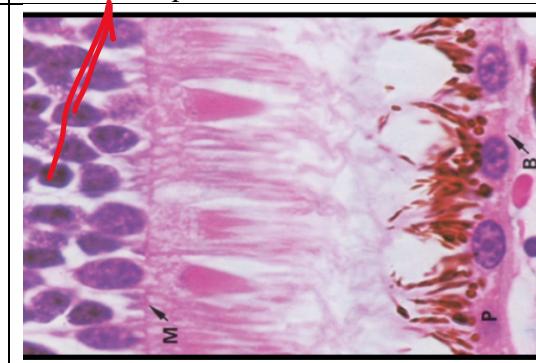
Simple squamous



Connective tissue



Stratified squamous



2. Atherosclerosis ("hardening of the arteries") is a disease hallmark by the build-up of plaques in blood vessels. These plaques make it more difficult for blood to flow, which blocks the vital delivery of nutrients to downstream tissue. Complications from atherosclerosis include clots, heart attack and stroke. This disease can manifest in many locations including the coronary artery (when termed "coronary artery disease"), the cerebral or peripheral vasculature. One way to treat extreme coronary artery disease is through surgery – a Coronary Artery Bypass Graft (CABG). In this surgery a healthy artery from elsewhere in the body is taken and used to bypass the segment of blocked vessel. The disease can become so progressed that it necessitates quadruple or even quintuple bypasses and typically the patients in this state do not have enough healthy vessels to sacrifice (see image where purple vessels indicate typical locations of bypass for the red coronary arteries).

A. What is the most common alternative vessel used when there are no arteries left for CABG? Saphenous vein (SV) is the most common vessel used after arteries, it has sufficient length and diameter, no fatty plaques and saphenous veins are superficial veins easily available.

B. What are the problems with this solution? What properties of this vessel are unmatched to the needed function? Please describe differences in both form and function.

Rates of failures using saphenous vein graft (SVG) is 25% after CABG. And the 10-year patency of vein graft is approximately 60%.

There are both biological and functional differences between veins and arteries which explain that CABG using arteries compared to venous vessel have better long-term results [1][2]:

Biological differences

Characteristics	Arteries	Veins
Walls	Thick and elastic walls	Thin and non-elastic walls which could collapse.
Lumen	Narrow lumen	Wide lumen
Diameter	Narrow (4mm)	Wider (5mm)
Layer	Tunica media: elastin and fiber	Tunica adventitia: elastin and collagen

Functional differences

Characteristics	Arteries	Veins
Blood circulation	Carry oxygenated blood away from the heart to tissues: O ₂ high, CO ₂ low.	Carry deoxygenated blood from the tissues back to the heart: CO ₂ high, O ₂ low.

Blood pressure	High	Low
Blood movement	Spurt movement of blood	Sluggish movement of blood
Blood velocity	Higher	Slower
Percentage of total blood volume	12%	60%
Contraction	Present	Absent

As described above, arteries have thick and elastic walls which can sustain bursts of blood pumped by the heart, therefore they can sustain high blood pressure. When using veins for CABG, veins are not designed to carry blood under pressure, their walls do not expand and contract like artery's walls.

C. Why does this not end up being a problem for many patients in the long run?

After SVG, the implanted vein is exposed to arterial flow, with blood pressure, shear stress, and a content oxygen content different from the venous environment. It perceived these new changes as an ischemia injury and in a successful graft, the vein remodels itself to become more arterial [3]:

- Progressive dilation happens resulting in an increase of diameter.
- Endothelial cells transduce the sheer stress to the vessel wall. There is an accumulation of smooth muscle cells and extracellular matrix components which leads to wall thickening.

In the long term, studies have shown that, survival after CABG is better in young adults and intervention with arterial grafts in younger ages produces high survival with low adverse events. However older people are more at risk of atherosclerosis which is a disease of aging. Therefore, older people are more at risk to have a CABG, and when they need one, for their age, arteries might have plaques and using veins makes more sense. Thus an SVG could improve significantly their life [4].

D. Describe 3 desirable design properties of tissue engineered blood vessels.

1. It needs to recapitulate vascular tissues. It should have similar mechanical properties, permeability depending the vascular tissue and organs: for example, mechanical strength of the scaffold should be higher and degradation time longer in arterial grafts than in venous grafts where compliance is more critical. Mechanical considerations should also include burst pressure, and fatigue resistance[5].
2. The engineered blood vessel needs to be a biocompatible structure that does not require immunosuppression, and not prone to infection or ectopic calcification. In addition, it needs a biocompatible surface in contact with the blood[6].
3. Blood vessels must have sufficient mechanical properties to stand stitching in vivo implantation[7].

And one additional important desire property, it needs to be able to grow with the patient.

References:

- [1] S. Aryal, "Difference between Arteries and Veins," *Microbiology Info.com*, Nov. 21, 2016. <https://microbiologyinfo.com/difference-between-arteries-and-veins/> (accessed Sep. 23, 2022).
- [2] M. Nicholls, "Veins to Arteries," *European Heart Journal*, vol. 38, no. 31, pp. 2387–2388, Aug. 2017, doi: 10.1093/eurheartj/ehx410.
- [3] T. Isaji *et al.*, "Improving the Outcome of Vein Grafts: Should Vascular Surgeons Turn Veins into Arteries?," *Ann Vasc Dis*, vol. 10, no. 1, pp. 8–16, Mar. 2017, doi: 10.3400/avd.ra.17-00008.
- [4] P. A. Anand, S. Keshavamurthy, E. M. Shelley, and S. Saha, "Does Age Affect the Short- and Long-Term Outcomes of Coronary Bypass Grafting?," *Int J Angiol*, vol. 30, no. 3, pp. 202–211, Aug. 2021, doi: 10.1055/s-0041-1735221.
- [5] C. D. Devillard and C. A. Marquette, "Vascular Tissue Engineering: Challenges and Requirements for an Ideal Large Scale Blood Vessel," *Front. Bioeng. Biotechnol.*, vol. 9, p. 721843, Oct. 2021, doi: 10.3389/fbioe.2021.721843.
- [6] H.-H. G. Song, R. T. Rumma, C. K. Ozaki, E. R. Edelman, and C. S. Chen, "Vascular Tissue Engineering: Progress, Challenges, and Clinical Promise," *Cell Stem Cell*, vol. 22, no. 3, pp. 340–354, Mar. 2018, doi: 10.1016/j.stem.2018.02.009.
- [7] R. F. S. Martinez, "Understanding the Development of Tissue Engineered Blood Vessels," p. 83.