Question 1

A)

Between the motor cortex and muscles contraction there are 2 motor neurons, two synapses and one muscles fibre.

$V_n = 100ms^{-1}$
$V_m = 4ms^{-1}$
$L_{n1} = 1m$
$L_{n2} = 1m$
$L_m = 0.04m$
$T_s = 0.001s$

$$Total\ time,\ T = T_{n1} + T_{n2} + T_m + 2xT_s$$
$$= \frac{1}{100} + \frac{1}{100} + \frac{0.04}{+4} + 2x0.001$$
$$= 0.032s$$

B)

Neurons: $\% = \frac{0.010}{0.032}x100 = 31.25\%$
Muscle: $\% = \frac{0.010}{0.032}x100 = 31.25\%$
Synapse: $\% = \frac{0.001}{0.032}x100 = 3.125\%$

C)

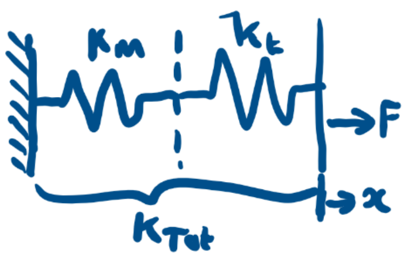
Total length the signal must travel $= 2.04m$
Speed of light, $c = 300x10^6ms^{-1}$
Speed of electrical signal down copper, $V_c = 0.68c = 2.04x10^8ms^{-1}$

$$Time = \frac{distance}{speed} = \frac{2.04}{2.04x10^8} = 1x10^{-8}s$$

Therefore, the time for a signal to travel in a copper wire is considerably faster than the time taken along the biological materials in the human body.

Question 2

A)



Compliance, $C = \frac{1}{K}\ ; C_{Tot} = \sum_{i-1}^{n} C_i$

$$\therefore \frac{1}{K_{Tot}} = \frac{1}{K_m} + \frac{1}{K_t} = \frac{K_t + K_m}{K_m K_t}$$

$$\therefore K_{Tot} = \frac{K_t K_m}{K_t + K_m} \quad (1)$$

$\lim_{K_t \to 0} K_{Tot} \to 0$. Therefore, since $F = Kx$, if $K = 0$ then it is impossible to turn the force in the muscle to a displacement and allow the musculoskeletal system to do work.

B)

$K_{\mathrm{h}} = 188\ Nmm^{-1};\quad K_{kt} = 25\ Nmm^{-1}$

Therefore, from equation (1):

$$K_{TotHuman} = \frac{188\kappa}{188+\kappa};\quad K_{TotKang} = \frac{25\kappa}{25+\kappa}$$

$K_{TotHuman} > K_{TotKang}\ \ \forall\kappa > 0.$ Since:

$$\frac{188\kappa}{188+\kappa} > \frac{25\kappa}{25+\kappa}$$
$$\frac{188}{188+\kappa} > \frac{25}{25+\kappa}$$

$$188\kappa + 4700 > 25\kappa + 4700$$
$$163\kappa > 0$$
$$\kappa > 0$$

Since the stiffness in a kangaroo muscle-tendon system is less that in a human, a given force will result in a much larger displacement, according to $F = Kx$. This, along with other factors, such as Effective Mechanical Advantage (EMA), allow a kangaroo to have a gait resembling a jump or hop, which would be considerably more energetically expensive for a human. As a result, the primary human gaits are walking jogging and running. The comparative

In the limit where $\kappa \to \infty$:

$$li\,m_{\kappa\to\infty}\frac{K_{TotHuman}}{K_{TotKang}} = li\,m_{\kappa\to\infty}\frac{188(25+\kappa)}{25(188+\kappa)} = \frac{\infty}{\infty}$$

Using l'Hôpital's Rule:

$$li\,m_{\kappa\to\infty}\frac{K\prime_{TotHuman}}{K\prime_{TotKang}} = li\,m_{\kappa\to\infty}\frac{188}{25} = 7.52$$

Therefore, for an equal force, it is expected that a kangaroo produces a displacement 7.52x larger than a human. In reality, the muscle tissue is not infinitely stiff, resulting in a ratio lower than 7.52, let's say half of that – 3.76x.

As a check, let us say that a human is able to jump around 1m, while a fully grown male red kangaroo can jump up to 25ft (National Geographic, 2018) which is 7.62m. Considering a human 1.8m tall and that fully grown male red kangaroos stand at around 1.4m (Carter, 2015), the normalised, unitless jumping length of humans and red kangaroos is 0.56 and 5.44 respectively. Thus, it is expected that a kangaroo will jump 9.71x the length which a human can. As said previously, the muscle-tendon system predicts an increase on only 3.56x. From this we can deduce that either a) the muscle stiffness of a human differs to that of a kangaroo or b) other factors in the physiology of a kangaroo allow it to jump comparatively further than a human.

References

(2018, January 29). Retrieved from National Geographic: https://www.nationalgeographic.com/animals/mammals/r/red-kangaroo/

Carter, L. (2015, October 30). Retrieved from Australian Museum: https://australianmuseum.net.au/red-kangaroo