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ENGINEERING TRIPOS PART IIB 2012
4G6 CELLULAR & MOLECULAR BIOMECHANICS

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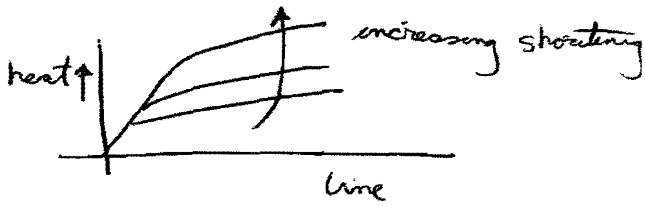
1 (a) ~~I~~ Shortening heat is the extra heat when it shortens compared to what it produces under isometric conditions. This is the Fenn effect. Fenn discover ~~that~~ this effect ie



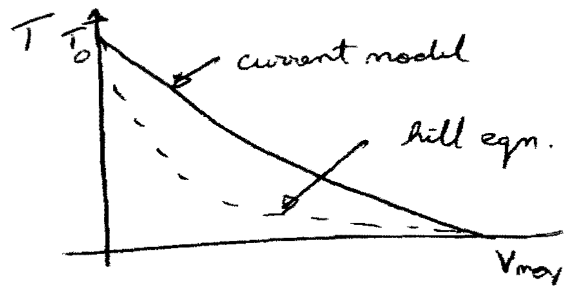
(b)

(i)
$$T l A = \int_{-\infty}^{\infty} \left[n(x) \frac{m A s}{2} \right] x \lambda \, dx$$

$$= \frac{m s \lambda}{2 l} \left[\int_{-\infty}^{0} n_0 e^{\frac{k x}{v}} x \, dx + \int_{0}^{h} n_0 x \, dx \right]$$

$$= \frac{n_0 s \lambda m}{2 l} \left[\frac{h^2}{2} - \frac{v^2}{k^2} \right]$$

(ii)



$$T_0 = \frac{n_0 s \lambda m h^2}{4 l}$$

$$V_{max} = \frac{k h}{\sqrt{2}}$$

Hill eqn. is hyperbolic while in current model T decreases quadratically with V.

②

Examiner's comment:

Well-answered by most candidates. Some candidates struggled on using the Huxley model to determine the tension-velocity relationship.

③

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(a)

(i) $(T+a)v = b(T_0 - T)$

$$v = \frac{b(T_0 - T)}{T + a}$$

$$\text{Power} = vT = \frac{bT(T_0 - T)}{T+a}$$

(ii) max power $\frac{d}{dT}(vT) = 0$

$$vT = P = \frac{b(T_0 - T)}{1 + \frac{a}{T}}$$

$$\frac{dP}{dT} = 0 \Rightarrow \left(\frac{1}{a} + \frac{1}{T}\right) = \left(\frac{T_0}{T^2} - \frac{1}{T}\right)$$

$$T = \frac{-2a \pm \sqrt{4a^2 + 4aT_0}}{2}$$

$$v_{opt} = \frac{b\left[1 + \frac{a}{T_0} - \sqrt{\frac{a^2}{T_0^2} - \frac{a}{T_0}}\right]}{\sqrt{\frac{a^2}{T_0^2} + \frac{a}{T_0}}}$$

(b) Myoglobin stores oxygen & releases it when the enviromental oxygen concentration is low. This is the mechanism that gives ~~the~~ the enhanced diffusion rate & not the actual transport of oxygen

(4)

(c) Large molecules such as glucose are transported across the cell membrane via carrier mediated transport mechanisms eg. uniports, symports etc.

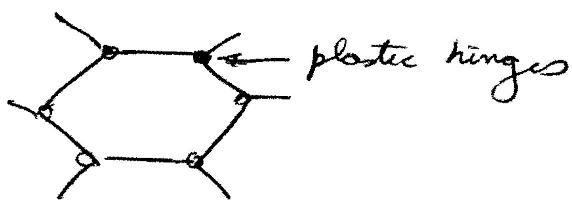
Examiner's comment: On the whole the question was reasonably well attempted but a number of students were confused on the dual role of myglobin.

(3)

(a) (i) The membrane comprises spectrin fibres in the form of a triangulated lattice. The fibres are wavy & hence there is a low initial modulus. With increasing straining, the fibres ~~straighten~~ straighten & hence ~~cut~~ we get a lock-up strain as further straining requires stretching of the spectrin fibres.

(ii)

Wood resembles a honeycomb structure - along the grain it is a stretching structure while ~~are~~ across it it is bending

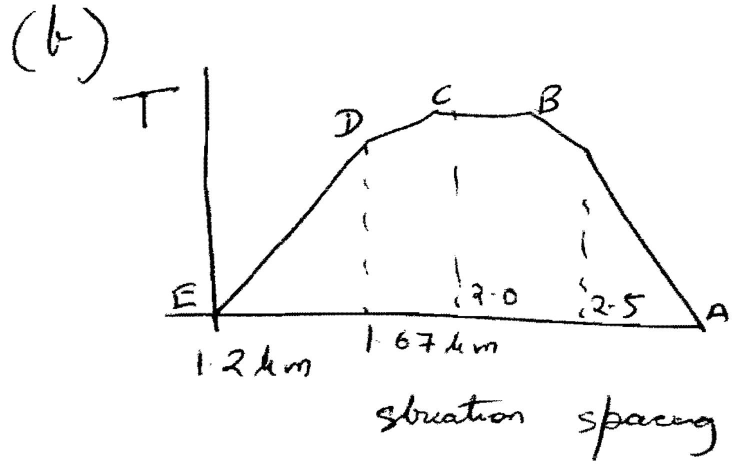


(iii) 5

Plants have chloroplasts for capturing energy & for storing this energy as glucose (& starches). They consume the glucose in their mitochondria & generate ATP.

Animal cells do not have chloroplasts but do have mitochondria. These ~~&~~ have proton driven pumps to use the energy liberated by aerobic & anaerobic hydrolysis of glucose to produce ATP & from ADP

(b)



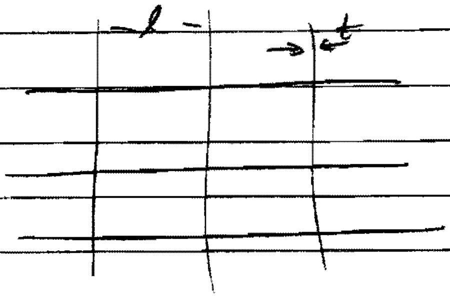
The tension changes with change in ~~ov~~ overlap between the thick & thin filaments as shown.

Examiner's comment:

A popular and straightforward question, well-answered by most candidates. However, a number of students not understand why spectrin is a bending structure at one length scale and a stretching structure at another length scale.

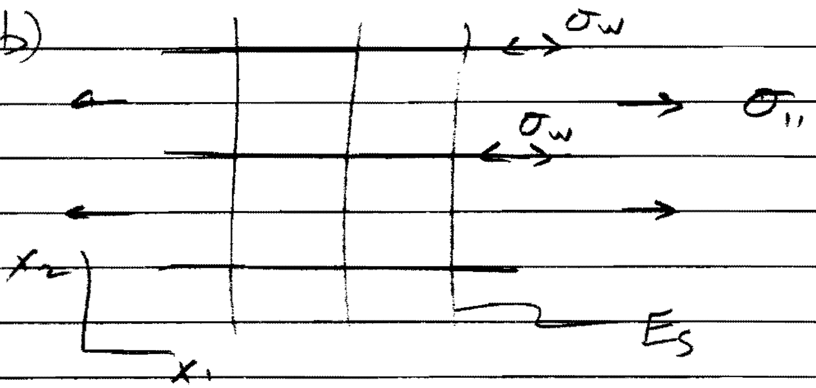
(4) Square Lattice

(a)



$$\bar{\rho} = \frac{1}{2}\frac{4tl}{l^2} = 2\left(\frac{t}{l}\right)$$

(b)



Macroscopic stress is σ_{11}.
Wall stress is σ_w.

$$\sigma_w t = \sigma_{11} l \Rightarrow \sigma_w = \sigma_{11}\frac{l}{t}$$

wall strain is $\varepsilon_w = \dfrac{\sigma_w}{E_s}$

Macroscopic strain = wall strain

$$\Rightarrow \frac{1}{E} = \frac{\varepsilon_w}{\sigma_{11}} = \frac{\varepsilon_w}{\sigma_w}\cdot\frac{\sigma_w}{\sigma_{11}}$$

$$= \frac{1}{E_s}\cdot\frac{l}{t}$$

$$\Rightarrow E = \frac{t}{l}\cdot E_s = \frac{1}{2}\bar{\rho}E_s$$

⑦ (11)

contd.

(b)

Transverse strain in wall is:

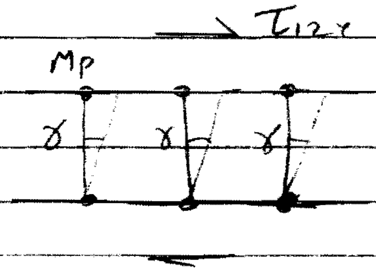
$$\varepsilon_{w22} = -\nu_s \cdot \varepsilon_w = -\nu_s \frac{\sigma_{11}}{E}$$

$\Rightarrow$ Macroscopic transverse strain is $\underline{\text{zero}}$

(c) Tensile strength $\sigma_{11Y} = ?$

$$\sigma_{11Y} = \frac{t}{l} \cdot \sigma_{YS} = \frac{1}{2} \bar{\rho}\, \sigma_{YS}$$

Shear strength $\tau_{12Y} = ?$



$$\tau_{12Y} \cdot l t \cdot (\gamma l) = M_p \cdot \gamma \qquad M_p = \frac{1}{4} \sigma_{YS} t^3$$

$$\Rightarrow \quad \tau_{12Y} = \frac{1}{4} \sigma_{YS} \left(\frac{t}{l}\right)^2 = \frac{1}{16} \bar{\rho}^2 \sigma_{YS}$$

(d)

The elastin fibres reduce the rotation stiffness and strength of the joints $\Rightarrow$ large drop in τ_{12Y} but a small change in E

Examiner's comment: An unpopular question similar to the previous year. The students struggled with calculating the shear strength of the square lattice.