UNIVERSITY OF CAMBRIDGE

NATURAL SCIENCES TRIPOS Part 1A

PHO/WP

Physiology of Organisms – Written Practical

Wed 2 June 2021 (0900-1030)

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*Answer **ALL 30** questions. This written practical paper (Section B of the exam) represents 25% of the total mark for Physiology of Organisms.*

You have 1.5 hours (plus any pre-agreed individual adjustment) to answer this paper. Please write your answers within this time-period. Uploading time should not be included in the allocated exam time.

You must submit your answers to these questions in the special answer sheet provided. The answer sheet is provided in alternative formats (.docx, .rtf and .xlsx) and you can use any one of these.

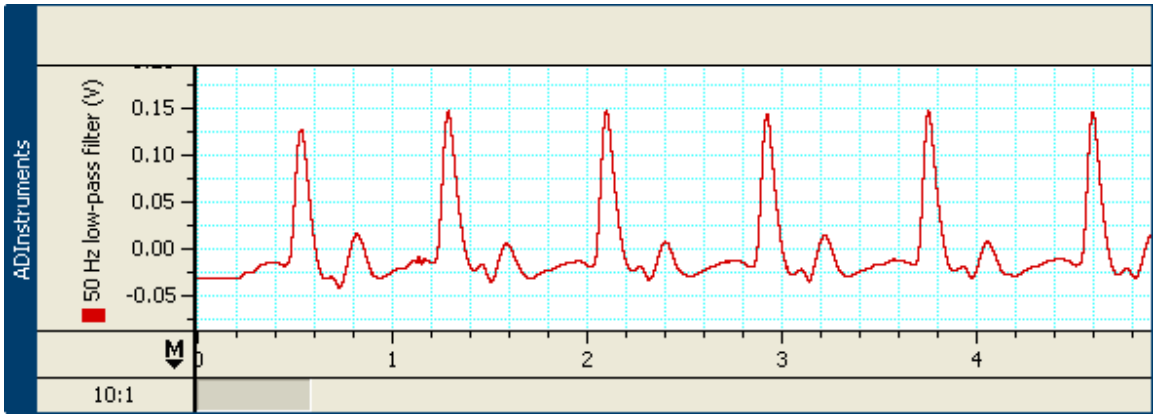
Please name your answer sheet:

Candidate number_SectionB.xxxx (e.g. 7850X_SectionB.xxxx)
where 'xxxx' could be 'docx', 'rtf' or 'xlsx' according to the file format chosen

Follow the guidance on the online examination site on how to upload your answer sheet.

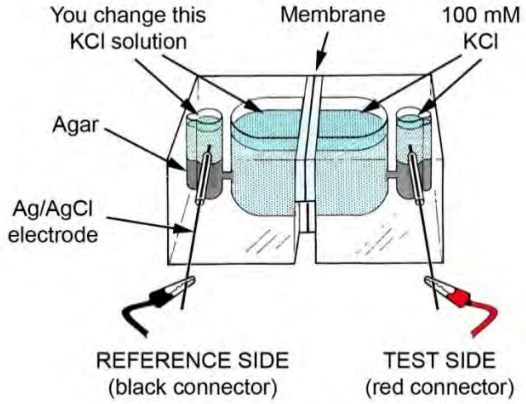
Candidates are permitted to use an approved calculator.

The trace below shows the response from a finger-pulse transducer, passed through a 50 Hz low-pass filter and sampled at 1 kHz. The *x*-axis time-scale is in seconds.



1) Which of the following would result in the biggest change to a subsequent recording from the same finger?
   A. Applying a 10 Hz high pass filter.
   B. Applying a 10 Hz low pass filter.
   C. Applying a 100 Hz low pass filter.
   D. Sampling at 10 kHz.
   E. Sampling at 100 kHz.

An artificial cell was set up as shown below. The solution in the 'test side' was 100 mM KCl, while the KCl solution in the 'reference side' could be changed but was always LOWER than 100 mM. The membrane separating the two solutions was known to be 10-20 times more permeable to K^+ than to Cl^-. The room temperature was 20°C. The voltage recorded was presented as the potential of the 'test side' relative to the 'reference side'.



2) With a reference side solution of 5 mM KCl, which of the following is CORRECT?
   A. The voltage recorded would be 0 mV.
   B. The voltage recorded would be -75 mV.
   C. The voltage recorded would be +75 mV.
   D. The voltage recorded would be between -75 mV and 0 mV.
   E. The voltage recorded would be between 0 mV and +75 mV.

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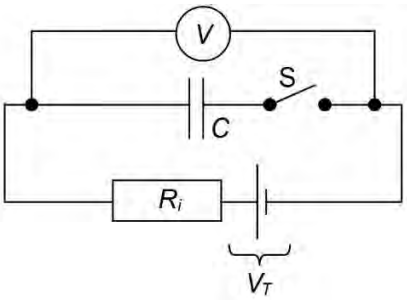
An electrical circuit was set up as shown in the diagram below. The capacitor C was initially fully discharged. After five seconds, the switch S was depressed and the voltage V across the capacitor was measured. The other elements in the circuit are a resistor of value R_i and a voltage source producing a voltage of V_T.



3) Which of the following is FALSE?

A. Before the switch is depressed, the voltage recorded would be V_T.
B. When the switch is depressed, the voltage recorded would fall immediately to zero.
C. Increasing R_i would make it take longer for voltage to reach 0.63 V_T, after the switch is depressed.
D. Increasing C would make it take longer for voltage to reach 0.63 V_T, after the switch is depressed.
E. Increasing V_T would make it take longer for voltage to reach 0.63 V_T, after the switch is depressed.

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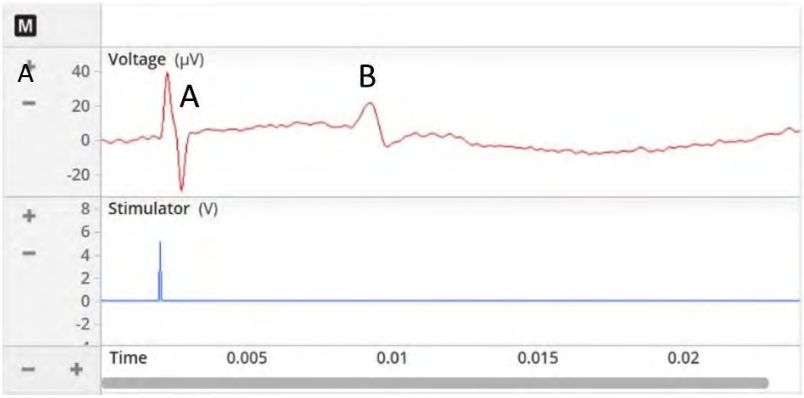
A student connected electrodes via pins to an anaesthetized earthworm, with stimulating electrodes at the anterior end of the worm and recording electrodes at the posterior end. The stimulating voltage was initially set at a low value of 0.5 mV and the recording below was made. The *x*-axis time-scale is in seconds.



4) The student then increased the stimulus voltage in 0.1 mV steps, stimulating each time. Considering only the effects on peaks A and B, which of the following would you expect the student to observe?

A. Both peaks would remain the same amplitude.
B. Peak A only would progressively increase in amplitude.
C. Peak B only would progressively increase in amplitude.
D. Both peaks would progressively increase in amplitude.
E. Peak A would not change. Peak B would remain the same amplitude to begin with, then, once a reasonably high stimulating voltage was reached, it would leap up to a greater amplitude.

5) Once the stimulus amplitude reached around 1 mV, a third peak appeared at a time of around 0.02 seconds. It was similar in shape to peak B, but of larger amplitude. What was this third peak (not shown in the recording above) most likely to represent?

A. The stimulus artefact.
B. An action potential from the median giant fibre.
C. An action potential from the lateral giant fibres.
D. The response of the earthworm's muscle.
E. Electrical noise.

6) It is recommended in this experiment that the stimulating cathode should be closer to the recording electrodes than the stimulating anode. If the stimulating anode and cathode are swapped around, it can be more difficult to record action potentials. Why is this?

A. Because it is more difficult for the neuron to reach threshold with this arrangement.
B. Because this would create a short-circuit with the earth electrode.
C. Because this would greatly increase electrical noise, reducing the signal-to-noise ratio.
D. Because action potentials would be travelling the wrong way along the nerve fibre.
E. Because action potential propagation can be blocked by hyperpolarisation at the position of the anode.

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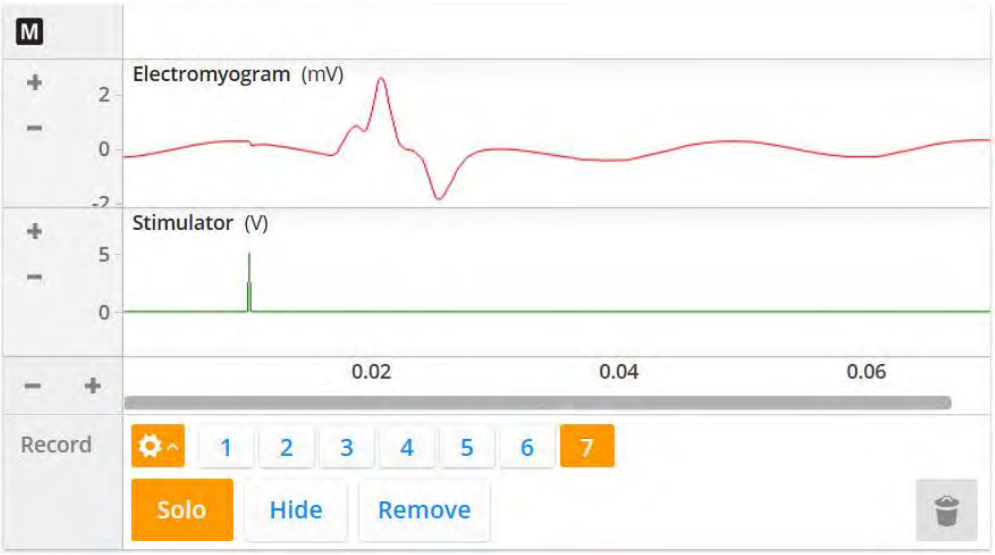
A student stimulated their own ulnar nerve at the elbow and recorded the electromyogram from the abductor muscle of the little finger, using electrodes attached to the edge of the hand. The following recording was made. The *x*-axis time-scale is in seconds; the 'Stimulator' trace indicates the point of stimulation as a spike at 0.01 s.



7) A student attempted to estimate conduction velocity of the fastest fibres within the ulnar nerve by dividing the distance between the elbow and the hand by the latency between stimulus and response. The latency was measured from the trace above as the difference in time between the stimulus and the first deflection of the electromyogram trace. A wise and kindly lecturer pointed out that this method would not yield a good estimate of conduction velocity. What is the main reason for this?

A. Because the distance between elbow and hand cannot be accurately measured.
B. Because of the irregular shape of the electromyogram response.
C. Because of the delay between stimulating and initiating an action potential.
D. Because of the delay associated with neuromuscular transmission.
E. Because velocity should be calculated as latency/distance.

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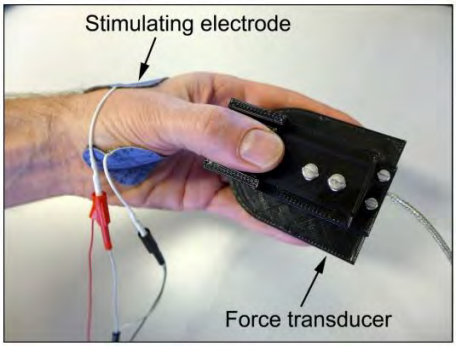
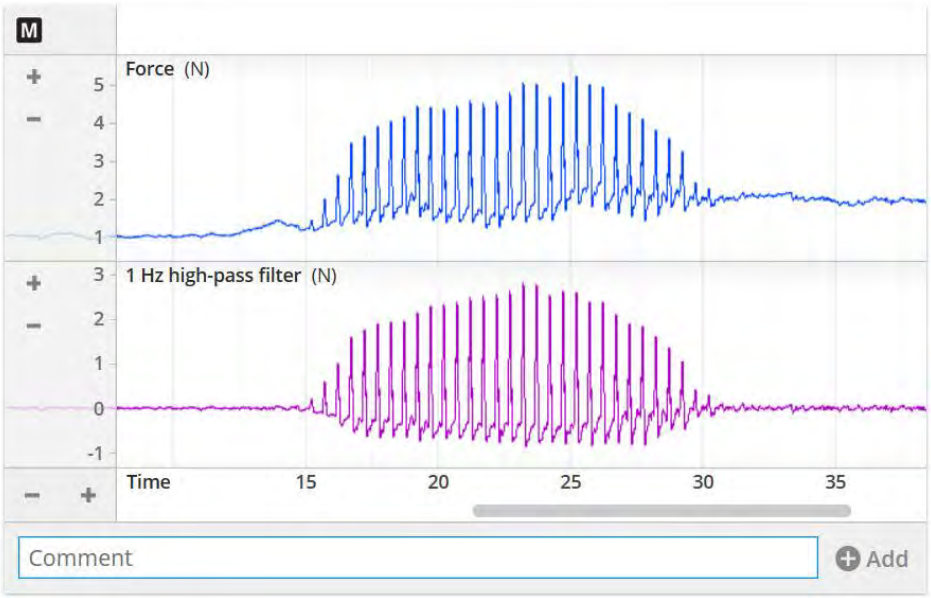
In a different experiment, a student grasped a force transducer while their hand muscles were stimulated directly using a Cefar Rehab stimulator, as shown in the photograph. A succession of stimuli were produced by the device, using progressively higher then progressively lower stimulus amplitudes. The following recording was made; the *x*-axis time-scale is in seconds.





8) Why did the peaks get larger in amplitude and then smaller, as the stimuli got larger and then smaller in amplitude?

A. This reflects different levels of muscle fibre recruitment.
B. This reflects different levels of motor unit recruitment.
C. This represents hysteresis.
D. This represents force summation, followed by fatigue.
E. This reflects the fact that we are looking at compound action potentials rather than individual action potentials.

The next two questions relate to an experiment in which students measured their own blood pressure.

9) Using sphygmomanometry, a student established that their blood pressure was 130/85 mmHg. The 85 mmHg represents:

A. Pressure in the left ventricle during diastole.
B. Pressure in the right ventricle during diastole.
C. Pressure in the aorta during diastole.
D. Pressure in the left atrium during diastole.
E. Pressure in the right atrium during diastole.

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10) Which of the following values is closest to the mean arterial pressure of this student?

A. 85 mmHg
B. 100 mmHg
C. 108 mmHg
D. 115 mmHg
E. 130 mmHg

The trace below is an electrocardiogram recorded with lead I electrodes. The *x*-axis time-scale is in seconds.

11) The S-wave in this recording is clearly negative, reaching around -0.4 mV. Why does it take a negative value in this case?

A. Because the electrodes were attached to the wrong wrists.
B. Because at that point in time, the ventricles were repolarising.
C. Because at that point in time, the 'instantaneous mean vector' was angled to the right.
D. Because at that point in time, the 'instantaneous mean vector' was angled upwards.
E. Because at that point in time, the 'instantaneous mean vector' was angled downwards.

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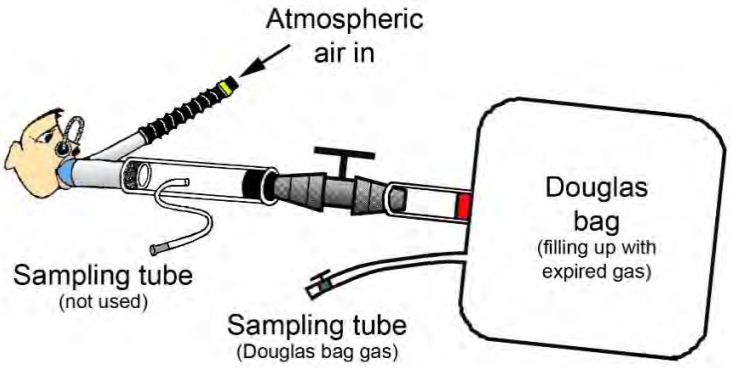
The following simple experiment is not something that you encountered directly in your practical exercises. The questions that follow are answerable based on your wider knowledge of the Physiology of Organisms course.

A resting subject breathed in and out through a special piece of apparatus that contained valves, such that they breathed *in* gas from the atmosphere but breathed *out* into a special leak-proof bag called a Douglas bag (see diagram). They did this for 5 minutes, and all the gas they exhaled in that time was collected in the Douglas bag. The total volume of expired gas collected in the Douglas bag over that 5 minute period was 32 litres. The gas collected in the bag was at room temperature (20°C) and pressure (765 mmHg), and you can assume that it was saturated with water vapour. Saturated water vapour pressure is 17.7 mmHg at 20°C and 47 mmHg at 37°C.



12) What would be the volume of the bag, expressed as a STPD (standard temperature and pressure, dry) value?
   A. 28.0 litres
   B. 28.2 litres
   C. 29.1 litres
   D. 29.3 litres
   E. 30.0 litres

The gas collected in the Douglas bag over that 5 minute period was then passed via a sampling tube through a gas analyser, which first dried the gas and then revealed that the composition of what remained included 5% CO_2 and 15% O_2.

13) What was the subject's alveolar partial pressure of CO_2 (P_ACO_2)?
   A. 35.7 mmHg
   B. 35.9 mmHg
   C. 37.1 mmHg
   D. 37.4 mmHg
   E. It cannot be determined from these data.

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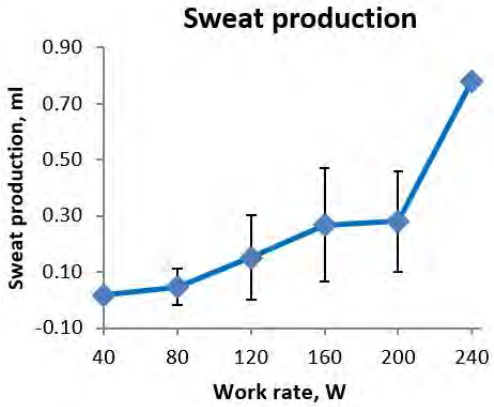
The following question is not related to the previous experiment

14) What would you expect to happen to a subject's alveolar partial pressures of oxygen (P_AO_2) and carbon dioxide (P_ACO_2) during moderate exercise, compared to resting values?

A. P_AO_2 would rise, P_ACO_2 would fall.
B. P_AO_2 would fall, P_ACO_2 would rise.
C. Both P_AO_2 and P_ACO_2 would fall.
D. Both P_AO_2 and P_ACO_2 would rise.
E. No significant changes would be expected.

In an experiment to assess how sweating rate depends on work-rate, the following graphs were obtained from a previous year's class. The results shown are means with error bars representing standard deviation. Exercise was performed on bicycle ergometers; the 'sweat production' was collected over a 5 minute period from part of the forearm.



15) A student wanted to demonstrate convincingly that a higher work-rate leads to a higher rate of sweat production. Before they started, they wrote down a list of things that would be required to ensure a robust experiment. Which of the following should NOT be on that list?

A. Ensuring the subject did not remove any clothing part-way through the experiment.
B. Ensuring that the sweat was always collected from the same part of the arm.
C. Performing the experiment in a random order of work-rates.
D. Making sure room temperature did not change over the duration of the experiment.
E. Ensuring the subject had the same length of time to rest in-between exercise bouts.

16) At 160 W work rate, the mean sweat production was 0.27 ml and the standard deviation (SD) was 0.20 ml. The number of students contributing to these data were 11. What was the standard error of the mean (SEM)?

A. 0.06 ml
B. 0.08 ml
C. 0.20 ml
D. 0.27 ml
E. 0.74 ml

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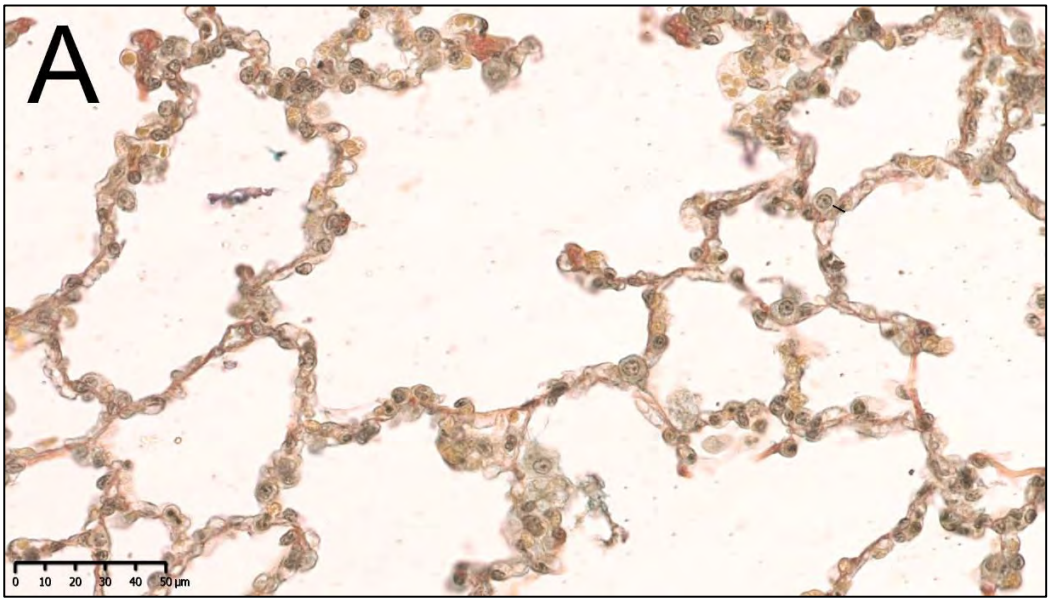
17) A subject breathes in air which is at 20°C and fully saturated with water vapour. They breathe in only through their nose. Which of the following statements is FALSE?

A. Gas exhaled through the mouth will be fully saturated with water vapour.
B. Gas exhaled through the nose will NOT be fully saturated with water vapour.
C. More water vapour will be lost if exhaling through the mouth than would be lost exhaling through the nose.
D. Gas exhaled through the nose will be at a temperature lower than core body temperature.
E. In humans, daily respiratory water losses are less than the maximum daily water loss possible through sweating.

The following three photomicrographs show sections through three tissues. You have seen histological sections through these tissues in your course, but you have not seen these particular photomicrographs. Please be aware that colours of tissues may vary according to the stains used!



18) Photomicrograph A (above) shows a section through:

A. A nerve trunk
B. Alveoli
C. Kidney tubules
D. White adipose tissue
E. Spongy mesophyll.

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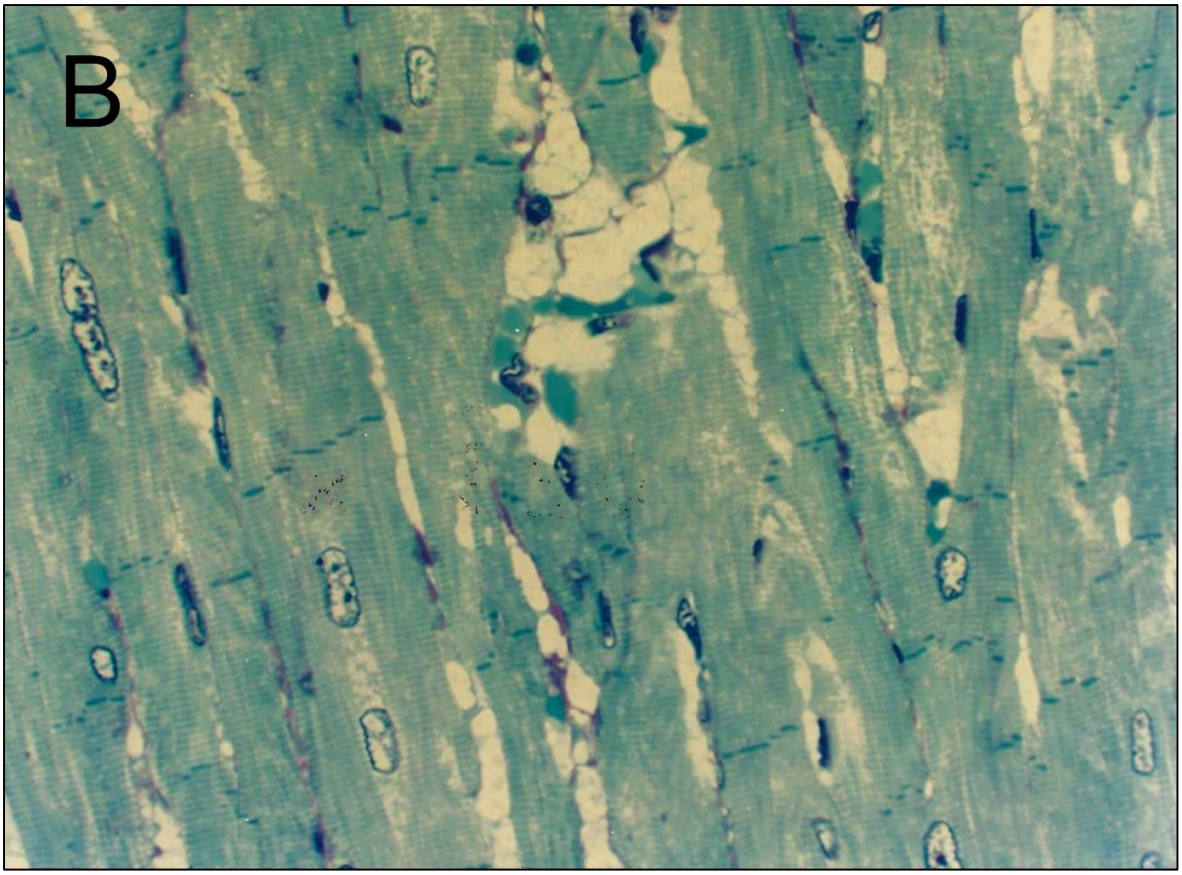

19) Photomicrograph B (above) shows a section through:

A. A nerve trunk
B. Smooth muscle
C. Cardiac muscle
D. Skeletal muscle
E. Skin.

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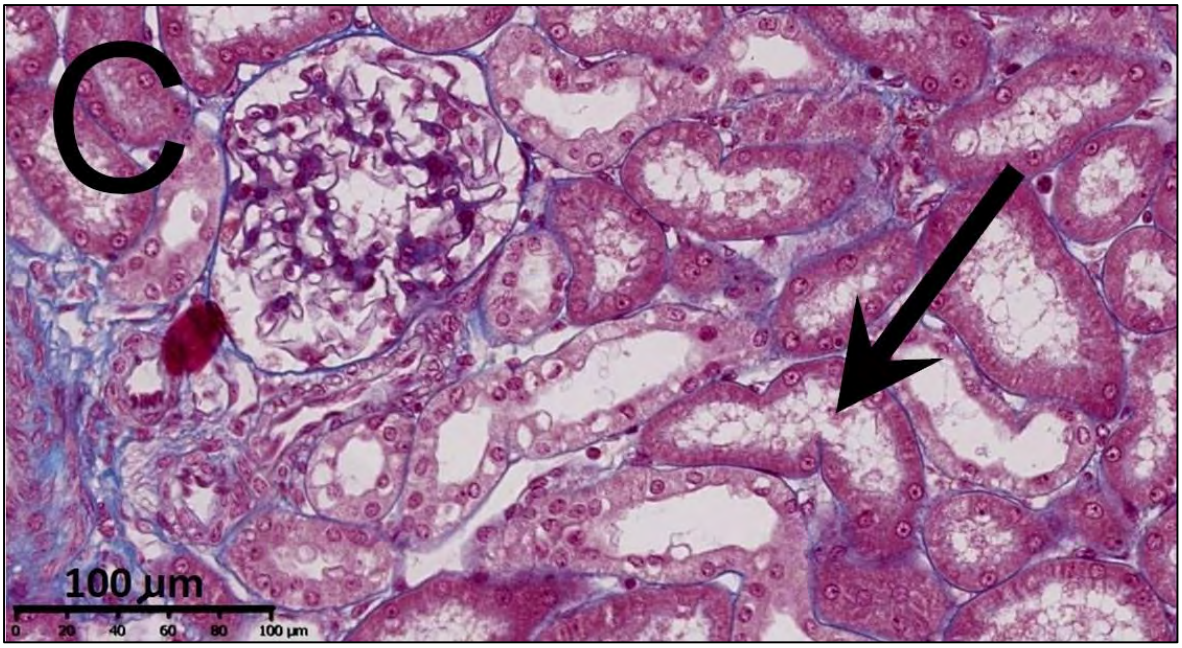

20) The arrow in Photomicrograph C (above) is pointing to:
   A. A nerve trunk
   B. A blood vessel
   C. A distal convoluted tubule
   D. A proximal convoluted tubule
   E. The coiled base of a sweat gland.

21) Using an oxygen electrode, you measure that a 125 mg shrimp has an oxygen consumption of 10 µl O_2 per hour. Assuming that Rubner's surface hypothesis is correct, what oxygen consumption rate would you expect for a baby shrimp weighing 1 mg?
   A. 0.4 µl per hour
   B. 7.5 µl per hour
   C. 0.75 µl per hour
   D. 0.08 µl per hour
   E. 6.66 µl per hour

22) You measure the tibia lengths and jump distances of locusts of different body masses, and plot your results as log-log graphs to measure the scaling coefficients. Assuming that the locusts are isometric, you would expect that:
   A. Tibia length should scale with body mass to the power 0.75.
   B. Jump distance should be unrelated to body mass.
   C. Acceleration before take-off increases with body mass.
   D. Ignoring air resistance, larger locusts should jump further as they have longer hind legs.
   E. Larger locusts slow down more because of air resistance than small locusts.

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The remaining questions relate to plant physiology

23) In epidermal strips, why does high potassium (K^+) concentration in the bathing medium decrease guard cell sensitivity to ABA in the light?

A. ABA receptors are competitively inhibited by K^+.
B. At any given membrane potential, a much higher internal concentration of K^+ will accumulate passively, so ABA is less effective.
C. High K^+ concentrations inhibit the release of Ca^{2+} from the vacuole, preventing the generation of calcium transients in ABA signalling.
D. Anion efflux is inhibited by high extracellular K^+ levels.
E. ABA is a weak acid and tends to dissociate in high ionic strength solutions.

24) *Commelina communis* epidermal strips were incubated in 50 mM KCl, 10 µM MES buffer, pH 6.0, with 10 µM fusicoccin, a fungal toxin. Which of the following would you NOT expect to observe?

A. Stomata would be open in the light.
B. Stomata would be open in the dark.
C. The inner lateral subsidiary cells would shrink.
D. The terminal subsidiary cells would shrink.
E. If a whole plant were infected by this fungus, the plant would likely wilt after a day or two.

25) In the experiment on nitrate reductase (NR) induction, radish seedlings were grown with or without additional nitrate. Then, cotyledon extract was assayed for NR activity. In one test, seedlings were grown with the additional nitrate and cycloheximide. Why?

A. To induce NR synthesis and stabilise its activity.
B. To induce NR synthesis and suppress inhibitors of NR activity.
C. To induce NR transcription and inhibit its synthesis.
D. To induce NR transcription and inhibit basal NR activity.
E. To promote basal NR activity and inhibit its further synthesis.

26) When measuring absorbance (A) of a solution using a spectrophotometer, what value of A (to two decimal places) would be generated by a sample that absorbs 75% of the incoming light?

A. 0.60
B. 0.70
C. 1.33
D. 1.39
E. 1.88

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27) In the colorimetric assay of nitrite production by radish cotyledon extract, what estimate of nitrate reductase activity would result from the following data? Ten cotyledon pairs were harvested and homogenised with extraction medium. Final volume after homogenisation: 4.5 ml. Volume of homogenate centrifuged: 1.5 ml. Volume of homogenate supernatant (V): 1.2 ml. 250 µl of this extract was mixed with 750 µl of solution containing buffer, KNO_3 and NADH. Estimate of nitrite from the standard curve: 20 nmol ml^{-1}. Assay incubation time: 20 minutes. All other conditions as per practical schedule.

A. 28.80 nmol nitrite per cotyledon pair per minute.
B. 1.44 nmol nitrite per cotyledon pair per minute.
C. 3.60 nmol nitrite per cotyledon pair per minute.
D. 1.20 nmol nitrite per cotyledon pair per minute.
E. 14.40 nmol nitrite per cotyledon pair per minute.

The image below shows a tobacco leaf that has been inoculated with tobacco mosaic virus (TMV).

28) Examine the image above of a tobacco leaf that has been inoculated with TMV. Which is the best explanation for the leaf's appearance?

A. The tobacco plant has N genes and the plant has initiated programmed cell death.
B. The tobacco plant has N genes and the virus has caused apoptosis.
C. The tobacco plant does not have N genes and the virus has caused apoptosis.
D. The tobacco plant does not have N genes and the plant has initiated programmed cell death.
E. The brown patches shown in the image are fungal mycelia, which represent a secondary infection of the diseased tissue.

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29) In a lateral flow immunodiagnostic test of a viral protein, how many different antibodies are required and why?

A. One: specific to the viral protein.
B. Two: one specific to the viral protein and one specific to the latex bead.
C. Two: one specific to the viral protein and one specific to the absorbent pad.
D. Two: one specific to the viral protein and one specific to that antibody.
E. Three: one specific to the viral protein, one specific to the latex bead and one specific to the latex bead antibody.

30) A plant cell just below the surface of pure water has a turgor pressure of +0.65 MPa. The cell is isolated and in equilibrium within its surroundings. What is its internal solute concentration, expressed in milliosmoles per litre? The atmospheric temperature is 20°C and the gas constant is 0.0083 MPa litre mol^{-1} K^{-1}.

A. -650 mOsm l^{-1}
B. 0 mOsm l^{-1}
C. 267 mOsm l^{-1}
D. 650 mOsm l^{-1}
E. 1026 mOsm l^{-1}

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