NATURAL SCIENCES TRIPOS 2018

IA PHYSIOLOGY OF ORGANISMS

SENIOR EXAMINER'S SUMMARY REPORT

Examiners

[redacted]

Assessor

[redacted]

Structure of the examination

The examination consisted of a Written Practical paper of 90 minutes duration and a Theory paper of three hours duration.

The Written Practical paper consisted of three short-answer questions on material taught in the practical classes. The questions required the candidates to explain experimental procedures, interpret results similar to those acquired in the practical classes, and to perform calculations based on experimental data or measurements made from experimental records. One question related to a Plant Physiology practical class and the other two to Animal Physiology classes. The questions were equally weighted and together carried 25% of the total marks for the examination.

The Theory Paper contained two sections. Section A consisted of 45 multiple choice questions designed to test factual knowledge central to the understanding of the course material. Candidates were asked to select one answer out of five options. The completed sheets were delivered with a master answer sheet to Cambridge Assessment for scoring. Section A carried 25% of the total marks for the examination.

Section B required the candidates to write essays on two questions chosen from a total of six. Four of the six questions required integration of course material relating to animals, plants and microorganisms, while two questions (available as on either/or option) were specific to course sections relating to either plants or animals. Section B accounted for 50% of the final mark with the two essays being equally weighted.

178 candidates completed the examination. After scaling as laid down by the Natural Sciences Committee, 24.72% of successful candidates received a first class mark, 65.17% a second class mark and 10.11% a third class or fail mark. Two candidates failed. Four candidates withdrew before the start of the examination.

Written Practical Paper

The mean raw mark for this paper was 58.2%, with a standard deviation of 12.1% and a range of 36.4% - 82.8%

Theory Paper: Section A

The mean raw mark for Section A in the Theory Paper was 63.4%, with a standard deviation of 11.9% and a range of 24.4 - 93.3%.

The candidates were divided into quartiles on the basis of their overall Section A mark and the examiners scrutinised the distribution of correct answers given by each quartile. In two questions the first quartile slightly underperformed the second, but on inspecting the questions the examiners allowed the marks for these questions to stand. The lectures setting these questions of those achieving poor discrimination will be informed ahead of the next examination.

Theory Paper: Section B

Marking was guided by the Faculty of Biology mark scheme. The mean raw mark for Section B was 57.9%, with a standard deviation of 12.0% and a range of 35.0 - 80.0%.

Conduct of the examination.

The sitting of both papers passed without incident. No questions were asked of the examiner in attendance.

An error in one question on the Written Practical paper was discovered a few days before the examination. This involved the switching of two panels showing electrocardiograms. The Board of Examinations was informed and the Board arranged to distribute a hard copy of a correction to all candidates.

Feedback on the practical component of the exam:

Question 1

Mean mark: 55.0%

This question was based on a practical class comprising a video demonstration of venous occlusion plethysmography and recording of the electrocardiogram (ECG). The measurement of arterial blood pressure was also included in the same class but not examined on this occasion. Many candidates showed some or considerable ignorance of venous occlusion plethysmography and the physiology discussed in the demonstration. A number described the technique used to measure arterial blood pressure by the auscultatory method even though the question stated that the technique was used to investigate blood flow. Most candidates showed a better knowledge of the experiments relating to the electrocardiogram. However, very few candidates correctly explained how heart rate is increased during exercise. With many candidates not addressing the effects of the autonomic nervous system on the sino-atrial node and a large proportion writing instead about what they believed to be the underlying causes of the increase in heart rate, suggesting these to be changes in PO_2, PCO_2 and pH in arterial blood. Most measurements made from ECG records and the calculations performed using these data were done well.

Question 2

Mean mark: 58.2%

Students showed good comprehension across this question, with full marks scored on each section by multiple students. Overall I was happy that students had been given sufficient information to answer the entire question. More detail per section:
a) Students found graph drawing largely easy. I felt that 10 marks was perhaps generous for this section.
b) The long calculation tested understanding well and marks were awarded for method steps in the working. Many students failed to account for one dilution step, which was the main cause of dropping marks here.
c) Students largely quoted Beer's law but then approximately half applied it correctly and the other half applied it incorrectly. A little common sense should have been able to confirm which was the right way and this misunderstanding is not likely to be due to the question.
d) This question was highly challenging to the students and many got partial credit for good ideas. Across all scripts, all elements in the mark scheme were mentioned, but very few papers managed a full combination of considerations.
e) This section was the least well answered, and often helped separate out first class scripts.
f) Marks were awarded here for correctly describing what would be seen on the gel based on their answer to d, and marks were not docked for answers to d being incomplete.
g) Most students were able to score at least 4/5 marks on this question, pushing several scripts over a grade boundary.

Question 3

Mean mark: 51.8%

The average mark for this question was only 51.6%. The main reason for this was the large number of candidates who failed to write anything for certain parts of the question. For instance, parts c & h has ~80 candidates who failed to write anything. These were the parts dealing with why the recorded EMG has bumps and does not look like an intracellular action potential and why the weight calibration of the force transducer is not a straight line. These questions are exactly why the students do the practicals – the answers are not in textbooks. By contrast parts e & i were only missed by ~8 candidates (calculation of conduction velocity and explanation of the tetanic force traces). The highest scoring parts were the measurement of latency (part d), conduction velocity (e), highest mass applied to transducer (g) where the average mark was over 70%. The worst scoring parts were c & h – as mentioned above – where the average mark was 31%. Of those that actually wrote something for that answer, the average mark was 57%. Those candidates who answered parts d & g got full marks. The main reason for poor performance on this questions was simply the failure to write anything down at all!

Specific section comments

a. 5 marks. Any candidate that noticed something odd about (i) which meant that is was unlikely to be a 'normal' recording got additional credit. It has a regular waveform with an exponential like decay and is probably mains noise due to a high resistance. (ii) is a moderate contraction, (iii) relaxation and background noise, (iv) a more prolonged period of more intense contraction.

b. 5 marks. There are a number of possibilities. Electrode placement, lower resistance to muscles (skin, fat, wetter), bigger muscles, more vigorous contraction. Some candidates just said one is male, or plays the piano rather than giving a physiological explanation.

c. 5 marks. A statement that it is not an intracellular recording, but a surface electrical recording from many cells in a biphasic recording system where the cells become active at difference times (different CVs) with NMJ is different locations would have got full marks.

d. 1 mark - 6 ms was the ideal value, but I also allowed the latency to the peak of the response.

e. 4 marks - 0.3m / 0.006s = 50 m/s. 1 mark for the equation regardless of whether the calculation was correct. Any reasonable CV was marked correct if they had explained the values used - synaptic delay correction, or peak muscle response time used were allowed.

f. 5 marks – I was ideally looking for underestimate since there are other delays in the system. However, under or over were marked correct if a plausable explanation was given. The best for overestimate was that the nerve was potentially being stimulated closer to the muscle than measured due to a high stimulus intensity and stimulus spread. The best students had both over and under with the relevant explanations – this was excellent.

g. 1 mark. A simple question to which the answer should have been 164g. But, any value in the range 160-170g were marked as correct. In a fit of generosity I also allowed marks for mass in Newtons. It might be helpful if the practical classed emphasises the difference between force and mass in future.

h. 3 marks. I would have allowed full marks for anyone who drew a line showing that the 0.44N measurement was NOT out, but it was the lower one. No one did. Any comments along the lines of; mass positioning error (not central), mass not as stated (damaged weight), miss recorded value, non-linear transducer, transducer not vertical – got a mark.

i. 5 marks – This was a difficult question. The key point being that the nerves are being activated by the CNS – asynchronously and at lower firing rates than artifical electrical stimulation tetany. Maintenance of force difficult due to fatigue, movement of other muscles (repositioning) etc leads to noise in the force trace.

j. 5 marks – I was hoping that students would mention that the surface EMG is an electrical recording from the surface of the body which is poorly earthed and the body acts as an aerial picking up electrical signals from radiated mains AC. The force transducer is, however, in a sealed earthed box and therefore not subject to the same electrical pickup. Many got the gist of this and I was generous with the marks if they seemed to understand the difference.

k. 3 marks – A high pass filter which removed the DC or baseline offset. They got a mark if they mentioned filter, even if they said low pass. I was hoping they would mention the flatter baseline together with something many referred to as 'dishing'.

a. 5 marks – Twice as many peaks at 30Hz but smaller as the tension recovers less – total force greater at 30 Hz and smoother as there is not sufficient time for the tension to dissipate as much - possibly due to raised Ca^{2+}. Elastic elements stretched. Followed by some form of standard textbook like explanation. The best answers mentioned the mechanical stretch of the elastic elements rather than just ascribing everything to calcium remaining high. On the whole this part was done well.

Feedback on the essay component of the exam:

Question B1a: ***What adaptations allow plants to survive fluctuations in the availability of soil nutrients?***

Mean mark: 62.1%. 41 candidates.

Most answers set the scene for the sessile nature and need for plasticity in mechanisms of nutrient acquisition, but failed to define micro- and macro-nutrients, or define range of fluctuations to include limitation, replete supply or possible toxicity. The best answers set the scene for temporal and spatial changes in nutrient supply, and then used each example to keep the "fluctuation" relevant to specific examples and some included the induction of assimilation (N, occasionally S) and storage of excess assimilates. Most tended to define nutrient uptake processes in terms of absolute availability, and went into detailed mutualistic associations (mycorrhiza, N2 fixation) and some included parasitism and carnivory. The best answers were able to provide a sophisticated contextual framework, and also provided mechanistic details of nutrient acquisition mechanisms and the associated plasticity in growth traits or induction of transport and assimilation processes.

Question B1b: ***What mechanisms allow animals to survive fluctuations in the availability of their principal energy source?***

Mean mark: 61.1%. 33 candidates.

My expectation was that most candidates would have started by defining what sort of fluctuations might occur and then sub-divide the mechanisms (fuel storage, mechanisms that make an organism efficient (i.e. training/detraining), motivation to forage, substrate switching, longer term metabolic changes, epigenetics). The question is relatively clear that it is the animal's principal energy source which is fluctuating. Since different animals have different energy sources, there also needs to be a discussion of substrate switching. Almost no candidate mentioned the single most important mechanism which is that most organisms are fairly efficient and have physiological mechanisms that ensure that they do not carry excess tissue beyond what is required (except for fat) - i.e. training/detraining. Many mentioned cows and rabbits whilst a few mentioned pandas all in the context of either not having fluctuations or switching fuel source. Some students decided to define glucose or ATP as the principal energy source – using the perspective of either cellular or sub-cellular fuelling as the starting point. Most did cover survival overnight – although very few actually tied this in to a reason for the fluctuation in energy source availability (i.e. darkness or sleep). Some used the classical diagram of fuel selection over time during starvation. Most mentioned protein sparing and ketones, but few gave any indication that the amount of protein available to be metabolized ranges more than the 50% given in the lectures. Gluconeogenesis was well covered as was the size of the liver versus muscle glycogen stores and the different end-points for the glucose. Most mentioned the need to build-up fuel stores (glycogen and fat) as well as food larders. Many mentioned scaling of metabolic rate (thyroid) and various forms of hibernation (some mentioned torpor). No one mentioned epigenetics (e.g. the Dutch low birth weight babies giving birth to low birth-weight babies). Many did however mention the need to focus on physiologically necessary processes during starvation (e.g. drop in fertility). Given the large amount of information to cover, few defined the boundaries well and gave concise conclusions. I was impressed by the coverage of ghrelin and leptin by a few students and the example (with drawing) of the 'honeypot ant' was good to see. It would have been good to have a bit more quantitative comparison of the size of the fuel stores and the relative costs of just basal metabolism versus exercise (foraging).

Question B2: ***How do animals and plants detect and respond to rhythmical changes in the environment?***

Mean mark: 59.6 %. 37 candidates.

Most gave a clear introduction and explained the distribution of a centralised circadian oscillator in multicellular animals and the cell-specific clock in plants. Generalised outputs were usually described in terms of metabolic regulation or behavioural responses (animals) versus developmental plasticity (plants). Some failed to distinguish between rhythmic detection and responses, and focussed more on more generally on sensing of absolute changes in light intensity (particularly for transduction of animal vision) and temperature. The best provided a clear comparative overview, as well as mechanistic details of both clock systems, and compared photoreceptor form and function between plants and animals. Most went on to describe associated physiological outputs in terms of daily circadian and seasonal responses, which the best integrated in a comparative essay.

Question B3: ***Discuss the diverse implications of Laplace's law for the 'design' of organisms.***

Mean mark: 63.5%. 13 candidates.

Most candidates managed to provide an acceptable form of Laplace's Law – there were two notable exceptions who gave Darcy's Law and wrote essays about the relationship between flow, pressure and resistance. Almost all students gave the example of blood vessel structure with capillaries being a single endothelial cells layer and arteries having circular and longitudinal muscle. They all also went on to talk about xylem, capillary action and cavitation. There was only one mention of collapsing alveoli and the role of surfactant and no one mentioned wall stress and the mammalian heart (Starlings Law) - neither is explicitly covered in 1A, but are relatively well known elements of physiology. A few discussed skin and exoskeleton (e.g. difference between terrestrial and tree climbing snakes) and the problems with size scaling and wall tension that are encountered. One candidate mentioned air bubble breathing aquatic insects – although the argument made concerning the mechanisms by which gases diffuse and the relationship to Laplace were at odds with the literature. Single-celled organisms were generally not discussed nor was scaling of other vessels beyond xylem and circulatory vessels. No candidate also discussed the problem of structures that swell considerably or the growth of cells and the limits on cell size. Nevertheless, the essays were of a generally high standard considering this was a new question.

Question B4: ***What mechanisms allow water loss to be minimised while organisms carry out essential gas exchange with air?***

Mean mark: 56.2%. 120 candidates.

The best answers to this question were quite impressive accounts of mechanisms used by animals and plants, with good detailed descriptions or diagrams of the underlying mechanisms. A number of answers included interesting examples from outside of the lecture material (e.g. efficient oxygen extraction by bird lungs reducing the total volume of gas used and so water lost). However, most answers were rather poor with candidates choosing to ignore the question and instead write in general on mechanisms of water conservation and osmoregulation unrelated to gas exchange. Many candidates failed to offer any mechanistic detail even when they correctly named an appropriate mechanism. Coverage of animal mechanisms was often poor. A large number of candidates illogically argued that mammals conserve water during gas exchange by producing concentrated urine and wasted time describing renal function. Some stated that animals cannot conserve water during gas exchange, even though slides of the lecturer conserving water during nasal breathing were included in the osmoregulation course. Plant mechanisms tended to be covered better, although many ignored C4 metabolism and only one candidate correctly explained how C4 helps conserve water. Some candidates confused C4 and CAM metabolism.

Question B5: ***What mechanisms do animals and plants use to produce rapid movements?***

Mean mark: 60.0 %. 112 candidates.

The majority of candidates provided reasonable answers to this question and clearly distinguished between tropic and nastic movements. Again most candidates understood that plant movements involved ion-fluxes and electrical signals. The best answers included most detail. Surprisingly the majority of candidates failed to quantify the speed of movements. Nearly all candidates used *Mimosa pudica* and *Dionea muscipula* as examples. A minority also discussed the response to wounding and spore ejection. Coverage of the animal mechanisms was impressive. Most candidates provided a detailed account of neuromuscular junction and muscle contraction. More creative answers included discussion of the swim bladder, sound production and flight in insects.

[redacted]

[redacted]

Date: June 22nd 2018