NATURAL SCIENCES TRIPOS 2018

IA PHYSIOLOGY OF ORGANISMS

SENIOR EXAMINER'S SUMMARY REPORT

Examiners

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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.

187 candidates completed the examination. After scaling as laid down by the Natural Sciences Committee, 25.1% of successful candidates received a first class mark, 64.7% a second class mark and 10.2% a third class or fail mark. 22 candidates sat the exam outside of the main hall. Two candidates failed. No candidates withdrew before the start of the examination.

<u>Written Practical Paper</u>

The mean raw mark for this paper was 61.8% (up from 51.8% in 2018), with a standard deviation of 10.1% and a range of 22.1% - 82.0%. All three questions during drafting were shortened, which seems to have had the desired effect of making the overall practical exam performance more consistent with that in the written paper.

<u>Theory Paper: Section A</u>

The mean raw mark for Section A in the Theory Paper was 64.8%, with a standard deviation (SD) of 12.9% (compared to 63.4 and 11.9%, respectively, in 2018) and a range of 28 – 93 (24.4 - 93.3% in 2018).

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 three questions there was a very low proportion of correct answers by all quartiles (one question had been identified as containing a typographical error, and another a poorly defined stressor) but the marks from all three questions were discounted and the remaining 42 marks scaled accordingly. The upper quintile consistently outperformed the lower quintile in nearly all questions; of those questions which were least discriminating, 4 had a high proportion of correct answers (80 - 90+%) and another 4 with many wrong answers (20 - 40% correct). The lecturers setting these questions 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 60.3%, with a SD of 8.03% and a range of 20 - 90%. This compares with 57.9% SD 8.03% and a range of 35- 80% in 2018).

Impact of Scaling and comparison across exam components

The overall performance in the exam showed a higher mean performance across all degree categories than in 2018, with the mark required for scaling to increase the number of Firsts (67.03%) increased (from 63.9% in 2018). There was a high correlation between performance in each of the three elements of the exam, with the MCQ (0.78), essays (0.83) and practical exam (0.81) demonstrating that the written practical performance did not help to discriminate between between experimental aptitude as compared to MCQ or Essays. A comparison with 2018 showed equivalent comparisons with the MCQ (0.89), essays (0.94) and practical exam (0.89). In the light of these findings, the examiners discussed whether the separate Practical exam was a worthwhile additional component of the examination process, or could perhaps be tested by extending the MCQ sections, and suggested this issue should be discussed at the Management Committee.

Conduct of the examination.

The sitting of both papers passed without serious incident. Two questions were asked of the examiner in attendance which related to the MCQ questions in the written paper. Two errors were found to have slipped into the final draft of the MCQ questions: for Q18, a typographical error left two identical (correct) answers, and Question 22 had wrongly been labelled as Q12. For each case, an announcement was made in the main exam hall. The Board of Examinations was informed and Colleges / Computing Suite duly notified in each instance. Q18 was one of those three questions removed from the final markbook (see above).

Administrative support during exam preparation

Recent changes in organising the management of NST courses led to individual Departments retaining administrative and organisational responsibility whilst the formal appointment of Course Organiser and Examiners continues to rotate between contributory Departments. The Senior Examiner understands that for many of these NST courses administrative support is available for organisation, preparation and formatting of examination papers, prior to submission for reproduction. He feels that some support of this nature might have precluded the minor errors which crept into the papers, whereby the pressures of crafting a range of question types (MCQ, Practical and Essay) and their typographical transcription needed to be completed within a very tight timetable given other academic demands at that time. The Senior examiner requests that some support should be available for future teams of examiners co-ordinating the Physiology of Organisms papers, and would like to explore the possibility with the PDN to see if this is a possibility. HG is grateful for the support of Teaching Staff in the Department of Plant Sciences for processing and sorting scripts after the examinations.

Feedback on the practical component of the exam (all questions compulsory):

Question 1
Mean mark: 67.0% (SD 13.4%)
This question was based on a practical class covering measurement of human blood pressure and recording of the electrocardiogram (ECG). Answers relating to blood pressure measurement varied but many candidates showed a reasonable knowledge of the technique used and results from the class.

Question 2
Mean mark: 64.3% (SD 13.1%)
Students showed good comprehension across this question about an ABA signalling pathway mutation, with full marks scored on most sections by multiple students. Overall it was clear that students had been given sufficient information to answer the entire question. The average mark for this question was quite high, as most were able to score at least some marks on each section (generally for describing results, even if not able to interpret them).

Question 3
Mean mark: 54.2% (SD 15.1%)
A surprising number of students seemed to be confused about what sort of recordings were being shown, using which transducer and from what structures despite the detailed image and textual description. There was a generally poor understanding of synaptic delays and what the EMG recorded on the surface of the skin represents.

Feedback on the essay component of the exam:

Question B1a*: What are the strategies that animals use to survive fluctuation in temperature?*
Mean mark: 59.1%. 69 candidates.
The essays reveal that many students have a good recollection of lecture material on the topic of thermoregulation however, a rather poorer ability to analyse and answer a specific essay question. The performance on this essay was largely down to the extent that students could identify and address the strategies that animals use to survive thermoregulatory insults. There is obviously far more material than could be written about in the time. So, the essay required an analysis of what is meant by survival, fluctuation and strategy. Instead of analysing survival most students stated a form of temperature optimum for enzymes and denaturing. Some did mention freezing but none negative energy balance and starvation. Students seemed largely ignorant of the effects of temperature on neuronal function - especially the brain in mammals. The exquisite temperature sensitivity of the brain has to be one of the main reasons for thermoregulation within tight bounds. For strategies I was expecting an argument as to why the student was going to include or exclude adaptations - and that would also require a definition of the time course of fluctuations. Some did sub-divide short and long term fluctuations and strategies. About 60% talked about ecto- and endotherms together with enzyme temperature sensitivities. Most failed to understand the critical nature of the control of blood vessels in 'normal' thermoregulation and few spoke about internal

heat generation as one of the drivers of temperature fluctuations. My advice to students would be to spend some time before writing considering what is actually being asked for and then grouping the mechanisms to allow generalizations to be made. There are (perhaps) three main strategies that operate on physiological timescales: avoidance of the external or internal lethal temperature challenge (loss of motivation to exercise, hibernation, torpor, circadian rhythms, aestivation/shade, burrowing etc); modifying heat exchange with the external environment; internal heat generation (skeletal muscle, BMR, brown fat). Then as species evolving there are also adaptations which might be considered as 'evolutionary strategies'. The extent to which those might be included depended upon the student.

Question B1b: ***Contrast the processes which control cell expansion leading to growth in plants, fungi and bacteria***

Mean mark: 55.5 %   9 candidates.
The limited number of candidates, and their high overall attainment, suggests that only those who were confident in having a detailed understanding of these comparative approaches were prepared to take on the challenge of this question. It was therefore addressed with some excellent insights by a number of the candidates, the best of whom demonstrated considerable breadth in knowledge of the contrasting cell wall structures for plants, fungi and within bacterial groups. Most clearly explained commonalities associated with expansion driven by a combination of relaxation (autolysis versus cell wall acidification/expansin activity) in plants and bacteria, and the contrast with the septate and polar focus of fungal hyphal expansion. This was generally set in the context of the primary or secondary role of solute accumulation in driving cell expansion, and the contrasts to be found between unicellular versus multicellular organisms. Some also demonstrated considerable knowledge of regulatory processes, environmental signalling and response factors regulating directional growth in fungi and plants. No candidates really set the context for plant cell expansion and differentiation into the concept of the apical or lateral meristems, although some described clearly the interaction between plant growth regulators (auxin, gibberellin) and underlying regulatory signals. The less successful essays either only described mechanistic processes without the comparative aspects, or provided a descriptive, comparative overview, lacking detailed explanation of cell expansion and growth fundamental processes.

Question B2: ***Discuss how organisms can use symbiotic relationships in order to gain nutrients.***

Mean mark: 59.7%   74 candidates
Most candidates covered plant symbiotic relationships with nitrogen-fixing bacteria and mycorrhizal fungi and animal gut flora. Some candidates also included other examples at least briefly. The best answers gave detailed accounts from the lecture material. Weaker answers gave very little physiological information, failing to comment where appropriate on how the symbiotic relationships named are established or how they function. Some candidates failed to mention both ecto- and endomycorrhyzal fungi or to mention both foregut and hindgut fermenters. A number of candidates thought that nitrogen-fixing bacteria produce nitrate rather than ammonium ions.

Question B3: ***What are the fundamental principles which govern fluid movement within organisms?***

Mean mark: 60%. 119 candidates.

Overall, this popular question was tackled with detail and a wide range of examples. The best integrated examples from across organismal continuum, and developed detailed regulatory processes. However, many focussed on plant and animal examples separately, rather than focussing on the commonality of underlying principles in the context of the contrasting physiological solutions in such organisms. Most essays started with a commentary on the limitations of diffusion in relation to organism size, and some quoted Einstein's Law. Nearly all candidates then defined Darcy's Law and the Poiseuille equation to explain the driving forces required for fluid flow and in particular the resistance imposed by pipework radius and the need for laminar flow. Some also used Laplace's Law to explain fluid movement in capillaries and a few applied this in a sophisticated fashion to explain the driving force for the movement of the transpiration stream in plants. Various examples were used to demonstrate pressurised fluid flow, which was often defined in terms of the movement of both liquids and air and illustrated by open and closed circulation systems and counter current flow. The best drew comparisons with the energy sources used to drive such systems which contrasted with ATP powered musculature, or the opportunity to use solar power directly (Xylem, through evaporation of water) or indirectly as a means of generating solutes for phloem transport. Other frequent comparisons included the constraints imposed by body size, and the need to deliver respiratory substrates and remove waste products, or provide a linear, more unidirectional transport system. The physical constraints of the plant cell wall and ultrastructural modifications to the ducting systems between plants and animals also provided fertile comparisons of elasticity, resistance to pressure (positive and negative) and occlusions when scaling flow and conducting area within vascular systems. Some wide ranging essays also gave examples of osmotically powered water movement in terms of kidney function, saliva generation and phloem loading/unloading. Others also included extensive regulatory detail of the heart function, vascular dilation or stomatal regulation to demonstrate how fluid flow could be regulated within organisms. Most essays only managed to include some of these comparative aspects of fluid flow and associated regulation, as compared to the limitations imposed by diffusion. Often the essays tended to lose focus after a promising start, and whilst including some of the basic laws and principles, failed to develop the physiological relevance in a comparative fashion.

Question B4: ***Compare and contrast the mechanisms used by plants and animals to sense the dark/light cycle***

Mean mark: 62.0%. 31 candidates.
This question was quite focused and many candidates spent too much time discussing the detection of light in general rather than keeping to dark/light cycles. It appeared that some candidates had come prepared to answer a different question. The weakest answers gave very complete descriptions of phototransduction in general, including that observed in *Drosophila*, but failed to link this to the dark/light cycle. Nearly all candidates identified phytochrome as a plant photoreceptor and could discuss in some detail the two interconvertible states. Some answers correctly identified the role of phytochrome in providing information about night time temperatures (in *Arabidopsis*). Nearly all answers reported that the plant clock has evolved separately from the mammalian clock and that each plant cell has its own clock. Better answers included a discussion of short- and long-day plants. Most candidates could discuss the role of ipRGCs and the SCN in circadian rhythms.

Question B5: ***Compare and contrast plant growth regulators with endocrine control in animal systems, and in doing so, consider how plants manage without a central nervous system.***

Mean mark: 60.5%. 73 candidates.

Overall this was a well answered question.

Many candidates could discuss phenotypic plasticity in the context of plant growth regulation. Most candidates avoided discussing the low concentrations of plant growth regulators (low molecular weight organic molecules) although every cell could produce PGRs and can be induced by environmental input. Surprisingly few candidates could discuss all the PGRs mentioned in the lectures: auxin, cytokinin, gibberellin, abscisic acid, ethylene and strigolactone.
Most candidates were able to discuss, in reasonable detail, the role of ABA (they would have come across this in the practical classes) and chose to compare this with the role of ADH in responding to dehydration. This was a suggested key theme in the handout and therefore pleasing that the candidates had clearly considered this in some detail. Given the amount of information in the lectures on endocrine control in animal systems it was surprising that many candidates did not stray far from ADH or thyroid hormones.
While many candidates gave a good description of the chemiosmosis model of polar auxin transport, including a discussion of the efflux carrier PIN1, weaker answers lacked detail including the velocity of IAA^-. Surprisingly few answers mentioned apical dominance or nitrate availability driving lateral root development. The suppression of lateral bud outgrowth by strigolactones was also not commonly mentioned. Most candidates could discuss the negative regulation i.e. the inactivation of repressor proteins and that negative regulation has been shown by mathematical modelling to allow a faster induction of downstream responses (although no examples were given). They were able to compare this with the positive regulation of animal hormones. Many candidates were able to describe in some detail the role of Gibberellins via the destruction of the DELLA protein. A number of answers included a brief discussion of the role of jasmonic acid in the response to wounding or leaf injury.
The weakest candidates spent the majority of the time addressing the second part of the question, and while largely correct, they could not score highly as they had failed to compare plant growth regulators with endocrine systems in any detail.

Conclusions and Recommendations:
(i) The Physiology of Organisms Management Committee should discuss the scope and extent of the practical exam and perhaps modify the format
(ii) The Biological Sciences Committee or NST Committee should be asked to provide a statement to quantify the level of administrative support that should be provided by the hosting department of Part I courses to Course Organisers (as relates to maintenance of a Course website and Moodle site preparation) and Examiners (Exam script co-ordination, appointment of assessors). This is particularly relevant for those key post-holders who may not be associated with the hosting Department

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Date: June 24th 2019