NATURAL SCIENCES TRIPOS

SENIOR EXAMINER'S REPORT

SUBJECT: **Part 1A Biology of Cells**

Senior Examiner: [redacted]

Examiners: [redacted]

[1] previously acted as an examiner and senior examiner in this subject
[2] previously acted as an examiner in this subject

Assessors:
Theory paper, Question 1 short answer questions: [redacted]
Written Practical paper: [redacted]

[1] acted as an assessor for this subject in previous years

Structure of the examination:

Written papers:
Theory paper BOC/1: section A contained 15 compulsory short answer questions, section B contained 9 essay questions, of which 3 are chosen.

Written practical paper BOC/WP: 9 compulsory questions.

Practical components: none

Number of candidates: 276 candidates listed, of whom 2 were withdrawn, leaving 274 who sat both the Theory and the Practical papers. All candidates are registered for the Natural Sciences Tripos.

Number sitting the exam/s outside the main exam hall/s: 28 (10%) for both papers.

Conduct of the Examination:

- The Written Practical paper was composed of 9 questions. Last year the questions were only 8 because of industrial action during 2018 Lent term.

- The time tabling of the examinations was exactly as scheduled. Both examinations were held in the Sports Hall of the Cambridge Sports Centre: BOC/1 on Tuesday 4th June from 9 am – 12 noon; BOC/WP on Saturday 8th June, 9am - 12noon.

- The Senior Examiner was present for the beginning (first 45 min) of both papers. In addition, [redacted] was present for the beginning of the BOC/1 paper and [redacted] were present for the beginning of the BOC/WP paper.

- All examiners were also contactable by mobile phone throughout each examination.

- Students were asked to not take any paper, including the exam paper itself, from the examination hall, and exam papers will be published online (*via* Moodle) about 3 weeks after both exams had finished, once the process of marking has been completed.

- Students were asked to remain in the exam hall whilst papers where collected.

- There were no student questions of substance in either exam. Most questions related to students labelling and assembling answer booklets *etc.* at the end of the exam. In all cases the Examiners instructed and reassured students that any errors would not affect their marks.

- Numbers of students answering each of the BOC/1 essay questions (3 chosen from 9) were:

	Theory – Essays								
Question	**Th 2**	**Th 3**	**Th 4**	**Th 5**	**Th 6**	**Th 7**	**Th 8**	**Th 9**	**Th 10**
Number of answers	175	164	172	19	88	54	62	40	43

We received only two essay answers from three candidates. Two candidates recorded only two essay questions attempted. One candidate recorded 3 questions answered on the yellow cover sheet but only 2 questions were recovered.

Marking/Scaling:

- Scripts were collected by [redacted] at the end of each examination and delivered to the Department of Zoology, Elementary Teaching Laboratory. Each script was verified and checked against the yellow cover sheets. Question numbers for each candidate were recorded and verified independently. This was a smooth operation without difficulties.

- Scripts were distributed by 5pm of the day of the exam to assessors (BOC/1 short theory questions; BOC/WP questions - all) and examiners (BOC/1 essay questions) for marking.

- Late scripts from candidates, who sat papers in colleges, were distributed within approximately 48-72 hours.

- One candidate stated on the front yellow sheet that he/she was answering Q4 but it was instead answering Q3. This created a bit of confusion and the script had to be transferred from one examiner to another.

- No scripts needed transcribing after having been collected by the Examiners.

	Number of students	Percentage %
First class	70	23.7
Second class	174	69.3
Third class	29	6.6
Fail	1	0.4
Total	**274**	**100**

	Theory % (unscaled)	Written Practical % (unscaled)	Unscaled combined mark %	Scaled final mark %
Mean mark	37.9	19.6	57.8	57.5
SD	12.9	6.9	18.9	19.3

The mean performance across the Theory and Written Practical papers was very consistent, with a higher variation between students in the Written Practical Paper. Fine-grained analysis showed that most students perform similarly well in both exams, with occasional students doing better in either the theory or practical paper.

Variation on performance: The mean performance across the Theory Essays was very consistent (11.8-13.6). There was more variation amongst the answers for the short theory and written practical questions, but this was not a concern as the short theory and practical questions were all compulsory in those sections, and some of the variation can be attributed to weak, or incomplete attempts by some candidates for some compulsory questions.

Subject Examiners' Meeting:

After checking and correcting the entry of marks, the scaling exercise was carried out by pasting the raw marks in a spreadsheet obtained from [redacted], the administrative officer for NST. This automatically identifies the values of a and b (as described in appendix 5) and produces a scaled ranking. Those values have not been modified.

The value for *a*, the raw mark for the lowest individual in the top 25% of the candidates was 70.32, and the value for *b,* the raw mark for the lowest individual in the next 65% of the candidates, was 51.61.

Administration:

The Senior Examiner is greatly indebted to [redacted] and their colleagues in Zoology for their exemplary, efficient and friendly support while sorting and delivering the scripts and throughout the marking period. This is especially important in years, such as this one, when the Senior Examiners is not a member of Zoology. The fact that processing of scripts remains with this experienced team even when the Senior Examiner role rotates through four different Departments is noted and thoroughly appreciated. The extent to which [redacted] in particular has taken responsibility for ensuring that this process runs efficiently, including the chasing up of late scripts, is always impressive and highly commendable.

All Examiners and Assessors are thanked for completing their share of marking to an impressively high standard within the short time available.

Conclusions and Recommendations:

- **Recommendations relating to the conduct of the examination for the Final Senior Examiners meeting.**

None.

- **Suggestions for change in post-exam procedure for the Course Management Committee**

The Senior Examiner is pleased that a long-term solution for the transportation and the sorting out of the scripts at the end of each examination has been found. This is a time-consuming task where mistakes can easily occur and can have a serious detrimental effect on the correct and timing completion of the marking process. The SE is also very pleased that [redacted] and colleagues at the Zoology department have accepted to look after this task and is convinced this is the best solution to minimise future problems.

Based on the suggestions of the previous Senior Examiner, complete model answers will no longer be released to Supervisors after the examination. Instead the Senior Examiner has decided to release a heavily redacted set of answers comprising only the mathematical solutions to calculation problems. This decision has been reached to provide the maximum possible support to the supervisors without affecting the exam process. With a limited range of questions available to the examiners for the Written Practical Paper any release, intentional or unintentional of model answers to Undergraduates would potentially compromise the assessment by written examination. The release of redacted answers prevents the risk of compromising of the Examination because the solutions to the problems are unique on a year by year basis.

This year the SE has decided to wait until the process of marking has been completed before publishing on Moodle the text of both papers (around three weeks after the end of the exams). This is to avoid any interference in the delicate process of marking.

- **Suggestions for changes to procedure for future Subject Examiners**

In the Biology of Cells Consultative Committee held on the 12th of June 2019, the students' representatives have raised the question about knowing in advance the percentage values of each practical question and the values of each sub-questions in order to prioritise the most important questions to answer. The SE pointed out that each question in the practical exam worth the same value (as stated in the exam paper cover sheet). For the sub-section, it is complicated to write in advance the exact value for each of them. Moreover, often the sub-questions have to be answered in order (i.e. later sub-questions cannot be answered if the previous have not been answered already) therefore the choice of which sub-question to answer becomes irrelevant.

The use of exam booklets and allowing students to write on both sides continued to work well after its introduction three years ago. The use of separate answer books for each of the questions of the practical exam introduced few years ago was continued and was found to be helpful for distributing the answers amongst the assessors. The rubric of the Written Practical paper should be improved to clarify that each answer should be in a separate book. This is very important when it comes to distributing the questions to the assessors. If multiple questions are answered on a single booklet, photocopies are needed to allocate the right question to the right assessor incurring a serious waste of time and increasing the possibilities of mistakes.

- **Recommendations for inclusion in the Chairman's report for taking forward either to the NST Management Committee or to the Board of Examinations.**

The Senior Examiner would like to commend the participating Departments for taking to heart forward planning with regard to putting examiners in place in good time.

The Senior Examiner also thanks the administrative support received by the Department of Biochemistry (in particular from Sandra Fulton and Wendy Bundi) and strongly supports the fact that the role of Course administrator ceased to rotate. The knowledge base and skills of an experienced course administrator are an effective resource to the Senior Examiner.

It was noted again this year that the amount of time devoted by senior UTOs to running the whole examination procedure is excessive. For BoCs, five UTOs spend many hours facilitating the process, adding up to serious FTE expense for the University. The examiners would like the NST Management Committee and the Board of Examinations to consider if automating part of this process would be advantageous *e.g.* barcoding exam scripts with an automated link to marking spread sheets. In many Universities, commercial software is used to speed up the grade collation and scaling processes.

Senior Examiner
25th of June 2019

Appendix 1

A comparison of the distribution of students (%) prior to scaling 2011–2019

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Class size	330	306	286	293	295	282	268	285	276
I (≥70)	9.7	14.1	18.2	10.6	14.9	21.3	17.2	21.1	26.6
II (50-70)	78.2	73.5	68.5	79.8	67.8	70.9	73.1	71.9	66.4
III+F (<50)	12.1	12.4	13.3	9.6	17.3	7.8	9.7	7.1	7.0

A comparison of the distribution of students (%) after scaling 2012–2019

	2012	2013	2014	2015	2016	2017	2018	2019
Class size	306	286	293	295	282	268	285	276
I (≥70)	23.5	24.8	25.3	25.8	24.8	25.0	25.3	25.2
II (50-70)	66.3	65.0	65.0	64.1	64.6	66.4	64.5	65.3
III +F (<50)	10.1	10.1	9.6	10.1	10.6	8.6	10.1	9.5

Distribution of raw marks in each 2019 BoC paper:

THEORY PAPER

Short questions (1a–1o) were marked out of 5 and the essays (2–10) marked out of 20.

Key: mn = mean, sd = standard deviation, % "0" = percent answers that scored zero marks or were not attempted.

Short questions:

	1(a)	1(b)	1(c)	1(d)	1(e)	1(f)	1(g)	1(h)
mn	2.2	3.3	2.9	3.0	2.5	2.6	3.8	2.9
sd	0.8	0.9	1.0	1.1	1.6	1.4	0.9	1.5
%"0"	3.1	2.4	2.4	1.7	14	12.6	0.7	13

	1(i)	1(j)	1(k)	1(l)	1(m)	1(n)	1(o)
mn	3.3	3.4	2.4	3.2	3.0	2.7	2.4
sd	1.3	0.8	1.4	1.4	1.2	1.4	1.4
%"0"	5.5	1	11.6	8.5	8.5	17.1	20.5

Essays:

	2	3	4	5	6	7	8	9	10
Number of scripts	175	165	172	19	89	54	62	40	43
% students	59.7	56.3	58.7	6.5	30.4	18.4	21.2	13.7	14.7
mn	13.6	12.2	13.1	12.6	13.5	12.6	13.2	13.5	13.0
Sd	2.8	3.1	2.4	2.6	3.1	3.8	3.4	3.1	2.2

PRACTICAL PAPER

Questions (1-9) were marked out of 10.

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
mn	5.8	6.5	6.3	6.7	5.5	6.6	6.7	5.8
sd	1.4	2.2	1.6	1.7	2.6	2.0	2.0	1.5
%"0"	0	0	0	0	3.4	1	0	0

Appendix 2

Feedback on questions from Assessors and Examiners *(edited by the Senior Examiner where appropriate)*

Theory paper

Question 1 *(short answer questions, all compulsory)*

(a) Excluding DNA replication, summarise two ways in which the information encoded in DNA sequence can be "read" by cellular processes.

Nearly everyone correctly identified transcription as a cellular process involved in reading the information encoded in DNA. A complete answer should have described transcription by RNA polymerase involving local denaturation/unwinding of the DNA double helix allowing base pairing of ribonucleotides to generate a complementary mRNA transcript. This can then be used in translation to synthesise protein (carried out by ribosomes). Relatively few students identified a credible second process: DNA binding proteins (e.g. transcription factors like sigma factor) reading base sequence information in the major/minor groove. Unlike the example above, this does not require unwinding of the double helix, but the protein can recognise certain base functional groups exposed in the grooves. This controls regulation of gene expression.

(b) Summarise the advantages and disadvantages of electron microscopy, as compared with confocal light microscopy, for examining the structure and function of cells.

This question was very well answered by the vast majority of students. I would say that a large number of students were good at describing the advantages/disadvantages of EM, but were less good at incorporating the comparison to CLM into the structure of their argument (e.g. “EM requires fixation/staining so only dead samples can be viewed” compared to “EM requires fixation/staining so only dead samples can be viewed, while CLM allows one to view live cells and to study dynamic processes occurring in real-time”).

(c) How many chiral carbons are present in the linear form of D-glucose, and does this change in the pyranose ring form? Why is stereochemistry important for the biochemistry of sugars?

A number of students correctly identified that there are 4 chiral carbons in linear D-glucose, and this increases to 5 in the pyranose form (with generation of the additional anomeric chiral carbon on C1).

(d) How does the structural diversity of membrane lipids help cells to function as temperature varies?

Overall a strong set of answers to this question. Students should have noted:

(i) Importance of maintaining the liquid crystal state (membrane fluidity/integrity/protein function) over a wide range of temperatures
(ii) Varying phospholipids in the membrane broadens the phase transition temperature range
(iii) Varying the fatty acid side-chain is an important factor (lipid composition)

(iv) Especially the number of C=C double bonds (degree of unsaturation). Fatty acid chain length also plays a role
(v) Phospholipid generally 1 saturated, 1 unsaturated chain: cis unsaturated C=C bonds generate kinks in the tail meaning the membrane is less likely to gel at lower temperatures
(vi) Sterols restrict temperature-induced structural changes by preventing tight packing of fatty acid tails at low temperatures (intercalation of rigid steroid ring) and stabilising the membrane at high temperatures through interactions of polar -OH group with fatty acid heads (preventing dissociation)

Might be worth emphasising the difference between cis and trans double bond – with cis generating a more pronounced kink in the tail.

(e) Briefly outline the different mechanisms used by organisms to synthesize glutamate.

Answers to this question were quite variable in quality and detail, but an impressive number of students could give an accurate account of both pathways:
Animals/fungi:
2-oxoglutarate + NH_4^+ → glutamate (Glutamate dehydrogenase)
Reductive amination via formation of Schiff base (requires NADPH)
Km for GDH = high compared to tissue concentrations of NH4+
Plants/fungi:
GS-GOGAT cycle
Glutamate + NH_4^+ → glutamine (glutamine synthetase)
Glutamine + 2-oxoglutarate → 2 glutamate (glutamate synthase)
This process requires ATP (energy investment) but Km for GS is much lower than for GDH

(f) How does GluT4 regulate glycolysis in skeletal muscle and adipose tissue?

Twenty-seven students scored zero on this question. The students who scored zero fell into two groups; those who did not know what GLUT4 was, and invented wildly different roles in cell signalling and gene regulation, and those who mixed it up with GLUT2 and therefore described insulin independent transport. One student (entertainingly) admitted to not knowing what GLUT4 was and spent a page and a half suggesting different biological roles for what it might be. None of which were correct. Of those who correctly described insulin dependent transport, roughly half just gave a few sentences on the insertion of the carrier into the membrane, with no mention of the different tissues. However, a number of excellent answers described the transport in the different tissues, and several made comparisons to GLUT2. One outstanding candidate also sketched the kinetics of GLUT2 vs GLUT4, which was even correct.
If one wished to make this an easier question in future years it could be rephrased to insulin-dependent transporter, rather than GLUT4. However, I thought this was a great question to test a specific area of knowledge, and clearly differentiated between more and less able students.

(g) Describe the structure of glycogen and starch with reference to how the structure influences their roles as energy stores.

There were a few common errors in the structure of the polysaccharides. Several students confused the structure of starch for cellulose, and talked about beta glucose. A large minority of students also got the branching frequency out by an order of magnitude. The best answers

to this question included some descriptions of enzyme kinetics for glycogen break down compared to starch. As this cropped up a few times one assumes they had a common supervisor. Weaker candidates still managed to score a mark on this question by the comparison between the roles of the polysaccharides in plants vs animals, even if they didn't manage to give the correct structure. Interestingly only 5 candidates actually drew out the structure. It was not required, but in previous years there have been more students illustrating the branching position. The majority of diagrams were not useful and made an attempt to poorly sketch the differences in branching.

(h) Why is it appropriate to refer to dominant and recessive phenotypes, but not to dominant and recessive alleles of genes? Illustrate your answer with one specific example.

In general, this question was well answered, with the majority of candidates using the expected example of sickle cell anaemia and presenting the comparisons of phenotypic levels either in a table or listing the different dominance types in text.
Some candidates included a table with no explanation, and several of these had incorrect information in the table. Some candidates did not use an example, which was a shame.
The candidates who scored zero misunderstood the question and described epistasis.
The majority of answers were well thought through, and showed a good understanding of basic genetics. There were three answers in particular which shone through, as they used examples of different variants in p53 and described clinical and molecular features.
Several students tried to use p53 as an example, and did so superficially, but these three (presumably from the same supervision group) went through the different dominance types very clearly.
A few students use the example of mouse coat colour, but not many. A small number of students worryingly gave the opposite answer to what was expected

(i) What is a sigma factor and how is it important for the initiation of transcription in bacteria such as E. coli?

The majority of students were able to give the correct sequence for the -10 and -35 boxes, with some students correctly describing the -10 box as the Pribnow box, which I wasn't expecting to see. Marks were lost on this question for two main area, one, not understanding what sigma factors actually are (the majority of candidates made no mention to the holoenzyme, and a few seemed to believe they were not proteins!).
Secondly, a number of students seemed to be confused between the mode of action of sigma factors, and 2D scanning. Several students had clearly misunderstood the comparisons to be made between sigma factors and the basal transcription factors in Eukaryotes. These misunderstandings extended to the use of TATA box as well. The majority of students made some attempt at a sketch to show the location of the -10 and -35 boxes relative to the transcription start site (although several sketched them downstream…).
Students who scored zero on this question described the role of sigma factors in DNA replication. In these cases I have no idea what they were mistaking it with.
A number of candidates demonstrated an excellent knowledge of the different sigma factors in *E.coli*, often by including a table showing all of them and the types of genes activated.

(j) Name, and briefly describe, the characteristics and functions of three types of RNA involved in the process of protein translation.

The majority of answers to this question were relatively superficial. A number of low scoring answers simply listed mRNA, tRNA, and rRNA. The next set of cohorts added a single word or short sentence to each type of RNA, many of which offered no explanation or context. Most candidates were at least able to describe mRNA in some level of detail. Few candidates gave any detail on rRNA.
There were a number of common errors in answers to this question. Many students mixed up translation and transcription, which is concerning. Several students described mRNA as DNA that had been "cut out" to be translated. Some candidates who attempted to give detailed answers gave incorrect descriptions of the constituent sizes of prokaryotic and eukaryotic RNA subunits, whilst others gave incorrect tRNA motifs.
The best answers included detailed diagrams of tRNA with the correct motifs and key bases labelled, comparisons of prokaryotic and eukaryotic rRNAs and comparisons of the role 5'cap and shine delgano sequences in mRNA.

(k) Briefly describe the main challenges in annotating eukaryotic genome sequence and how they can be overcome?

Many students failed to read the question properly and instead answered problems with sequencing a eukaryotic genome. This resulted in a large number of students getting a 0 or a low mark.
Where students did understand the question, there were many very strong answers and solutions presented to the problem. Students had grasped well the way mRNA sequencing could be used to aide in annotation – particularly tissue specific expression of splice variants. A small number of students also connected this to ChIP-Seq to identify regulatory binding sites upstream of particular transcripts.

(l) Name and briefly contrast two alternative cycles of viral replication.

Where students understood the material, they were easily able to answer the question. There was some confusion regarding the level of specificity, some students appeared to think the question was asking for two answers rather than two broad classes.
Almost all students were able to partly answer the question, suggesting that the material was widely understood.

(m) Describe how the membrane phospholipid phosphatidylinositol 4,5-bisphosphate is used to generate second messengers.

The question was well answered. Most students understood the basics of the signalling system and excellent students were able to highlight their knowledge of the pathway. There were many very high-quality answers. Students obviously understood the material very well. There were no obvious points of weakness.

(n) How could you experimentally test if the sequence responsible for the localisation of an mRNA to the anterior of the developing Drosophila egg (oocyte) is in the 3'UTR (untranslated region)? Briefly describe one experiment and one control.

The question asked the students to design an experiment to test the hypothesis that the 3'UTR of an mRNA was responsible for localization and to suggest a control experiment. The question was poorly answered with many students instead explaining experiments involving bicoid/oskar and development instead of mRNA localization. Furthermore, many students misunderstood that the localization was of an mRNA not of a protein.

The control experiments were also poorly designed, with many students seemingly unaware of how to design a control. Where the students suggested a control, it was frequently just another experiment (for example a substantial number of students suggested deleting the 3'UTR as a control experiment).
A small number of students provided excellent comprehensive answers – suggesting that they understood fundamental principles of experimental design.
The main problem appeared to be a misunderstanding about experimental design. This likely suggests a wider issue in the course structure and perhaps should be addressed in the practical sessions.

(o) What sets the apico-basal axis of the plant embryo, for example in Arabidopsis?

Some students had run out of time with this question. However, when answered this question was well attempted. Students understood the question and the topic.

Essay questions (3 chosen out of 9)

2. *Macromolecular polymers enable enormous functional diversity of molecules to be created. Discuss this statement in relation to the properties of polysaccharides, nucleic acids and proteins, and give examples of how functional diversity is achieved in each.*

On the whole this question was answered well, where answers generally differed by the amount of detail, or by the engagement with the question. Occasional scripts had examples that differed from others, although most used similar details – just varied in terms of detail etc.

3. *Using examples, explain how ionic gradients are formed then dissipated across the cell membrane and why these processes are important for transport of small molecules across membranes.*

Overall quite strong answers. Strong answers related the question to the Nernst equation and introduced diverse examples of transport. Strengths were integration of material from PoO and from throughout the BoC course, including the signalling component in Easter term. Stronger answers presented a detailed understanding of transporter protein structure and function. Weaker answers were thin on detail or failed to consider energetic aspects of the topic.

4. *With examples, outline the principles and main components that underpin the functioning of electron transfer chains in biology.*

This was a very popular question and many students had a good overall understanding of electron transport chain in both mitochondria/oxidative phosphorylation and in chloroplasts/photosynthesis, if lacking a bit in the detail of the individual components. The essays that scored the highest made use of a number of diagrams in part because this helped demonstrate that the students understood how the electron transport chain contributed to H+ pumping. Some students went further and could talk about electron transport chains in bacteria, including those that relied on nitrogenase and chemotrophs. Good answers could discuss how individual components pumped protons and drove ATP

synthase. Poor answers focused either just on oxidative phosphorylation or photosynthesis, or made numerous mistakes in their description of the electron transport chain.
It was difficult to discriminate between the bulk of these essays as many students had a good grasp of the overall picture but less of an understanding about specific components. I suppose it's good the main message goes in but it did make for a lot of similar answers!

5. *What role does the NAD^+/NADH ratio play in regulating metabolism across the cell?*

This question was meant to bring together a number of lectures to summarise how redox potential in the form of NAD+/NADH ratio influences metabolic flux and regulates glycolysis, the citric acid cycle, beta-oxidation and oxidative phosphorylation. The comparable question asked previously has been the role ATP in regulating global metabolism and this is done well. As a result, I was rather disappointed by the small number of students that attempted this question and the quality of some of the answers. Very few students mentioned that oxidative phosphorylation is tightly coupled and hence if ATP is not being consumed NADH will accumulate and inhibit the citric acid cycle. Many of the essays rambled somewhat, particularly after covering regulation of the citric acid cycle. Despite my disappointment there were a few essays that dealt with the NAD+/NADH across core metabolism and even managed to discuss its role in the regulation of pyruvate dehydrogenase and oxoglutarate dehydrogenase.
It might be useful to provide some specimen questions that tries to synthesize information across lectures but I imagine that students will always find tough questions that require synthesis of information from several different lectures.

6. *What were the main contributions of bacteriophages to progress in genetics and molecular biology during the second half of the 20th century?*

Answers ranged from the very good to the thin and scrappy, and provided good discrimination.
Most students discussed the Benzer rII intragenic mapping and complementation experiments, with greater or lesser precision in the logic. Most also discussed the use of phage as cloning vectors. About a quarter discussed the Hershey/Chase experiment, and about the same number the Crick/Brenner triplet code experiment. Only a few discussed the phenomenon of general transduction explicitly, or mentioned the discovery of restriction enzymes as resulting from phage research. Two or three mentioned CRISPR. None mentioned M13 phage in DNA sequencing. I guess this must have been mentioned in a different set of lectures.
Quite a lot of students thought that Benzer invented complementation tests, and that he made the first genetic map. The nuance that he was the first to do this in haploid organisms (at least for complementation) was clearly lost on some of them.
The better students spelt out the logic of the Benzer experiments really well, but a lot of weaker students thought that the rII complementation test involved recombination, not just multiple infection in the permissive host.

7. *Describe two common approaches for genome sequencing and discuss how the development of next generation sequencing approaches have impacted on our understanding of the human genome.*

This question was answered quite correctly. The students were mostly evaluated by the amount of details they were retrieving. Only few students were discussing in a constructive way the ethical implications of human genome sequencing.

8. *Describe the molecular events in the mitotic spindle checkpoint and what happens once the checkpoint has been satisfied to allow the cell cycle to progress.*

This question was correctly answered by most of the students. The role of Cdc20 and APC in the checkpoint was described quite well. Less clear was the role of Bub1 and BubR1. The molecular aspects of cytokinesis were also mentioned in the best answers.

9. *How does fertilisation of a vertebrate egg by a sperm begin the development of the embryo and establish polarity.*

This question was set on the cell signalling component of the course, but also relates to some material in the development section of the course.
The best students wrote about both of these topics, and provided answers that I considered to be strong firsts. They provided a detailed account of calcium signalling in the context of the acrosome reaction, sperm entry into the nucleus, calcium waves, and the downstream effects thereof. They also discussed cortical rotation induced by sperm entry in Xenopus, and the effects of this on shifting maternal determinants to determine dorsal/ventral polarity.
Some of the students talked about only one or the other of these topics. Those who talked only about development had relatively little to say of direct relevance to the question. A good number chose to include material on polarity determination in Fucus and Drosophila (oskar, bicoid, etc.), generally without commenting that these are not vertebrates, and some talked about Hox genes defining differences along the A/P axis, and polarity in the context of the vertebrate limb.
Almost all students said that gravity determined the animal/vegetal axis of the Xenopus egg after the egg is laid, by making yolk and associated messages sink to one side (This is as stated in their notes.) Is this true? My understanding is that the animal vegetal polarity is determined in the oocyte, as it is in almost all other animal eggs, and that the asymmetric distribution of yolk and messages is already present before the egg is laid. This asymmetric distribution then causes the egg to float with vegetal pole down and animal pole up. It is true though that tilting the egg after egg lay can redistribute yolk and messages, and affect polarity. Please check and amend notes accordingly if inaccurate.
Some student said that in humans the direction of the calcium wave polarises the egg cell. None gave evidence for this. Is it true?

10. *Imagine you have been awarded unlimited funding to address the research question of "how do multicellular organism develop". However, you are restricted to the use of a single species for experimentation. Which species would you choose and why?*

Apart from a few very good scripts, the answers to this question were by and large disappointing. Fully 25 of the answers simply chose Drosophila, and did a more or less unfoccussed brain dump of what they already knew about Drosophila development, with little or no discussion of the purpose of studying development, or what makes a good model for studying it , beyond the basics of what makes Drosophila good for genetics - short generation, large populations and fast development. A further 9 scripts compared across species in a more focussed way, considering plusses and minuses of several species before opting for Drosophila in the end. These included some good scripts. The

remaining 9 scripts, after more or less comparison, made a range of different and sometimes surprising choices (2 each for human and Arabidopsis, one each for monkey, Xenopus, chick, mouse and "mammal"). These too were quite focussed on the question, and included some good scripts.
I had high hopes of this question, but in retrospect, only the very best students at this level have enough perspective on developmental biology, the range of possible questions to be asked and techniques to be used, to give a satisfactory answer. This would be a better Part 2 question!
The answers made clear that the Cells course focusses on "classic" developmental models, and barely introduces the students at all the new areas associated with mammal development - mouse manipulative genetics, stem cell biology, and single cell sequencing. They leave the course with no appreciation of the power of mouse as a model in developmental biology.

Written Practical paper

1. Microscopy [redacted]

The question was well answered overall showing that the students had sufficient knowledge and were quite able to deal with the situations presented. The higher marks correspond to answers showing good command on the topic and the ability to use on purpose the different microscopal techniques. The majority of the marks reveals a good understanding of the techniques with, to various extend, some lack of accuracy in the answers. The marks distributing at the lower end correspond to answers showing only partial knowledge of the techniques and difficulty to distinguish between them.
Question a) was well answered overall, the students could generally remember some technical details of their practical experience but they quite often didn't clearly describe the phase contrast microscopy as a technique to enhance the contrast required to visualise transparent samples by light microscopy.
Questions c) and g) were generally less well answered and many answers provided similar approaches to the ones developed for questions a) and b) respectively (visualisation of the tardigrades with phase contrast microscopy and visualisation of the distribution of mitochondria with some stain visible with bright field microscopy - toluidine blue suggested on several occasions).

2. Protein Structure

Part a: The majority scored full marks for this part, and the few students that didn't either believed that the alpha helices were left-handed, or merely listed all elements of secondary structure that they could think of.
Part b: ~2/3 of candidates recognised that this was haem, ~50 % of these recognised that Fe reversibly bound oxygen for transport.
Part c: No marks were awarded for listing haem from haemoglobin as a 'different' prosthetic group. The majority of successful students cited prosthetic groups from electron transport chains, but there were also some other pleasing examples of enzymes with prosthetic groups from elsewhere in the lecture course. This question highlighted where candidates were confused about terminology such as 'prosthetic groups', 'coenzymes' 'cosubstrates' and even 'ligands'.
Part d: Most candidates recognised that hydrophobic residues would be found within the core of the protein. The most favoured amino acid side chains drawn for this part were gly, ala, val, and leu. No marks were deducted for minor spelling errors, but the number of students missing the final 'e' from
glycine/proline/alanine/valine/leucine/isoleucine/aspartate/glutamate/arginine/ glutamine/phenylalanine/threonine/serine was notable this year.
Part e: Most candidates identified that hydrophilic residues would be present on the outside of the protein. Common errors included: a. confusing aspartate with glutamate, b. listing functional groups alone instead of full side chains (e.g. –OH for serine), and b. including carbons making >4 bonds.
Whilst the mean average score for this question does not appear to be significantly higher that for other questions on the paper, more students attained full marks. Most students correctly identified the alpha helices in **Part a**, and I suspect that they have now come to expect this as a standard element of structural questions. **Part c** (concerning other prosthetic groups) was a good means of assessing how well candidates understood the terminology surrounding cofactors. ~60 % of the marks for this question were awarded on

the basis of a candidate's ability to recall from memory amino acid side chains rather than their interpretation of the data (myoglobin structure) presented and I wonder whether this ratio of memory recall: data handling skills was slightly too high for this question this year?

3. Enzyme activity *([redacted]*

Part a: Mostly answered correctly (although some candidates spent time deriving this from first principles).
Part b: This was also mostly answered correctly and many candidates elected to represent this graphically
Part c: <10 % of candidates thought that Km=Vmax/2.
Part d: Candidates appeared to find this question the most challenging. Just over 50 % correctly identified Reaction 1, but their reasoning was often vague and this seemed to be a guess in many cases (full marks were only awarded for appropriate reasoning).
Parts e-f: Answers for these questions tended to be very similar.
Part g: A worrying number of candidates stated that the concentration of water in aqueous solution at room temperature was 1 M, and a handful discussed the hydrophobic effect.
Part h: Axes labels and units were required for the allocation of full marks.
Part i: Units were needed for full marks, +/- 0.09 accepted (for both Vmax and Km calculations.
Part j: A lot of confusion regarding the reciprocal nature of the plot presented itself here.
Part k: Most candidates realised that Vmax would double, slightly more than ½ of all candidates realised that Km would remain unchanged, but of this ½, only ½ again were able to correctly plot this. Interestingly, most students did not use the fact that the X intercept = -Km and spent time recalculating gradients.
Part l: Most students were able to recall this from memory.
I thought that this question provided an excellent means of testing candidates' fundamental understanding of enzyme kinetics in a way that did not solely rely on regurgitation of lecture material. There was a wide range of the types of question that were asked. I.e. **Parts a-c** asked for basic terminology, **Parts d-g** tested candidates' understanding of the principles and assumptions upon which MM kinetics is based, **Parts h-i** assessed data handling skills, and **Parts j-l** tested candidates' understanding of the nature of reciprocal plots. Only 3 students appeared to run out of time (and this is unusual for graphical questions). As an assessor, I really appreciated that this question was split into several parts with clear and even mark allocation. I felt that this question thoroughly tested candidates but at the same time, provided such a spread of questions that did not focus on one single element of the course. In other words, there was something here for all candidates, including those who had not thoroughly revised all elements of this lecture course topic, but those who had a better understanding of the fundamentals were justly rewarded.

4. Photosynthesis and the oxygen electrode *([redacted])*

Part a: ~1/4 of candidates wrongly believed that they needed to include factors to account for the dilutions in acetone and sucrose. This did not tend to affect their answers to **Parts c** and **d**.
Part b: The majority of candidates answered this correctly.
Parts c-d: Common errors included: 1. Not subtracting the background rate, 2. Wrongly determining the upper and lower limits for subtraction of the light and dark rates, 3. Failing to realise that 0.1 mL of extract as opposed to 0.2 mL of extract was used. ~10 students

elected to draw graphs and whilst they were not penalised for this, it was not necessary and may have restricted their time available for other parts of this question.
Part e: Whilst most candidates recognised that phenyl quinone accepts electrons from PSII, >75 % of these candidates believed that this meant that PSII was affected by the mutation.
Part f: This part was often omitted (particularly by those students who elected to draw (unnecessary) graphs for **parts c and d**.

5. Fungal Genetics *([redacted])*

Question number 5 on Fungal Genetics was quite well answered by most of the students. For question 5d not many gave the exact answer. Indeed most of the answers were about how to cross the *S. Cerevisiae* but not about the selection in uracil and leucine lacking plates.

6. Bacterial Plasmids *([redacted])*

Question number 6 on Bacterial plasmids was well answered by most of the students. For question 6a some students were confused with the bacterial conjugation. Among all the students only one received credit "*for a suggestion that plasmid-free cells could be transformed with diluted plasmid DNA to see whether any single-resistant colonies form*" as mentioned in the answer sheet.

7. PCR *([redacted])*

Question number 7 on PCR was quite well answered by all the students. I was surprised that in question 2b a lot of students were not able to write down the nucleotide sequence of the two best pair of primers F2 and R2 in the correct way.

8. Imaging Cell Division *([redacted])*

The question was well answered overall showing a global understanding of the use of phase contrast and fluorescence microscopy to analyse cell division.
The large majority of the students provided a partial answer to question b), rarely considering the two possibilities of karyokinesis and cytokinesis failure to generate missegregation of the chromosomes during cell division. The mutant phenotype was also compared to a wild-type situation in only around 15% of the answers.
The quality of the answers to question d) was quite variable due to the accuracy in the explanations provided. Whereas the vast majority of the answers discussed the use of different antibodies coupled to different fluorophores, less than 10% of the answer fully explained that primary antibodies are raised in different animals and are specifically recognised by secondary antibodies also generated in an other set of animals.

9. Embryology *([redacted]*

The question was overall very well answered by the students (94% of the scripts credited over 6 points out of 10, among which 67% credited over 8 points out of 10), showing a real engagement for the question and a strong knowledge of the topic.

NATURAL SCIENCES TRIPOS
SENIOR EXAMINER'S REPORT

SUBJECT: Evolution and Behaviour (EAB/1)

Senior Examiner: [redacted]

Examiners: [redacted]

Additional Assessors: [redacted]

Structure of the examination:

Written paper/s: 1 written paper (3 hours)
Practical components: 5 assessed practical classes
Number of candidates: 114 (98 NST, 16 PBS)
Number sitting the exam/s outside the main exam hall/s: 17 (15 NST/2 PBS)

Written paper:
Candidates were required to answer five questions, one from each of five sections (A-E). Each section covered roughly four weeks of the lecture course and offered a choice of two questions. Each question was set and marked by the relevant lecturer or their appointed deputy.

Assessed practical components:
There were five assessed practical components throughout the year. Assessment was by means of a written report or question sheet completed at the end of the practical session. The exercise was not timed, but the students were required to hand in their completed assessment before leaving the lab.

Each practical was run four times, so those students who missed an early session were encouraged to attend a later one. Where this was not possible, and the session was missed for a good reason (on the authority of their Director of Studies or their Tutor), the student was given an average mark for that practical. This occurred in 9 cases for 7 students. One student intermitted during the course and so will have marks carried forward until next year.

Conduct of the Examination:

The location of the exam was moved from Student Services to Mill Lane and unfortunately examiners and invigilators were not informed of this change until the morning of the exam. Some students also appeared to have not received this information, with several arriving just before the exam was due to start and one not arriving until twenty minutes later. In the feedback session with student representatives, students confirmed that some students were not aware of this change. However, as a result of a previous exam running late, the exam was nearly twenty minutes late starting, so the one late student did not miss more than two minutes of the exam, having been brought over from Zoology by a member of staff. The twenty minutes wait at the

beginning increased stress levels for all students and was far from ideal. An additional concern was that the venue was split into three rooms and it wasn't always clear where students should be sitting. At the end of the exam, there was considerable noise from students waiting outside. These students were asked to be quiet, but an invigilator recorded complaints from one room in particular. There were no questions from students about the exam and feedback from the student representatives confirmed that students felt it was a fair representation of the course. The timetabling did not raise any concerns.

Breakdown of students answering each question (no more than one from each section):

Section	A		B		C		D		E	
Question	1	2	3	4	5	6	7	8	9	10
Number of scripts	79	35	35	79	23	91	42	71	80	33

Generally, students showed a clear preference for one question of the two in each section. This was most marked in section C, perhaps relating to question six being quite long. Two students only answered four questions (missing a question from D or E).

There were four scripts this year where students either filled in the wrong question number or got pages mixed between questions. Thanks to speedy responses from the assessors, we were able to pick these up easily, but this should be flagged to students in future years.

Marking/Scaling:

The marking and scaling criteria for the NST Tripos were followed and the template spreadsheet used to calculate the final scaled marks. Note: PBS student scores were not included in the setting of class boundaries. This resulted in 25.5 % firsts for NST and 25.4 % for firsts overall, and 10.2 % thirds for NST and 10.5 % for thirds overall.

The distribution of marks awarded varied across questions and assessors used a good range of marks. Assessors generally thought that students answered the questions set well, although assessors for questions 7 and 10 were less satisfied with the overall quality of answers.

Below is a table showing the mean (out of 12) and standard deviation for each question. Major reasons for low marks as detailed by the assessors were a failure to answer the questions set or an incomplete answer to the question. Higher marks were generally given for essays that included material outside of the course. Individual assessors highlighted some general issues with poorer essays, including a difficultly in integrating material across lectures, not including diagrams, and some examples of students misunderstanding parts of the material, particularly differences between proximate and ultimate questions in evolution and the relationship between Neanderthals and anatomically modern humans.

Section	A		B		C		D		E	
Question	1	2	3	4	5	6	7	8	9	10
Mean	7.9	7.6	7.9	7.0	8.4	8.7	6.3	7.5	7.1	7.1
Standard deviation	1.8	1.4	1.9	2.1	1.9	1.6	2.4	2.3	2.0	2.0

Subject Examiners' Meeting (20/06/19):

[redacted] was not able to attend the meeting, but met up with the Senior Examiner at a different time to discuss the exam and sign the mark sheet and report. All other examiners were present. Examiners agreed that the problems with the venue change for the E&B exam caused significant stress to students, but that the exam had run smoothly and that students had generally showed a good knowledge of the material. The switch to including a short answer question was supported and examiners encouraged this being maintained in future years.

Administration:

Administration this year was led by Zoology and we would particularly like to thank [redacted] for all their work administering the course and exam, and collating the scripts. This was all extremely smooth. Thank you also to [redacted] for all her help and advice throughout the year.

Conclusions and Recommendations:

Issues surrounding the change in exam venue were clearly an administrative error, so no action need be taken. The single candidate who arrived late to the exam may have been disadvantaged owing to stress, so I would recommend that their scores be assessed during the final examiners meeting. As with last year, the timing of the PBS examiners meeting meant a quick turnaround of scoring. With notice from last year, we were able to plan for this, but there was no information from PBS that this could be an issue until a few weeks before the exam and after the marking schedule had been agreed, so this should be noted as an ongoing factor to bear in mind for future senior examiners.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]).

Date: 20/06/19

(Additional information may be required by Faculty Boards (e.g. question level data); this is not needed by the Chairman of Examiners but can be included if it is easier to provide one report. Faculty Boards may publish certain information and may therefore require content to be presented in a particular format.)