Online assessment styles and approaches

David P Smith NTF
Department of Bioscience and Chemistry, Sheffield Hallam University

Contributions:

Dr Ashley Le Vin – University of Glasgow
Dr Alfred Thumser – University of Surrey
Dr Catherine Duckett – Sheffield Hallam University
Prof David Coates – University of Dundee
Dr James McEvoy – Royal Holloway, University of London
Dr Nikki Jordan-Mahy – Sheffield Hallam University
Dr Nigel Francis – Cardiff University
Dr Joanne Stewart-Cox – University of Bath
Dr Philip Leftwich – University of East Anglia
Dr Stephany Veuger – Northumbria University

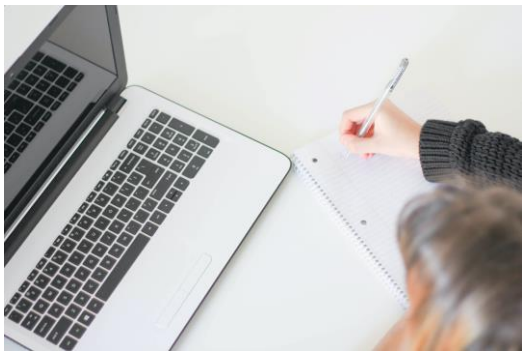
1. Context

Following the COVID-19 pandemic, many institutions have moved to online time-limited examinations as a final assessment and away from the traditional face-to-face invigilated (proctored) examinations (Grajek 2020; UNESCO 2020). The guidance document presented here aims to support academics in the writing of questions for time-limited online assessments. A variety of question types and strategies are offered to address higher-order thinking skills in relation to the students' understanding, application, analysis, and creativity. For this document, we use an adaption of Allan's (2020) understanding of online exams to be:

> "high-stakes summative assessment events,
> mediated by digital technologies, often taking place in a defined place or time,
> *under conditions allowing access to course materials, notes or communication*"
> (Allan 2020 p 1).

Online assessments are often unproctored open book assignments and care is needed that the student cannot simply look up the solutions. Assessment design strategies that require students to use a full range of skills are highlighted. It is recognised that collusion within online assessments is a major issue and strategies to address this through assessment design will be considered. Case study examples detailing current practice are drawn from Bioscience academics operating at a range of institutions and displayed here to demonstrate the breadth and depth of ideas that are possible.

The materials presented are broken down into several sections to aid navigation.



- Literature Review: What is the current understanding of online assessment practices and experiences?
- Assessment Design: Considerations for the design, delivery and assessment of online examinations.
- Checklist for online examinations.
- MCQs as an online assessment.
- Case studies: of assessment practices.
- Reference List

> *"What I found the most rewarding, and unable to Google, were questions which required short paragraph-long answers that drew on 3/4 different topics at once."*

Case study examples:

Online examinations occur in many institutions, and their delivery is often specified by local assessment and quality guidelines and circumstances. It is recognised that there are variations in the delivery platforms used and assessment time given. Here a range of case study questions has been collated from academic practitioners teaching in the biosciences. Each offers a robust assessment that targets the full range of cognitive abilities between them. An overview of the case studies indicates that the predominant approaches taken by bioscience educators have been to:

- apply knowledge to given situations, where students might, for example, be asked to: *change*, *choose*, *interpret*, *illustrate*, *predict*, or *modify*;
- analyse ideas to breaking them down, or finding evidence to support generalisations, where students might be asked, for example, to: *analyse*, *calculate*, *discriminate between*, *critique*, *infer*, *select*, *outline*, or *separate*;
- synthesise arguments, drawing on multiple sources for example in proposing alternative solutions, where students might be asked, for example, to: *categorise*, *construct*, *create*, *design*, *generate*, *reconstruct*, or *synthesise*;
- evaluate concepts or facts, for example, in making judgements based on agreed facts and evidence where students might be asked, for example, to: *argue*, *appraise*, *choose*, *contrast*, *estimate*, *justify*, *interpret*, or *judge*.

Each of the case studies has been pitched against the stage of the degree program they are most suited to and the cognitive level they address. Here we draw on Bloom's Taxonomy (detailed further in assessment design) as a frame of reference. Typically, but not exclusively, lower order thinking skills such as knowledge recall and testing understanding occur at the early stages of a degree program with higher order skills being assessed at the later stages.

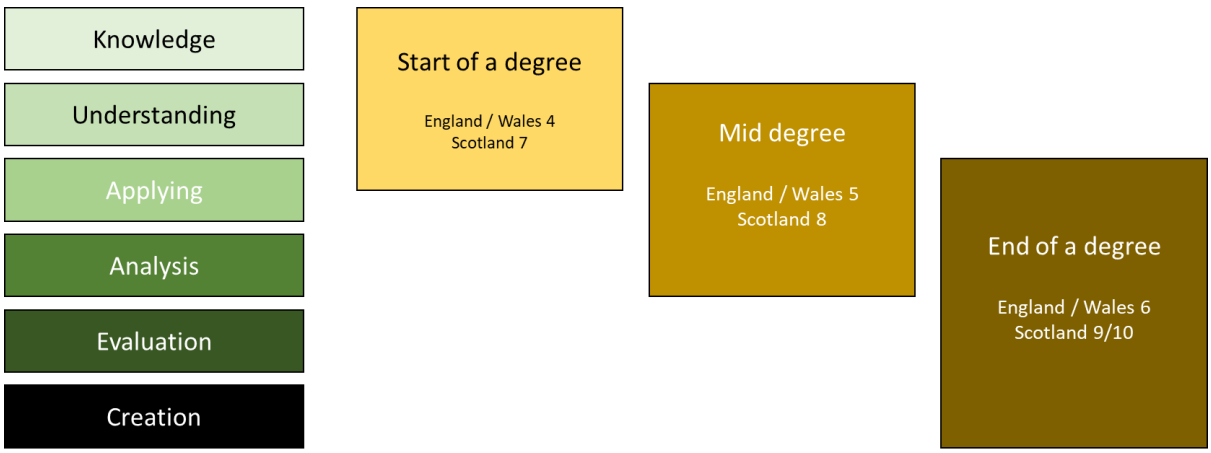


Figure 1. Cognitive ability by degree stage

Online assessment styles and approaches

				Early	Mid	End
1	Dr James McEvoy	Royal Holloway University of London	Data analysis (protein structure)			
2	Dr Alfred Thumser	University of Surrey	Understanding (threshold concepts)			
3	Dr David Smith	SHU	Spot the Error			
4	Dr Nicola Jordan-Mahy & Dr Kirsti Newton	SHU	Scenario Based Problem Solving			
5	Dr Joanne Stewart-Cox	University of Bath	Application (production of a novel piece of work)			
6	Dr David Smith	SHU	Evaluation / Lay Descriptions			
7	Dr Catherine Duckett	SHU	Data Analysis (Spectra)			
8	Dr Philip Leftwich	University of East Anglia	Experimental Design / Data Analysis			

Online assessment styles and approaches

9	Dr Nigel Francis	Cardiff University	Interpretation / Understanding (Papers)			
10	Dr Ashley Le Vin	University of Glasgow	Data analysis (statistics)			
11	Dr David Smith	SHU	Experimental Design			
12	Dr Stephany Veuger	Northumbria University	Scenario Based Bioethics			
13	Dr Stephany Veuger	Northumbria University	Analysis and Application (Drug Design)			
14	Various	Various	MCQs			

If you would like to contribute a case study, please e-mail d.p.smith@shu.ac.uk

2. Literature review.

Online examinations have seen an increased uptake as the primary means of undergraduate and postgraduate assessment. Such assessments typically involve students answering set questions within a time-limited setting. Without the use of proctoring, online assessments are open book with easy and direct access to knowledge. How then do you prevent the answer from being looked up and move towards high-order cognitive skills, deep learning and away from a surface understanding based on knowledge recall?

Authentic assessment and online examinations

Through structured interviews with academics in Norway, the Netherlands, the UK and Ireland, Allan 2020 explores the experiences of transition to online examination as an assessment tool. The research highlights the need to consider how "*digital technologies facilitate, proscribe or otherwise mediate the achievement of (learning) goals in online exams*". The work, however, highlights a need to consider the educational purpose of these non-traditional assessment processes. Boitshwarelo, Reedy and Billany 2017 in their review address online assessment and highlight "*the possibilities afforded by technology to drive and assess deep learning*" and by drawing on a range of practices conclude that effective use of online tests can be a valuable assessment tool. Throughout the reviews and publications, the predominant solution to online assessment is to employ an authentic assessment design. Such assessments require students to apply what they have learned to a new situation and require them to determine what information and skills are relevant and how they should be used (Wiggins 1990; Darling 2000). Scott 2016 explores the idea of "*right*" assessment, drawing on flipped learning principles where assessment design evaluates competencies and capabilities. The ability to consolidate learning and to apply knowledge, and skills, through assessment types such as problem-based learning, authentic learning tasks, and case studies are seen as being particularly powerful tools (Scott, 2016).

Jones 2021 notes in their study the effectiveness of examinations on the understanding of students entering undergraduate biological science courses. These students primarily experienced assessment focus on content recall rather than reasoning. Such examinations were observed to have no detectable effect on the understanding of key biology terms that students take with them to university. This can be understood through the studies of Google 2021 who set out in their review the approaches that biology students take to learning. They highlight in their analysis of over 30 peer-review publications that students are more likely to utilise surface approaches to learning (Biggs 2001) when faced with environments and

assessments that reward the memorisation of facts (Google 2021). In the context of online assessment, this manifests as examinations that are knowledge-based and searchable. They further set out that proficiency in biology through deep approaches to learning (Watters & Watters, 2007) requires complex problem-solving, innovative thinking, and adaptability to the rapidly changing knowledge base. The primary aim then of biology education is to develop cognitive and biological skills such that they can be applied to situations and environments the students may face on graduation as opposed to short-term memorising a collection of facts (Google 2021; Gouvea et al., 2019).

The integrity of online examinations

A primary focus of the literature on online assessment in exams is focused on delivery tools (Karim and Shukur 2016) and academic integrity (D'Souza and Siegfeldt 2017; Hylton, Levy, and Dringus 2016; Milone et al. 2017; Ullah, Ziao, and Barker 2019; Reedy et al. 2021). Studies have also been conducted that evaluated the performance of learners in online and paper-based exams (Ardid et al. 2015; Boevé et al. 2015; Karay et al. 2015; Werhner 2010; Bayazit 2012) finding no significant difference in learner achievement in proctored exams. In unproctored exams however, differences were observed and it was hypothesised to be due to the ability to look up answers (Igaz 2020). Students obtain answers from published test bank questions, collusion and searching (Cluskey, 2011). To address this pooled question banks delivered through the virtual learning environments are seeing increasing use. The questions the students see are drawn from a pool of variant questions in such a way that each student receives a unique question set at the same cognitive level as their peers and havebeen shown to be effective. Ardid et al. 2015 observed a difference in means and a greater spread in unproctored vs proctored exams using question pools and concluded that "*the online exam has a high discriminatory power, although the cut may depend on the methodology used in the assessment.*". By contrast, Hollister & Berenson, 2009 showed no difference between the unproctored and proctored assessments with no evidence of cheating. It is clear from the assessment design, and evidence from the studies, that unproctored exams run the risk of a loss of integrity. Studies suggest that cheating increases when online exams are unproctored (Harmon and Lambrinos 2008; Reich et al. 2018). These studies are countered by other studies indicating that cheating behaviours are not linked to surveillance but to the nature of the exam itself, with cheating less likely to take place when authentic forms of assessment are used and students are taught about ethical behaviour (Bearman et al. 2020; Harper et al. 2020; Harrison 2020). Authentic assessment design does have benefits when applied to the integrity of the exam, however, even this is prone to contract cheating (Ellis 2020). Nevertheless, one would envisage that the time-restrained nature of an online examination would limit the ability to cheat in this manner.

The design and delivery of the exam can counter some of these issues of collusion, such as the use of pooled question banks. In an unproctored environment, the prevention of collusion is a challenge, and it should be assumed that the use of search engines, course notes and recorded material will occur. Consideration of the questions asked and the design and delivery of the exam become paramount and can be addressed by drawing on the principles of authentic assessment. It is noted however that learning and understanding in Bioscience do require a fundamental understanding of the subject matter built upon a firm knowledge

base and this should not be overlooked (Google 2021). Although collusion and cheating are issues in online examinations, it should not be assumed that all students will cheat. Incorporating ethical behaviour and (research) integrity into skills modules prior to examination is a direct means of addressing this issue and limiting cheating within the examination setting.

Student Experience of Online Examination

The student perception of online examination has been investigated and valuable lessons learned around the design and delivery of assessment tools. Much of this research occurred pre-COVID-19 pandemic however the experiences of institutions in delivering Bioscience assessments have been incorporated.

Time: It is understood that the time taken to complete an online exam is increased over paper-based versions (Bernt 1988; Gvozdenko and Chambers 2007; Ilgaz 2020; Khalaf 2020). Bayazit 2012 reports that the time taken to complete the same MCQ test online was increased over the handwritten version. A particular issue was highlighted by Ilgaz 2020 where online examinations with a mathematical component were prone to students running out of time as they work out answers by hand and then transcribe them to the online platform (Ilgaz 2020). The time given to complete an online examination is also variable, with institutions varying between a few hours, to over a week (personal communications).

Typing: The physical act of typing an answer should also be considered. When students were given free choice between typing or handwriting answers in exams, no difference in scores were observed (Mogey 2016). However, when typing is the default option, the ability to articulate ideas in divergent thinking tasks (where several solutions to a problem are possible) has been shown to be affected by typing speed (Forthmann 2017). In addition, students report that the increased time taken to type answers rather than handwrite answers has affected performance (Khalaf 2020). Average typing speeds are reported at ~40 words per min with an approximate 92% accuracy rate. Under controlled conditions, the typing speeds for 17-year-olds are reported to be around 25 words per min (Horne 2011). These averages are calculated from transcription tasks and do not take into account the time needed to read, process and respond to the set question. Given the ranges stated typing a 500-word answer could take between 12 and 20 min to complete and those with high rates of typing are able to articulate more in the same period.

Technology: Dissatisfaction with online examinations stems primarily from technical issues (Milone 2016). Although technical issues are rare for the students, the anxiety that they might occur was noted as part of the pre-examination stress (Ilgaz 2020; Japp 2021; Khalaf 2020). Bayazit 2012 notes that the online versions of MCQs result in increased levels of fatigue and an inability to focus in the online environment. It is therefore important that students have the opportunity to practise and become familiar with the exam format and delivery (Boevé et al. 2015; Deutsch 2012; Stowell 2010).

Online assessment styles and approaches

Access: Students with declared physical disabilities were supportive of the online exam as it meant they could undertake the assessment in their own homes (Ilgaz 2020). Care should be taken to embed inclusive practices by removing barriers that prevent interaction with, or access to websites, digital tools and technologies, by people with disabilities. It should be recognised that not all students have equal access to appropriate devices, stable WiFi connections and a suitable working environment (Fuller 2020; Timmis 2016; Alruwais 2018). Students from less-advantaged backgrounds are more likely to experience these issues and so have the potential to contribute to differential attainment (Patterson 2017). Understanding the tools and environment the students have access to (device, connectivity, and suitable space) and contingency plans for those who cannot access these is an important consideration (e.g. allowing access to campus facilities to undertake the assessment (Fuller 2020)).

Complexity: Multiple complex sectioning on papers does not transcribe well to a digital platform and can lead to confusion, for example, “Answer 1 question from Section A, then 3 from Section B then question 1 from section C plus one other”. Simplicity in design will help the students perform to their best. As an example, having a single section with all questions compulsory, or a choice of, for example, three from four type structure.

Summary

The use of online exams as a replacement for the “traditional” written and invigilated (proctored) examination runs the risk of a like-for-like replacement without careful consideration of the pedagogical implications (Ferrell 2014 p1). Replication of factual knowledge recall in an open book environment is prone to problems of searching for the relevant information during the assessment and fosters a surface-level learning approach. There is also concern that online tests largely test only the lower levels of comprehension (McAllister & Guidice, 2012) and could lead to a surface understanding of the subject if the primary assessment design is that of recall (Google 2021). Such outcomes have been observed directly in MCQ tests with high performing students completing quickly whereas low performing students were seen to guess more (Karay et al. 2015).

3. Assessment Design for Online Examination

Online exams can be both an effective learning tool and a means to assess knowledge and competencies. However, they test a subsection of skills and should be used as part of a range of assessment types. Set your exams with the full knowledge of what you are asking your students to do and what you want the exam to achieve. Boitshwarelo in their 2017 review offers a principle of design for on-line assessment based on Bearman et al., 2020 Assessment Design Decisions Framework. The Assessment Design Decisions Framework breaks the decision-making process around assessment into six parts: purposes of assessment, the context of assessment, learner outcomes, tasks, feedback processes, and interactions.

Assessment design needs to be clear around its purpose and aligned to curricula and programmes of study (Norcini 2018). Online examinations can support educational goals, addressing high-order thinking skills such as critiquing, reflection on cognitive processes and problem-solving (Alruwais 2018; Timmis 2015). The use of digital technologies for assessment delivery offers academics the ability to think creatively about assessment and align with program specifications and foster a deeper engagement with the subject matter.

The creation of assessments that address the learning objective of the module or course yet are robust to online delivery can be addressed through careful consideration of the cognitive level of the questions asked. Bloom's taxonomy, a long-established theoretical framework, sets out a hierarchical ordering of cognitive skills (Bloom 1956). It is a useful tool for educators to reflect on their practice using frameworks such as this to classify their assessment or questions asked within it. Within the case studies presented here, example questions are presented at each of the cognitive levels.

Online assessment styles and approaches

Low order thinking skills, classified as knowledge and understanding, are prone to searching in online examinations with answers findable via search engines and course notes.

- **Knowledge**: Recalling facts and testing memory with the learning outcome to recall specific information. Questions here tend to be direct and a test of memory, aimed at knowledge recall. Such questions can be answered in an open book environment via the use of course notes or web-based searching.

- **Understanding**: Identifying examples of a given term, concept or principle. Interpreting the meaning of an idea, concept or principle. The stem of the question here takes established knowledge and asks the student to use that information in comprehension tasks.

Higher-order thinking skills require students to use cognitive processing to address a task or situation and go beyond memory or search for information. Such skills include the following categories:

- **Applying:** Using information, rules and procedures in concrete situations. Students are required to draw on a knowledge base and then use that to answer the question. The stem of the question presents a situation and the students are required to apply what they understand about a given situation to determine the answer.

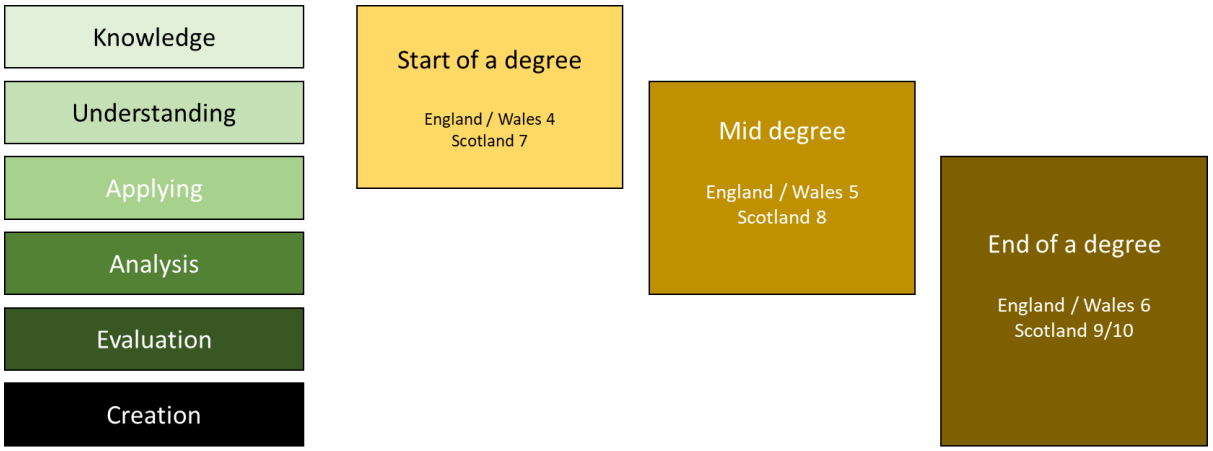
- **Analysing**: Breaking information into parts to explore patterns and relationships. Analysing data sets to support conclusions. The ability to analyse information can be assessed by asking students to interpret data sets. This information can be presented as images or figures, provided as part of the question stem or in the answer choices (Malamed 2018) and (Brame 2013).

- **Evaluation**: Justifying a decision or course of action. In this approach to measuring critical or creative thinking, students are asked to synthesise information into an explanation. The possible responses include the answer and then a variety of reasons that support the answer (Malamed 2018).

- **Creation:** Production of new or original work or ideas. In these instances, students used the full learning base to produce items such as research proposals or experimental designs.

Online assessment styles and approaches

Each of the cognitive levels of Bloom's taxonomy can be addressed at any stage during a student's educational experience, however, the higher-order thinking skills are often built on a sound foundation of knowledge and understanding. As such, high-order thinking is typically associated with the later stages of a degree program.



Action verbs for question STEMs

When writing questions that address higher-order thinking skills, you are looking to assess what the students can do with a given set of information. In the case study examples that follow, data analysis; scenario; opinion pieces; and experimental design are all used with the common theme being the application of knowledge, rather than recall.

To support the writing of such questions, consideration of the action verbs used can help target the question to the cognitive level. Action verbs in education are linked to writing course objectives and assessing learning outcomes (Newton 2020). They can also be useful in assessing students and help direct the cognitive level of the question asked. Exam and assignment questions typically contain one or more action verbs and are an indication to the student of what is required in the question. The following list is not exhaustive nor prescriptive but intended to act as a guide in assessment design, it is taken from Newton 2020 who collated existing lists and reported back the most common verbs used.

Knowledge	Understanding	Applying	Analysing	Synthesis	Evaluation	Create
List Define Recall State Label Repeat Name	Translate Paraphrase Discuss Report Locate Generalise Explain Classify Summarise	Operate Apply Use Demonstrate Solve Produce Prepare Choose	Analyse Question Differentiate Experiment Examine Test Categorise Distinguish Calculate Contrast Outline Infer Discriminate Compare	Create Compose Argue Design Plan Support Revise Formulate	Rate Evaluate Access Judge Justify	Arrange Compose Construct Design Develop Devise Formulate Hypothesise Plan Prepare Produce Propose Synthesise

Verbs to avoid: appreciate, know, familiar, aware, understand, select, explain, relate, arrange, choose

Assessment criteria

Assessment entails academics making professional judgements about the standard and quality of students' work. Many universities have a core mark or grade-based assessment criteria that describe in broad terms those graduate characteristics expected for each degree classification (Woolf 2004; Sadler 2010). The Quality Assurance Agency for Higher Education (QAA) in the UK exhorts institutions to *"consider including in their published documentation the criteria for assessment including, where appropriate, descriptors of expected standards of student attainment: what is expected in order to pass or to gain a particular grade or classification"*.

Assessment criteria relating to online exams should reflect the module and/or course learning objectives. Such judgments about the quality of student work, together with interpretations, are made against a background framework of information (Sadler 2010). In the case of online assessments, the background is that the assessment is time-limited, open book and follows a period of the taught content on a given subject.

Pass level descriptors: Careful consideration of the minimum expectations required to progress students should be undertaken by module teams. There is a skill in being able to look up and find relevant information and understand what is presented. For students at the earlier stages of a degree program, being able to report back a definition or meaning relevant to a prompt can be a learning objective. It involves the students understanding that what they are reading is relevant to the question asked. This would demonstrate a basic understanding of the course content.

High-level descriptors: These tend to emphasise complete understanding of the course or module content with the development of relevant skills and intellectual capability (Sadler 2010). Open-ended questions that draw on divergent thinking can lead to many possible solutions to a set question. The challenge for the marker then is that there is no predetermined correct answer and many possible solutions. Marking schemes need to recognise this and focus on understanding through explanation, originality of the idea and, often within the bioscience setting, the feasibility of the response. This then requires academics to use their judgement, based on their tacit knowledge, in order to allocate grades.

Assessment criteria then, in this case, needs to be written to meet the learning objectives of the course or module but also to be flexible enough to allow a broad range of ideas to be rewarded.

4. Checklist of exam design and delivery

The preceding literature review draws out several areas of good practice and considerations for online examinations.

- **Clarity**: Keep it simple, avoid multiple sections and large amounts of choice. Use clear and concise language.
- **Time and Length**: Reading and typing online are slower than writing by hand. Ensure the time needed to complete the exam is achievable. Give indicative word counts.
- **Accessible**: Be considerate of accessibility. It is not safe to assume that students have a stable internet connection, nor the ability to scan or print. Not all students have access to a suitable work environment and alternative provisions should be considered.
- **Inclusive:** Removing barriers that prevent interaction with, or access to websites, digital tools and technologies, by people with disabilities.
- **Achievable**: Weaker students will struggle with higher-level cognitive skills, and so a balance is required in the question or the paper as a whole.
- **Expectation**: Ensure students understand what is expected of them in the exam and consider exam preparation and mock papers to familiarise themselves with content and mechanics.
- **Cognitive Level:** Assume that students have full access to the internet and design your questions accordingly. Test the breadth of cognitive ability across the module or course programme.
- **Preparations:** High-level cognitive skills need formative assessment support and should be incorporated into module design. Students should be given the opportunity to experience the technology platform used for the assessment prior to the test. Ethical behaviour in online examinations should be discussed.

MCQs and as an online assessment tool

Online tests and examinations are readily delivered via virtual learning platforms such as Blackboard, Inspera and Canvas. These tools offer the ability to create self-marking questions such as MCQ, true/false questions, matching questions as well as predetermined short answer questions. They can be used to analyse data or to access higher levels of learning. Online they have been shown to be robust and achieve similar levels of attainment. They are thought to be robust to collusion through the use of question banks in which random question sets are delivered to students from a pool of similar questions.

One criticism of MCQs is that they only assess memory, knowledge and understanding. They can, however, be written to evaluate higher-order thinking skills, such as the ability to apply, analyse and evaluate information. It is worth noting that, when used for summative assessment, the highest orders of thinking such as *"*creation*"* are out of the reach of MCQs as their answers are predetermined. With only a single or limited answer being possible, it is also impossible to demonstrate a breadth of understanding outside the scope of the question stem. So although they are useful, they should be thought of as part of a broader assessment strategy in conjunction with other forms of assessment Douglas (2012).

Knowledge: Remember facts and tests of memory with the learning outcome being to recall specific information. Such questions are often easily searchable. Questions here tend to be direct and a test of memory.

Which of the following is the single letter amino acid code for arginine?	Which band first recorded the song "Let It Be"?
(a) C (b) H (c) I (d) R	(a) The Rolling Stones (b) The Beatles (c) The Beach Boys (d) The Who (e) The Kinks
The answer here is pure memory recall, there are twenty amino acids each with a single letter code. Knowing that R is for arginine is all that is required.	*Again, the idea here is around memory recall as to answer this question you only need knowledge of who wrote which song. Or the ability to search quickly.* *Source https://teaching.uwo.ca/pdf/programs/Writing-Higher-Order-MCQ-Fall-2018.pdf*

Understanding: Identifying examples of a given term, concept or principle. Interpreting the meaning of an idea, concept or principle. The stem of the question here takes established knowledge and asks the student to use that information in comprehension tasks.

For what reason is the side chain of the amino acid phenylalanine likely to be found in the core of a globular protein?

(a) It is hydrophobic
(b) It is bulky
(c) It can absorb UV light
(d) It is unable to make salt bridges

To answer this question the student needs to link two items of information. Firstly that phenylalanine is hydrophobic and secondly that the core of a globular protein is typically a hydrophobic environment. Incorrect answers are all possible but equally likely to be true for amino acids on the surface of a protein.

Applying: Using information, rules and procedures in concrete situations. Students are required to draw on a knowledge base and then use that to answer the question. The stem of the question presents a situation and the students are required to apply what they understand about a given situation to determine the answer.

The side chain of Histidine has a pKa of 6.4. At which pH would it carry a full positive charge?

(a) 4.4
(b) 6.4
(c) 8.4
(d) 10.4

Assume that you work for a drug company. You are trying to develop a new drug for the treatment of schizophrenia. Which of the following neurotransmitters are you likely to target?

(a) dopamine
(b) serotonin
(c) GABA
(d) acetylcholine
(e) norepinephrine

The students are required here to understand that amino acids can be protonated and deprotonated. They then apply what they know about the pKa values to determine the answer.

In this example, you first need to understand what each of the neurotransmitters does within schizophrenia, then use this information to identify a good target.

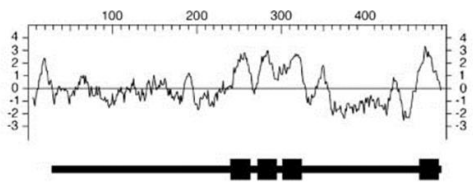
Source https://teaching.uwo.ca/pdf/programs/Writing-Higher-Order-MCQ-Fall-2018.pdf

One of the best ways to promote and assess higher-order thinking is to use scenario-based stems, particularly ones that simulate real experiences or data. These questions require the students to analyse and problem solve. The sample question pair below demonstrates how to transform a question from simple recall to higher-order thinking using the scenarios approach (Malamed). An alternative approach is to construct two-tiered questions – the first asking a student to select a response, the second to justify that response. These are very useful for exposing misconceptions, but they are time-consuming to produced and care should be taken that the stem of the first question does not lead to the direct response in the second question.

Simple recall: What symbol does a formula always start with in Excel?
Higher-order thinking: If you want to total the first ten data cells in column B, which one of the following formulas should you use?

Analysing: Breaking information into parts to explore patterns and relationships. Analysing data sets to support conclusions. The ability to analyse information can be assessed by asking students to interpret data sets. This information can be presented as images or figures, provided as part of the question stem or in the answer choices (Malamed) and (Brame).

A hydropathy plot for the protein X is shown below. Regions of the protein with a hydrophobicity index greater than zero are considered hydrophobic. Based on this information what kind of protein do you think X is?



You receive a report on the following patients at the beginning of your evening shift. Which patient should you assess first?

(a) Integral membrane protein with a single transmembrane domain (b) Cytosolic protein (c) Multi-pass integral membrane protein with multiple transmembrane domains (d) Lipid-anchored membrane protein (e) Peripheral membrane protein	(a) An 82- year- old with pneumonia who seems confused at the time. (b) A 76- year- old patient with cancer with 300ml remaining of an intravenous infusion. (c) A 40- year- old who had an emergency appendectomy 8 hours ago. (d) An 18- year- old with chest tubes for treatment of pneumothorax following an accident.
Students are required to interpret a given data set using pre-established rules. They then select the most likely answer from the given choices. The scenario is based on the identification of membrane proteins with all the answers being possible classes of this protein.	*Examples of a MCQ that could be classified at 'analysis' level (Oermann & Gaberson, 2009). This question requires the reader to read and synthesise the information in each statement, then make an informed judgement about what should occur next.*

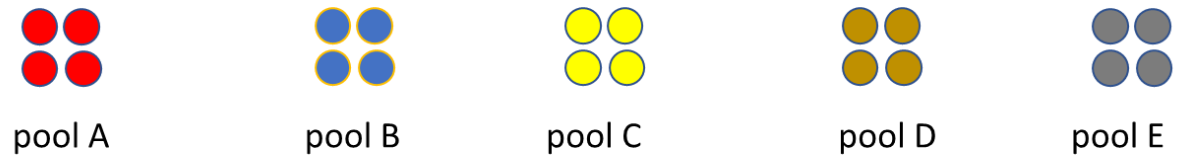
Evaluation: Justifying a decision or course of action. In this approach to measuring critical or creative thinking, students are asked to synthesise information into an explanation. The possible responses include the answer and then a variety of reasons that support the answer (Malamed 2018). If you have an existing question that states a rule, then the question can be reworded to ask the learner to identify the characteristics of that rule or concept. When writing, you can present the characters in the question stem and then ask the learner to identify the rule, reason or concept. In these questions, students are asked to evaluate the information given.

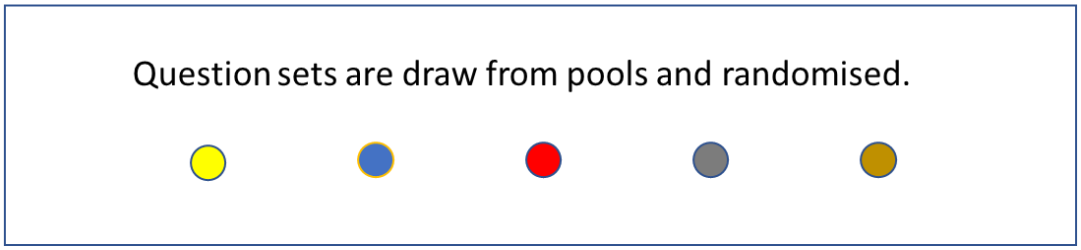
Your fitness regimen involves jogging on the school track 2–3 miles per day with a friend. On a particular day, about 15 minutes into your jog, your friend suddenly pulls up and falls down, grasping her right calf in pain. What should you do at that moment?	Enzymatic data has been acquired for a protein and its disease-related mutation. The mutant contains a single amino acid change. The conclusion is that the amino acid is involved in binding the substrate but not in the catalysis of the reaction. Which of the following statements is the most likely when comparing the data sets between the two forms of the enzyme?
(a) apply ice to the calf (b) apply heat to the calf (c) tell her to get up and walk slowly (d) get emergency help	(a) Km unchanged, Vmax unchanged (b) Km unchanged, Vmax changed (c) Km changed, Vmax unchanged (d) Km changed, Vmax changed

Here the student must be able to appraise the situation and evaluate the next course of action. The student's knowledge of both muscle function and injury are brought to bear in deciding which treatment to use. Source Crow 2009.	*The stem here gives the output to an initial proposal. The students are then required to determine which data set best matches the stated reasoning.*

Design and Delivery

The design and delivery of the exam can counter some of these issues of collusion. Pooled question banks delivered through the virtual learning environments are seeing increasing use. The questions the students see are drawn from a pool of variant questions in such a way that each student receives a unique question set at the same cognitive level as their peers.





There are also several design principles that have been set out by Cluskey 2011 relating to pooled question bank examinations but which are relevant to all online examinations.

1. Deliver the exam at a single set time.
2. Have the exam open for access and initiation for a limited time. (Preventing one student from starting and completing the exam then sharing the answers).
3. Randomisation of the question (and answer) order.
4. Present exam questions one at a time (* it has been noted that this can lead to stress due to a known length of time taken to complete the exam and an inability to backtrack (Khalaf 2020).
5. Design the online exam to occupy only the limited time allowed for the exam.
6. Allow only a single attempt at the exam.
7. Change at least one-third of multiple choice/objective questions on each exam every iteration.

Writing MCQ questions

MCQs, when written well, can be a very effective tool for assessing learning at multiple levels. However, as with any assessment, structuring the questions well is key to getting the most out of them. Poorly thought through questions can be confusing and have a negative impact on performance. They can also be a giveaway to the correct answer allowing guesswork to take over. Below are some tips when writing MCQs to help ensure the learning objectives are being met. There is also a quiz at the bottom to try out.

Distractors. These are plausible but incorrect answers to the questions. They should be the same length and grammatically correct. It's better to have three answers that are plausible/possible than four answers where one is clearly wrong (Vyas & Supe 2008). These can be very difficult to write as you might not know what the misunderstandings of the students will be. One option when creating them is to use students' own answers to similar short questions as content. This can be achieved with open text responses during prior taught sessions. For numerical question answers, potential outputs that are common mistakes make good distractors.

Bad example: The fundamental property of subatomic particles exploited in nuclear magnetic resonance spectroscopy is?	**Good example:** In the area of physical science, which of the following definitions describes the term "polarisation"?
(a) Platform (b) Table (c) Chair (d) Spin In this case a, b and c are all objects and clearly wrong. It would be better to have, (a) Mass (b) Energy (c) Charge (d) Spin	(a) The separation of electrical charges by fiction. (b) The ionisation of atoms by high temperatures. (c) The interference of sound waves in a closed chamber. (d) The excitation of electrons by high-frequency light. (e) The vibration of transverse waves in a single plane.
Each of these is a property of subatomic particles.	*The answers here are around the same length, grammatically correct and of similar complexity*.

Nottingham Trent University. Computer-Based Assessment

Grammatical cues. Poor wording gives away correct answers when one or more of the distractors do not follow grammatically from the stem. The stem should be written as a complete sentence. Other clues such as the use of ‘an’ in the stem points to the options that start with a vowel. Equally, the use of ‘a’ shows the answer starts with a consonant. The singular or plural form of pronouns or verbs points to options as being singular or plural. Gender-specific terms in the stem point at a gender-specific option.

Which of the following students has made several errors when completing a section of work?	What is the correct definition of a gurlefrop?
(a) John (2 errors) (b) Jane (1 error) (c) Keith (0 errors)	(a) means of frimp (b) act of zing (c) swing of a gurling in motion relative to frop (d) buggle of twang
This question could be answered by looking only at the stem.	*The correct answer is longer compared to the others and repeats the phrasing of the stem. Without knowing anything about a gurlefrop you can guess the answer.*

Students should select the best answer rather than the correct answer. Asking for the correct answer may invite arguments on contentious topics. By asking for the best answer, you can acknowledge that other responses have some element of truth or accuracy but one selected answer is best (Jacobs and Chase 1992).

Structuring. Include as much of the item in the stem as possible; the stem should be long and the options should be short. Answers should be presented in a logical order, e.g. alphabetical or numerical. If this is not possible then the correct answer should be placed in a random location. This can be achieved by use of a random number generator or even a dice (Brame 2013).

Clear Wording. The stem should be clear, brief and easy to read – to do this try to avoid irrelevant information in the stem. A good question stem poses a problem to address and is accessible to all learners, avoiding technical jargon or complicated terminology. (The exception to this is questions that involve definitions or mastery of language). Repeated or redundant phrases should be in the stem rather than the responses. The stem should be written in positive form avoiding words like “except”, “but” and “not”.

Traps in a bad stem. The way in which a question stem is worded can give away the answer. This can be also inadvertently done when the answer to one question is included in a response to another question within the same test.

Spin is a fundamental property of atoms exploited in which type of spectroscopy?	The motion of a gurling is measured relative to what?
(a) fluorescence (b) nuclear magnetic resonance (c) infrared and near infrared (d) spark or arc (emission)	(a) frop (b) buggle (c) frimp (d) huepim

In both of these examples, the answers are contained in the questions in the above sections.

Always and Never. Absolute terms – words such as “always” or “never” – are in some options. Learners can use these as cues and are likely to rule these statements out of consideration. “All of the above” and “none of the above” should be avoided as they reduce the effectiveness of the question. If the learner recognises one of the answers as incorrect then the “all of the above” answer is immediately redundant.

Resource List

Writing Good Multiple Choice Test Questions by Cynthia J. Brame, CFT
https://cft.vanderbilt.edu/guides-sub-pages/writing-good-multiple-choice-test-questions/

Writing Multiple Choice Questions For Higher Order Thinking by Connie Malamed
http://theelearningcoach.com/elearning_design/multiple-choice-questions/

How to use multiple choice questions for formative assessment (RSC)
https://eic.rsc.org/ideas/how-to-use-multiple-choice-questions-for-formative-assessment/3007976.article

How multiple-choice questions can motivate students to assess their own confidence and knowledge – without even knowing it
https://eic.rsc.org/ideas/self-assessment-grids-quick-and-easy-feedback/3008523.article

Designing Multiple-Choice Questions
https://uwaterloo.ca/centre-for-teaching-excellence/teaching-resources/teaching-tips/developing-assignments/assignment-design/designing-multiple-choice-questions

The Academy for Teaching and Learning Excellence (ATLE)
https://www.usf.edu/atle/documents/handout-multiple-choice-best-practices.pdf

Writing Good MCQs (Intelligent Assessment Technologies)
http://www.intelligentassessment.com/examonline/examonline-resources/writing-good-mcqs/

Multiple Choice Questions that Assess Higher-Order Cognition
http://www.sfu.ca/sfublogs-archive/departments/fhs-teaching/527_multiple-choice-questions-that-assess-higher-order-cognition.html

How to use Computer Based Assessment
https://now.ntu.ac.uk/d2l/lor/viewer/view.d2l?ou=111863&loIdentId=25839

Guidelines for the construction of Multiple Choice Tests
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3410060/

Case Study #1

Contributor
Dr James McEvoy (Royal Holloway, University of London)

Style of question
#ProblemSolving, #DataAnalysis, #Understanding, #ShortAnswer.

Level of Study
- England / Wales 4
- Scotland

Rationale This structured short-answer question begins by presenting the student with information that is related, but not identical, to that presented in class. On the basis of this prompt, the student is asked four sub-questions (a-d) targeting progressively higher cognitive levels. 25 marks are assigned to each question and are awarded five at a time according to the mark scheme, with occasional opportunities for partial credit (i.e. two or three marks for a partially correct point). Students are advised to spend around 20 minutes on the whole question (i.e. 5 minutes per sub-question).

Learning Objective Describe different levels of protein structure; explain structure/function relationships.

Example Question

B1 Figure 1 shows the two structural forms of a coronavirus spike protein. Before the virion attaches to the surface of a host cell, the spike protein adopts the “pre-fusion” form, and when it binds to a host cell, it changes to the “post-fusion” form.

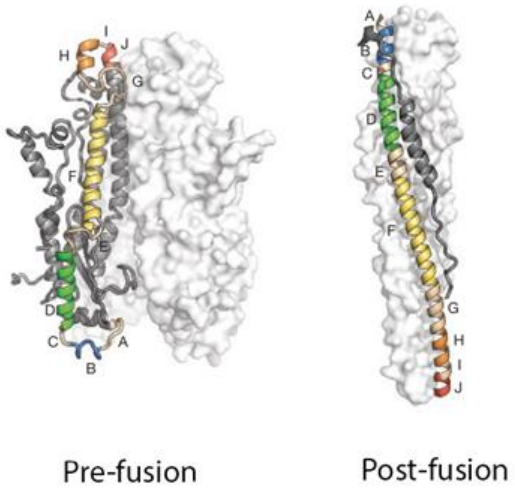


Figure 1. The pre-fusion and post-fusion structural forms of a coronavirus spike protein. Most of the protein is shown in light grey, using the space-filling representation. Selected sections of the polypeptide backbone are shown in dark grey and rainbow colours.

Case Study #1

Marking Scheme

(a) Identify and describe the type of secondary structure shown in the rainbow colours in the pre-fusion form (polypeptide regions B, D, F, H and J).

These sections are RH (5) alpha helices (5). The backbone is coiled (5), stabilized by intrastrand H-bonds (5), with a rise of 1.5 Å / residue and 3.6 residues / turn. (5)

(b) Identify and describe the type of secondary structure shown in the polypeptide regions A, C, E, G and I in the pre-fusion form.

These sections are (omega) loops (or turns) (5), without repeated structure (5). They are likely ordered (5) and well-defined (5), but they don't have distinctive torsion angle values (5).

(c) Explain what happens to the polypeptide structure as the pre-fusion form changes to the post-fusion form.

The loop sections (A, C, E, G, I) change their secondary structure (5) to become alpha-helices (5), becoming part of one long helix (A-J) (5) in a conformational change that extends the spike protein structure (5) through the cell membrane (5).

(d) Researchers replaced consecutive amino acid residues (Asn1067 and Leu1068) in region I of the pre-fusion form with Pro residues. They found that this mutation stabilized the pre-fusion form. Explain this observation, and its potential use in making a coronavirus vaccine.

Pro locks the backbone shape (torsion angles) / disrupts alpha-helices (5) because of its cyclic structure (5). It prevents the change in secondary structure and keeps the protein in the pre-fusion form (5). Antibodies to the pre-fusion form in the vaccine will be better at subsequently recognizing the virus before it fuses to a host cell (5), and the 2P mutant may therefore be useful for vaccines (5).

Case Study #2

Contributor Dr Alfred Thumser (University of Surrey)

Style of questions #Understanding #Analysis #VLE #SelfMarking

Level of Study

- England / Wales 4/5
- Scotland 7

Rationale In moving from in-class to online assessments, it is necessary to supplant previous “rote learning” questions, which can usually be searched online or in lecture presentations, with questions that require a deeper understanding of the materials.

- Address “threshold concepts”
- ‘Not in the notes’ type of questions

Learning Objective Critical understanding of biochemical concepts

Relevant Notes This approach can be used for in-class assessments. Provide students with ‘What?’ & ‘How?’. Assess the ‘Why?’. I have found it useful to base these types of questions on either classroom discussions or discussion forums, as these often provide viable alternatives to the correct answer and/or highlight misconceptions. As these questions are discussed in class, the ‘engaged’ students will not be disadvantaged.

Example Question 1

Identify the proteins and enzymes that are involved in the hydrolysis of glucose-6-phosphate to glucose, and transport of the latter out of the cell [**multi-select answer**]

Glucose-6-Phosphatase	Correct Answer
Glucose-6-phosphate transporter	Correct Answer
GLUT1	
GLUT2	
GLUT4	Correct Answer
GLUT5	
GLUT7	Correct Answer
Hexokinase	
FBPase-1	

Note: this question is discussed extensively and the answers are on a single lecture slide. One mark per correct answer; no negative marking.

Case Study #2

Example Question 2

Link the statements below, which are related to Glycolysis: [**linked statements**]

provides two ATP molecules

-The Preparatory Phase

- The Pay-off phase

-The overall pathway Correct Answer

utilizes two ATP molecules

-The Preparatory Phase Correct Answer

- The Pay-off phase

-The overall pathway

provides four ATP molecules

-The Preparatory Phase

-The Pay-off phase Correct Answer

-The overall pathway

Example Question 3

The enzyme Pyruvate Kinase is the final control point of glycolysis in the liver. Why is this beneficial?

- L-Pyruvate Kinase increases NADPH production
- L-Pyruvate Kinase increases NADH production
- L-Pyruvate Kinase prevents a futile cycle between Glycolysis and Gluconeogenesis **(Correct Answer)**
- M-Pyruvate Kinase is allosterically activated by Fructose-1,6-Bisphosphate **(Viable distractor)**
- L-Pyruvate Kinase is allosterically activated by PEP (Phosphoenolpyruvate)

Case Study #2

Style of questions: Short answer or multiple choice: **Data interpretation**, e.g. graphs; potentially addresses Problem Solving, Understanding, Data Analysis, Experimental Design, Application.

Level of Study

- England / Wales 4/5
- Scotland

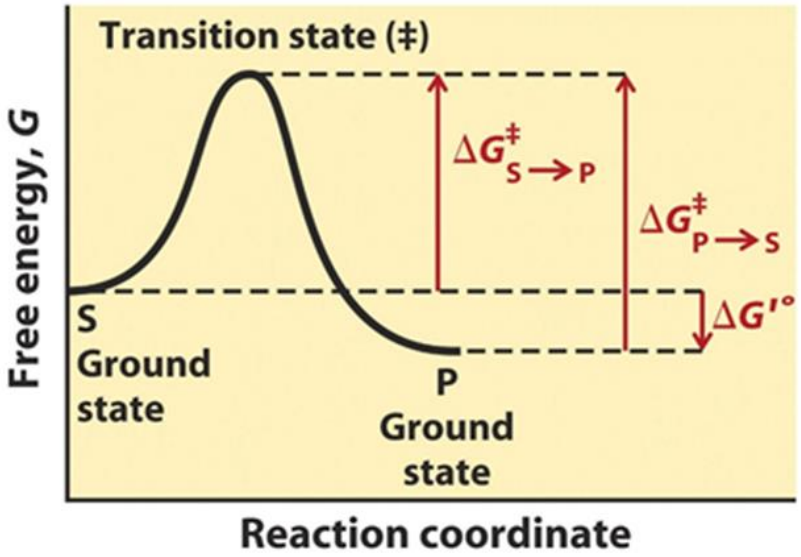
Rationale Many students find the interpretation of data/graphs conceptually challenging, thus a skill that needs to be developed. Threshold concept tested.

Learning Objective Critical understanding of biochemical/biological concepts

Relevant Notes* Exemplars should be discussed in class, which can be time-consuming

Example Question 4

The graph shown below indicates that the conversion of S → P is:



A. Exergonic — Correct Answer
B. Endergonic
C. Exothermic — Distractor
D. Endothermic
E. Reversible

Case Study #2

Example Question 5

Which of the amino acids shown below is the product of Kinase-mediated reactions?

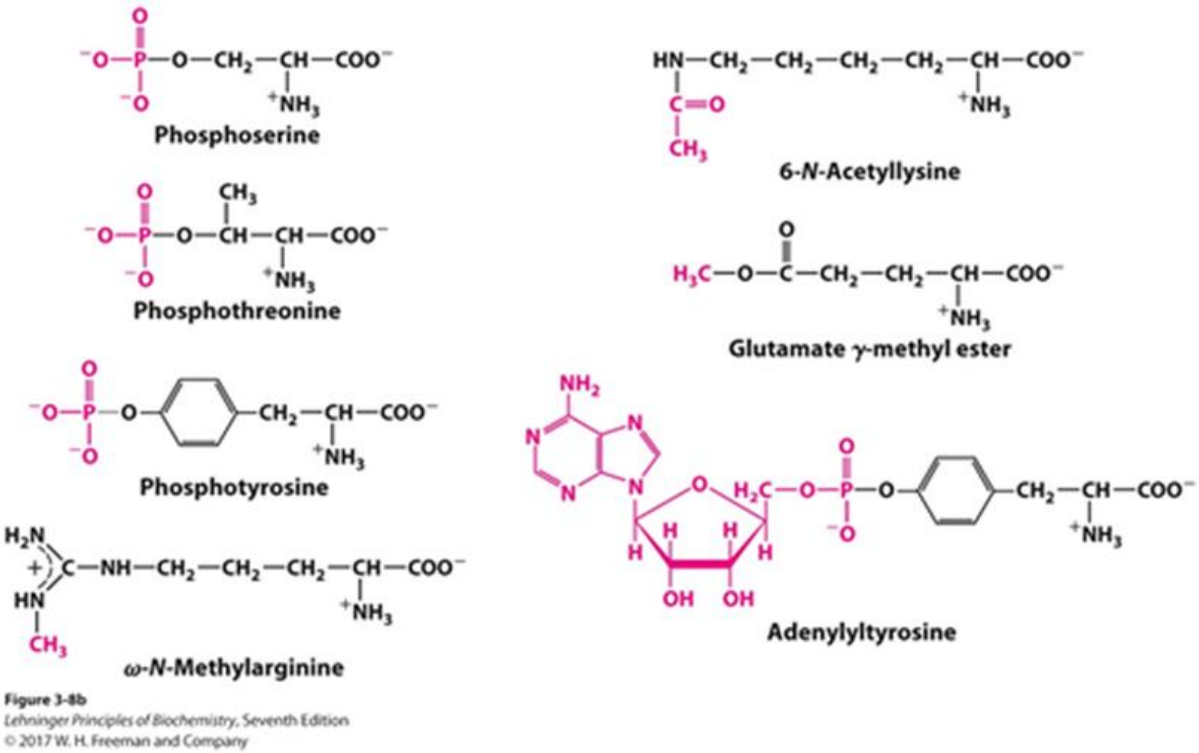


Figure 3-8b
Lehninger Principles of Biochemistry, Seventh Edition
© 2017 W. H. Freeman and Company

A. Glutamate methyl ester
B. Acetyllysine
C. Phosphoserine Correct Answer:
D. Methylarginie
E. Adenylytyrosine

Note: the diagram is from the lecture slides, with the concept of Kinases & Phosphatases extensively discussed but not explicitly included on the lecture slides.

Case Study #3

Contributor: David Smith (Sheffield Hallam University)

Style of question: #Understanding #SpotTheError #VLE #SelfMarking

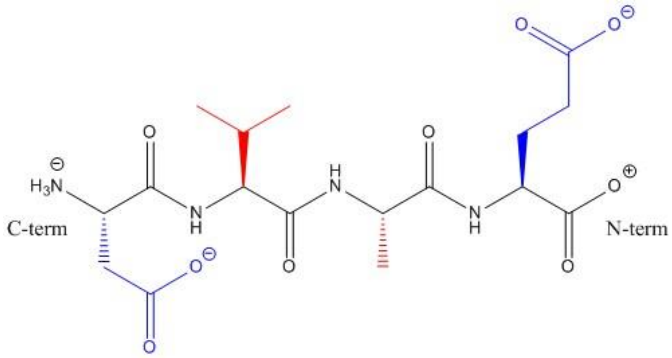
Level of Study:

- England / Wales 4/5
- Scotland 7

Rationale: In this question type, the idea is to take a statement, passage or image describing a given scenario or system and add in deliberate errors. The students are required to both identify and correct those errors. The other bonus to this type of question is that pools can be created and, by use of drop-down lists or fill in the blank style questions, the marking can be automated. The question style requires the students to analyse the text or image and demonstrate their understanding through the corrections. The VLE can also be set up with expected responses making the question self-mark. In the full answer, there were 15 possible correct/incorrect responses. If you write the text or create the images yourself, then the information cannot easily be googled.

Learning Objective: Students will be able to evaluate key information on a given topic.

Example Question: The peptide below has deliberate errors added in. Use your knowledge of amino acids and peptides to identify the errors.



Marking: The answer can be free text if you wish or, if you want to automate the process, the students can select the error from a list of possibilities:

a) C-term and N-term labelled incorrectly. *(correct answer)*
b) Incorrect charge on terminal residues. *(correct answer)*
c) The glutamine side-chain cannot be ionized.
d) The C-terminal amino acid backbone has too many carbon atoms.
e) The side chain of Aspartate carries an incorrect charge.

Notes: To limit collusion, a question pool can be created within the same answer set. In this case, different images would be created with errors included.

Case Study #4

Contributor: Dr. Nicola Jordan-Mahy & Dr. Kirsti Newton Sheffield Hallam University

Style of questions: #Scenario #ProblemSolving #Essay #CaseStudy

Level of Study

- England / Wales 5
- Scotland

Rationale: This scenario-based problem solving seen essay exam question, is part of the open book online exam for the Control Physiology module. This module is taught to Level 5 BSc Human Biology students. This module aims to expand students' knowledge of human physiology, and how the body homeostatically responds to physiological extremes. We wish students to study the physiology of the human body as a whole, and not to compartmentalise the systems of the human body and understand that changes in one system will impact on another system.

The Control Physiology end of module exam is made up of 40 randomised online MCQs and 10 short answer questions, which test the full breadth and depth of the module and a seen essay question which requires students to extract information from several areas of the taught material. The seen essay is released one month prior to the exam, allowing students to prepare the essay.

In the seen essay question, we use a newspaper-style article to outline a scenario, often based on real-life events or accomplishments of celebrities or athletes. Students must interrogate the scenario and consider a number of factors which may cause physiological changes and the activation of a number of homeostatic mechanisms. Students are asked to write a structured essay based on a series of questions, within a 1500 word limit. These questions highlight specific homeostatic regulatory systems and may ask students to compare scenario subjects, make recommendations or predict consequences or survival of extreme events or environmental conditions.

Learning Objective: To apply core learning and knowledge to a real-world scenario

Notes: A good essay will include the majority of the points from lecture material, a very good essay will show evidence of additional content. Extras marks will be given for all relative material not included here. Essay should clearly relate to the scenario given, and info given should be appropriate for gender, duration of ordeal, and ideally account for the environmental extremes (high temperature and lack of water) and the food/energy expenditure in the scenario. An excellent essay may mention additional material about the environmental conditions, and give advice/strategies how to survive. An excellent essay may briefly mention the effects of eating on hormone levels during starvation, though this is not necessarily expected in an essay of this length.

Case Study #4

Example Question:

Woman, 52, survives TWO WEEKS in the Australian Outback by drinking water filtered through her shirt.

Written by Mandy Whitehall

52 year old Tamra McBeath-Riley went missing for 2 weeks in the Australian Outback near Alice Springs. She and her friends 46 year old Claire Hockridge and 40 year old Phu Tran were on an afternoon four-wheel drive across the outback headed toward Stuarts Well, south of Alice Springs. During the drive, their car got bogged down in mud and could not move. Tamra stayed with the car whilst the others walked to try and get some help. Left alone with the car in the isolated outback, Tamra dug a hole underneath the car to provide shelter during the scorching daytime temperature of 40 ºC, and slept in the vehicle at night when the temperature dropped to 25ºC.

Tamra had limited food and drink. Initially, she drank 2 litres of bottled water left in the car, but when she ran out, she drank dirty water collected from puddles, which she purified by boiling and filtering it through a T-shirt. The only food she had was two packs of biscuits and some dry noodles. After 10 days when supplies had run out, Tamra left the car and set out to find shelter and water, leaving a note in the vehicle. After wandering for several days in the outback, she eventually stumbled across a cattle drinking hole, where she was later found by police and airlifted to hospital suffering the effects of dehydration, heat exhaustion and starvation. Her two friends still have not been found.

1. Explain the physiological changes that Tamra would have experienced during her ordeal.

(a) Explain the effect of dehydration on the body, and how the homeostatic mechanisms of the body would try to retain water (30%).

(b) Explain the regulation of body temperature in a hot climate such as that found in the outback, and what happens in heat exhaustion (30%).

(c) Explain the effect of starvation on Tamra's metabolism (40%).

Case Study #4

Marking Scheme

(a) Explain the effect of dehydration on the body, and how the homeostatic mechanisms of the body would try to retain water (30%).

- Water input & output is equal (1).
- We ingest 2.2 litres of food & drink (1)., with 6-15 g of NaCl, (1), plus 0.3litres from metabolism (1).
- Water input is attributed to habitual eating & drinking (1).
- Excess is lost in urine 1.5l/day (1)., sweat (1)., breath (1). (0.9L/day) (1) & faeces (0.1L/day) (1). insensible water loss (1).
- Water homeostasis is regulated by Thirst (1) & Urine formation (1).
- Tamara is dehydrated (1).and thirsty (1) & will produce small amounts of urine (1).
- She will experience: Cellular Dehydration (1). - an ↑osmolarity of bl plasma (1) & water is drawn out of cells (1) causing cell shrinkage (1).
- Hypothalamic osmoreceptors (1) (nerves cells) (1) are v. sensitive (1) to changes in bl. osmolarity and shrink (1) these send impulses to the cerebral cortex (1) and ↑thirst (1) & ADH production (1)
- ADH is normally at 2.5 pg/ml plasma (1) and this maintains a urine osmolarity of 600 mosm/kgH_2O (1).
- Plasma ADH levels can be ↑or ↓ (1).
- ADH ↑ water retention (1) & ↓urine volume (1) but increase its concentration. (1).
- Alternatively, drinking a litre of water. →↓in plasma osmolarity., causing swelling of the hypothalamic osmoreceptors. →↓ADH levels.
- This ↑excretion rate of the kidneys & urine volume which is dilute.
- At a cellular level: ADH binds to G-couple protein (1) on collecting duct cells (1).and increases aquaporin-2 (1) in the luminal membrane (1) and increases water resorbed (1).
- Extracellular Dehydration (1) a drop in blood volume (1) due to excessive sweating (1). plus expiration from working in a very hot environment (1), causes ↓ bl. volume (1).
- The CVS baroreceptors detect the↓ BP (1) and stimulate the hypothalamic thirst centre, (1). ↑ the levels ADH (1) and ↑ water reabsorption in the kidney (1) & ↑ Bl. & ECF volume (1).
- In the kidneys - ↓renal bl. Volume (1) or increase renal salt conc (1). causes the release of renin (1).
- Renin acts on angiotensinogen (1) and converts it to Angiotensin I (1). and then to angiotensin II (1) under the influence of ACE (1) (produced in the lungs) (1).
- Angiotensin II: Acts on the hypothalamus & stimulates thirst (1) & ↑ ADH (1) which↑ renal water retention.
- ↑vasoconstrictor (1) → ↑peripheral resistance (1). & BP (1).
- ↑ aldosterone. (1) from the adrenal cortex (1). → ↑reabsorption of sodium (1). to parallel water resorption (1).
- Aldosterone acts directly on the kidneys (1) & further ↑sodium absorption (1). ↑thirst (1). and ↑ sensitivity of tongue salt receptors (1) → ↑ consumption of salty food (1).
- Aldosterone → ↑ Na+ reabsorption & ↑ K+ excretion. the in kidney principle. or P-cells in the DCT
- ↑ Na+ retention & ↑K+ excretion in sweat glands, . salivary glands . & the intestine by the activation of Na+/K+ ATPase
- Once the GFR is normal, renin production is inhibited by NO (1). from the macula densa
- Increased sodium concentration in the GF: ↑ renal water retention & ↑ peripheral oedema, ↑ GFR to ↑ renal sodium excretion.

Case Study #4

(b) Explain the regulation of body temperature in a hot climate such as that found in the outback, and what happens in heat exhaustion (30%).

- Normally: Humans regulate their own body temperature between 35.5 – 37.7°C (1). = Homoeothermic (1).
- Energy generated by metabolism is enough to maintain body temperature. in a Thermoneutral zone (1). 27.8-30°C (1). outside this thermoregulation mechanisms are required (1).
- Overheating is more serious than cooling (1)., even moderate rises in body temperature will cause malfunction of nerves (1). & protein damage (1)..
- Tamara heat gain is from: (a) Metabolism (BMR). Muscle contractions, Hormones & Thermic effects of food. or from (b) the environment (1)
- The hypothalamus acts like a thermostat (1). & regulates body temperature(1). It is sensitive to changes of 0.1°C (1).
- Peripheral thermoreceptors in the skin (1). & central thermoreceptors (1). in the core relay information to the hypothalamus (1).
- The anterior region is activated by warmth (1) which triggers heat loss (1) and causes a ↓ the sympathetic adrenergic stimuli (1). to bl vessels & ↑ sympathetic acetylcholine activity (1). causing vasodilation of skin bl vessels (1). & ↑ heat loss by radiation (1). & conductive (1). which is enhanced by convection(1).
- The hypothalamus. ↑ sympathetic activation (1). of sweat glands (1) & ↑sweating(1). and ↑ cooling by evaporation (1) .
- We can produce 1.4 l/hr under moderate conditions(1)., which ↑ to 4 to 6 l/hr in very hot conditions(1).
- Exercise in a hot environments causes excessive sweating (1) and this can led to ↓ CO(1). & ↓BP (1) . & ↑ oxygen demand (1).
- The CVS regulatory mechanisms override those of thermoregulation (1) and ↑ peripheral vasoconstriction (1)., ↑ BP(1). & ↑ blood volume available to carry oxygen to muscles (1).
- There is also an increase in ADH(1) ↑water (1)& ↑ cardiac volume (1) & ↑BP (1).
- Aldosterone(1). is also produced ↑ sodium resorption(1).
- Exercise causes unregulated heat production(1)↑ BMR (1)20-25 times above resting level (20 kcal/min) (1)which ↑ in core temperature by 1°C every 5-7 mins (1).
- Tamara could remove clothes, (1) drink cold water(1), decrease muscle activity(1). move at night (1) or seek shade(1) under her car/ make an umbrella.
- TAmara is at risk of heat exhaustion - severe dehydration with a body temperature of 37.5 -39°C (1). Caused by excessive vasodilation and sweating (1), that caused a ↓bl volume (1)., CO (1). & BP (1).
- The CVS reflexes cause vasoconstriction (1) and. shunts blood to the CVS (1) causing a loss of colour (1), fainting. (1), muscle cramps (1)., nausea (1). & headache (1).
- It can progress to heat stroke (1) and possible death (1).

Case Study #4

(c) Explain the effect of starvation on Tamra's metabolism (40%).

- Should mention number of calories available (1) and calorie expenditure (1).
- Muscle (1) and liver glycogen stores (1) will have been depleted within first few hours (1)
- Resistance phase of stress response (1) will lead to increased cortisol (1) production.
- The decrease in insulin (1) and increase in cortisol (1) will decrease protein synthesis (1) and increase protein catabolism (1)
- Muscle (1) tissue has large protein reserves (1), releasing amino acids to circulation (1).
- Under the influence of cortisol (1) there will be an increase in utilisation of glucogenic amino acids (1) for gluconeogenesis (1) in the liver (1). Ketogenic amino acids can be metabolised in the TCA cycle (1).
- Blood glucose will decrease over the first day or two (1) then stabilise at approx. 65mg/100ml (1).
- Free triglyceride (1), and free fatty acid levels will rise rapidly (1) via lipolysis (1) in adipose tissue (1).
- The glycerol (1) from triglyceride breakdown can be utilised for gluconeogenesis (1).
- The liver (1) takes up free fatty acids, and in conditions of high fatty acid metabolism (1), resulting acetyl Co-A (1) will be used for ketogenesis (1), driven by glucagon (1) and indirectly by cortisol (1).
- The ketone bodies (1) can be used by many tissues (1) including the brain (1), and under the influence of cortisol (1), many other tissues are able to utilise this for ATP production (1).
- Fatty acids (1) undergo beta-oxidation (1) to provide ATP in many tissues (1) as they switch fuel under the control of cortisol (1).
- After approx. 2 days of starvation approx., one-third of the brain's fuel will be supplied by ketone bodies (1).
- The switching of fuel to ketone bodies and fatty acids (1) in many tissues (1) enables the conservation of glucose (1) and limits the breakdown of protein (1).

Case Study #5

Contributor: Dr Joanne Stewart-Cox (University of Bath)

Style of question: #Application

Application of subject-specific and experimental knowledge to produce novel figures and corresponding figure legends in a style which might be used in a published scientific review article.

Level of Study

- England / Wales 5
- Scotland 8

Rationale: It is sometimes the case that students produce exam answers which are a regurgitation of lecture material with the inclusion of diagrams which are barely more than a replication of what has been presented to them. The rationale for this question type is that there are aspects which are non-googleable and answers require not only assimilation of knowledge, but also an appreciation of the required detail needed in figures used in published scientific review articles. This question type aims to prompt students into producing a novel piece of work which requires deeper thinking rather than a surface-level of understanding.

Learning Objective:

1. Demonstrate knowledge of major cell signalling systems and explain methods used to study these cell signalling events.
2. Synthesise and summarise information in order to effectively communicate subject information using scientific writing conventions.

Relevant Notes: A taught session was provided to the students to make sure they understood the purpose of a figure and figure-legend. There were multiple examples of published data shown to the students in the form of figures throughout the semester from a range of scientific journals. Students didn't have prior knowledge that this type of question would appear in the examination, but this could be specified in advance.

Example Question

a) Produce a figure and use it to illustrate the signalling pathway that allows light to be perceived by the vertebrate eye. Figures should be produced in a style as seen within scientific review articles, with diagrams labelled and explained using a figure legend. The figure can be hand-drawn or produced digitally (approximately 200 words). (40% of the marks).

AND

b) Discuss the importance of signal amplification, mechanisms that allow rapid reversal and adaptation in this process (approximately 200 words). (30% of the marks).

AND

Case Study #5

c) Explain how deep sea fishes are adapted to detect light at over a mile below the ocean surface (approximately 200 words). (30% of the mark).

Example Marking Scheme

a) Figure and explanation of the pathway from absorption of a photon by retinal and activation of the rhodopsin molecule to inhibition of neurotransmitter release, with better answers also considering key features of the photoreceptor cell.

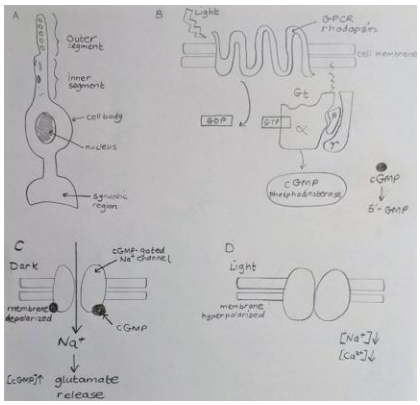


Figure 1: Light signalling pathway in the vertebrate eye, illustrating the perception of light via rhodopsin GPCR coupled to Gt alpha transducing within rod cells. A) Structure of a rod cell. Rhodopsin GPCRs are present within internal membranes in the membrane discs of the outer segment. **B)** Rhodopsin-Gt signalling cascade. A photon of light causes a conformational change of rhodopsin GPCR, allowing interaction with the G-protein, transducin (Gt). This causes the helical domain of the α-subunit to open, allowing GDP to be exchanged for GTP. This GDP to GTP exchange causes activation and dissociation of the α-subunit from the β-γ-subunits. The active α-subunit interacts with cGMP phosphodiesterase, activating it to hydrolyse cGMP to 5'-GMP. **C)** In a dark environment, cGMP allows for the opening of cGMP-gated Na+ channels on the cell surface membrane, causing an influx of Na+ ions and membrane depolarisation. This results in downstream signalling for glutamate release (the signal inhibitor). **D)** In a light environment, with low levels of c-GMP, due to its conversion to 5'-GMP, cGMP-gated Na+ channels remain closed, and the membrane becomes hyperpolarized as the [concentration] of Na+ and Ca+ ions are actively reduced. The hyperpolarization of the rod cell prevents the release of the glutamate. A signal is transmitted to the brain that light has been perceived by the cell.

b) Identification of amplification steps in the signalling pathway and importance, especially in low light levels (exceptional answers may refer to adaptations in deep sea fish). How Na+ channels are re-opened through the actions of Ca2+/recoverin, RGS proteins and retinal recycling. Role of G protein receptor kinases and arrestin.

c) Amplification of opsin gene numbers and optimal 'tuning' of key residues involved in detection of light in blue/green wavelengths with better answers pointing out how this matches biology bioluminescent signals likely used for social interactions.

Case Study #5

Comments on general student performance

The nature of the question meant that it was comparatively easy to judge academic ability against the marking criteria; assigned marks were widely distributed as a result, rather than being clumped around a relatively narrow mean. As an example, the question asked for a figure and description in the form of a figure legend, but this was frequently ignored. Most answers neglected to include a title for the legend or indeed to present the text as a proper legend. Where present the figure title could often have been improved to be concise and/or accurate in describing the figure. Similarly, detail, clarity and labelling of figures varied enormously. The three parts of each question related to each other and there was scope to use the figure drawn in the first part to illustrate mechanisms discussed in the later parts. The best answers were concise and well organised, and addressed each part of the question in good detail.

a) Some students chose to show signalling in their figure at the molecular level without showing the cellular context, while others showed the cell context but not the molecular pathway. Figures in the best answers tended to incorporate both views.

b) Answers could often have been clearer in identifying the amplification steps in the signalling pathway. One way to do this was to use the figure from a) to highlight each amplification step. Explanation of signal reversal and adaptation varied in accuracy and detail and students were sometimes confused.

c) This was generally answered well, with most covering the expansion of the Rh1 gene family and specialisation to gather light at the wavelengths encountered in the deep sea (notably including bioluminescence). Exceptional answers also explained how the sequences of deep-sea fish RH1 genes have evolved to encode rhodopsin receptors tuned to detect those wavelengths through a series of specific amino acid substitutions. Some described the adaptations as enabling detection of a broader range of wavelength, which is inaccurate.

Case Study #6

Contributor David Smith (Sheffield Hallam University)

Style of question #ProblemSolving #ExperimentalDesign

Level of Study

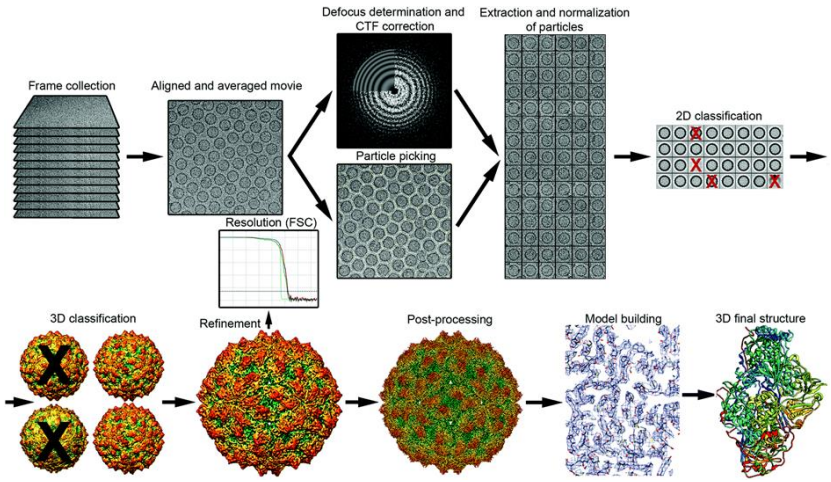
- England / Wales 6
- Scotland 9/10

Rationale Lay summaries are short accounts of research that are targeted at a general audience. They play a significant role in most research grant applications and can also be useful in supporting public engagement with research and hence represent an authentic assessment. Lay summaries are particularly important for research in medicine and health and usually are a prerequisite for grant applications made to the UK research councils and to medical charities. Within an online exam, students will be able to look up technical details of a given method or application, however, translating that understanding into an alternative format requires skills in understanding and creativity.

Learning Objective Students will be able to apply their knowledge and understanding to generate unique solutions to a given problem.

Relevant Notes Marking schemes need to be flexible and adaptable, assessing the idea and feasibility of what's being suggested. Students were prepared for this style of assessment via formative assessment during a workshop related to the delivery of core knowledge.

Example Question The image below shows an overview of single-particle cryo-EM workflow, from data collection to 3D model.



Write a short (~200 word) lay description of cryo-EM for the structural determination of membrane proteins that would be understandable by an A-level student studying Chemistry and/or Biology. (10 marks)

(We will be looking at the accurate descriptions of the stages rather than the spelling and structure of the answer)

Case Study #6

Example Marking Scheme

>8 Content is scientifically correct and written in an easily readable style for the target audience. Avoids complex or meaningless terms and phrases. Text is logical, flows and is presented in the active voice. Aims and objectives are clear and understandable by the general public.

7-8 Scientific content has depth and detail and is easily readable for the target audience. Avoids complex or meaningless terms and phrases. The structure is logical from point to point but may be presented in the passive voice. Aims and objectives are described in a way the general public would understand.

6-7 Scientific content and detail, may not be easily readable for the target audience. Some complex terms are used. Structure leads from point to point but may be presented in the passive voice. Aims and objectives are described in a way the general public would understand.

5-6 Scientific content but is not easily readable for the target audience. Some complex or meaningless terms are used. Structure leads from point to point but may be presented in the passive voice. Aims and objectives are adequately described, and may not be understandable by the general public.

4-5 Scientific content is not easily readable for the target audience. Complex or meaningless terms are used. Lack of structure between aims. Text was written in the passive voice. Aims and objectives are insufficiently described.

3-2 Errors in scientific content and the text is not readable for the target audience.

2-1 Meaningless terms or phrases used. Lack of structure between aims. Aims and objectives are insufficient described.

Little or no attempt was made at writing the description.

Case Study #7

Contributor Dr Catherine Duckett (Sheffield Hallam University)

Style of question #ProblemSolving #Understanding #DataAnalysis #Application

Level of Study

- England / Wales 5
- Scotland

Rationale

Interpretation of analytical data is a fundamental skill in a host of bioscience graduate careers or in further study. Many graduate roles require that data be understood and interpreted and as such represents an authentic assessment style. Addressing such questions requires a sound theoretical underpinning, however, the answers cannot be searched if the data is novel. Collusions can also be addressed by using large sets in which each student gains their own data or spectra. To prepare the students exposure to spectra and regular practice is the overriding key to success and progression to advanced characterisations in problem-solving.

Learning Objective

LO1. Students will be able to interpret and evaluate both qualitative and quantitative data obtained from analytical measurements.
LO2. Students will be able to develop problem-solving strategies that are appropriate for a given analytical situation.

Relevant Notes

Students practice spectral interpretation throughout the module, with a focus on IR, NMR and MS spectra of small molecules. They are also encouraged to predict simple NMR spectra, MS ions and IR bands from given structures, based on their theoretical knowledge. By practising throughout the module, they get to recognise their own individual approaches to interpretation and how they pull pieces of the jigsaw together from each spectrum – and there is not just one correct way to reach the endpoint.

Example Question

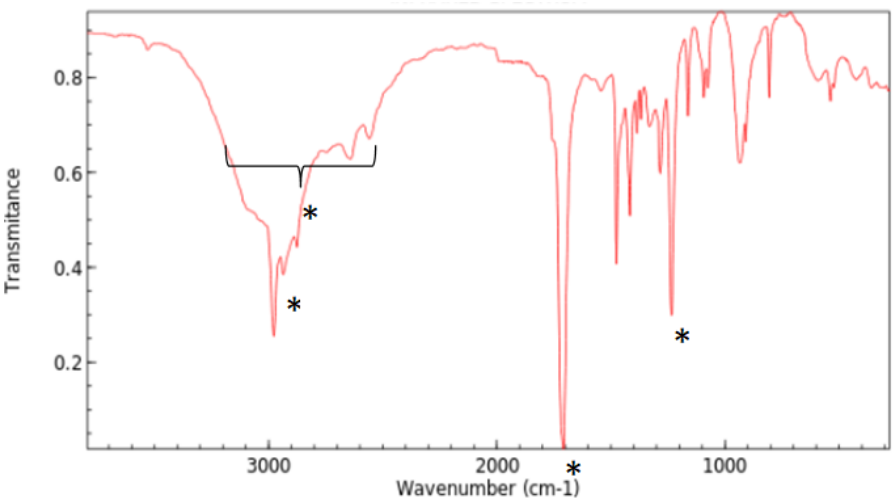
> a) Using the information and spectra given below, determine the empirical/molecular formula, structure and name of the unknown compound. Show all workings.
>
> b) Fully assign peaks in the spectra provided (the molecular ion and 3 key associated peaks for MS; the banks indicated * in the IR; and all for the ^{1}H NMR and ^{13}C NMR). Marks will be awarded accordingly.

Case Study #7

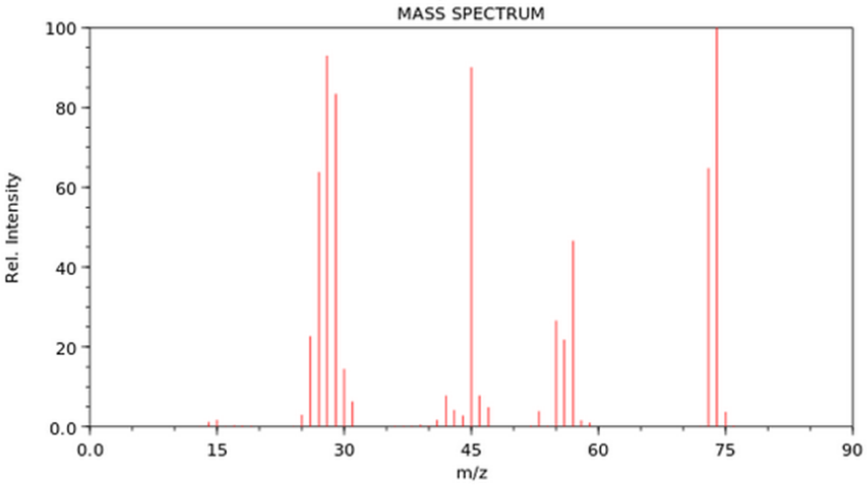
Elemental Composition:

C 48.7% H 8.1% O 43.2%

InfraRed Spectrum:

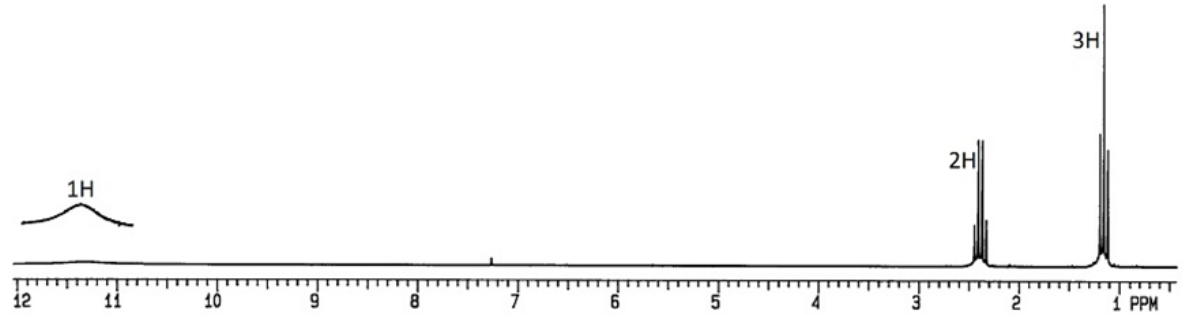


Mass Spectrum

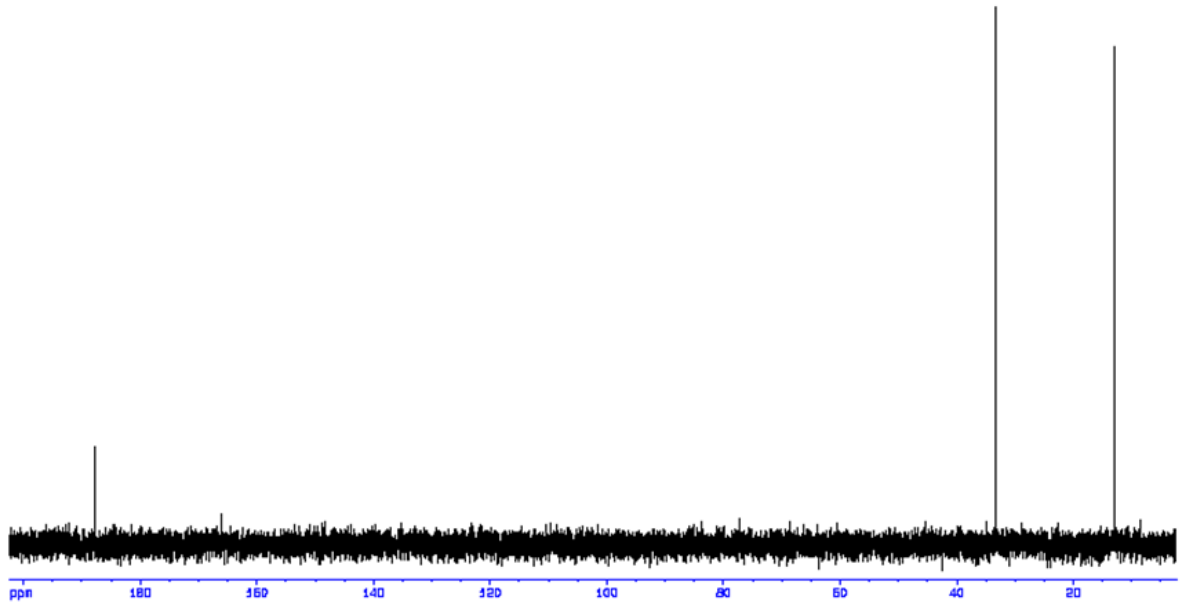


Case Study #7

^{1}H NMR Spectrum



^{13}C NMR Spectrum



Example Marking Scheme

Show workings through for calculation to reach $C_3H_5O_2$, propanoic acid name and correct structure. The structure that is close is awarded some marks accordingly, or attempt at the correct name.

IR- assign OH, CH, C-O and C=O. State 'of acid' or according to their structure derived.

MS – molecular ion; loss of water; carboxy; ethyl.

^{1}H NMR – CH_3 of ethyl; CH_2 of ethyl; OH of carboxylic acid; or according to their structure derived.

^{13}C NMR - C of CH_3, C of CH_2; C of carbonyl; or according to their structure derived.

Case Study #8

Contributor: Philip Leftwich (University of East Anglia)

Style of question #ProblemSolving #Understanding #DataAnalysis, #ExperimentalDesign #Application

Level of Study

- England / Wales 5/6
- Scotland 8/9/10

Rational In this question type, the idea is to present an experimental scenario, observation, or problem. Students must identify an ideal lab protocol that would allow experimental validation of a hypothesis; requirements are to make predictions against which they would check lab results, providing details of equipment, reagents, and conditions required (where appropriate). Answers can be requested as free-form text, multiple-choice drop-down lists, or fill in the blanks as required. Questions are problem-based, and additional web tools are encouraged (where students have experience of using them). Each problem requires the application of lab and theoretical knowledge, therefore, students cannot easily google answers.

Learning Objective Students will be able to apply taught theory and practical lab skills to solve new problems.

Relevant Notes: The scenarios presented work well when embedded clearly in scenarios gathered from their taught lecture content, and require analytical lab skills previously developed in practical classes. Students in my classes are familiar with electronic lab notebooks and common molecular biology web tools for primer design, sequence translation, enzymatic cleavage sites, gel electrophoresis simulations – and are expected to use these to make precise predictions. The example below is one section of a multi-part question as such additional context is provided that would otherwise be introduced alongside other sections.

- Question over the page-

Case Study #8

Example Question

Background You are rearing populations of the fruit fly *Drosophila melanogaster* when you observe a male with white eyes instead of the normal red eye colour, this is determined to be a result of a mutant allele in the gene *white* (*w*).

In order to understand more about this gene, we have developed a transgene known as *miniwhite* which produces a functional replica of the protein produced from w^+ and has been shown experimentally to restore eye colour to wildtype in homozygous (w^-) mutants when introduced through transgenesis.

i) As a follow up to this first experiment, Site Directed Mutagenesis (SDM) was used to modify the rescue gene *miniwhite* and generate the sequence shown below, which is also introduced to *Drosophila melanogaster* using the same protocol. What is your prediction on whether this mutated version of *miniwhite* will also be able to restore eye colour? Explain your reasoning.

a) Original *miniwhite* sequence

Atgggccaagaggatcaggagctattaattcgcggaggcagcaaacacccatctgccgagcatctgaacaatggtgacagcggagcggcttcgcagagctgcattaaccaggg
cttcgggcaggccaaaaactacggcacgctcctgccacccagtccgccggaggactccggttcagggagcggccaactagccgagaacctcacctatgcctggcacaatatgg
acatctttggggcggtcaatcagccgggctccggatggcggcagctggtcaaccggacacgcggactattctgcaacgagcgacacataccggcgcccaggaaacatttgctca
agaacgtttgcggcgtggcctatccgggcgaacttttggccgtgatgggcagttccggtgccggaaagacgaccctgctgaatgcccttgcctttcgatcgccgcagggcatccaag
tatcgccatccgggatgcgactgctcaatggccaacctgtggacgccaaggagatgcaggccaggtgcgcctatgtccagcaggatgacctctttatcggctccctaacggccagg
gaacacctgattttccaggccatggtgcggatgccacgacatctgacctatcggcagcgagtggcccgcgtggatcaggtgatccaggagctttcgctcagcaaatgtcagcacac
gatcatcggtgtgcccggcagggtgaaaggtctgtccggcggagaaaggaagcgtctggcattcgcctccgaggcactaaccgatccgccgcttctgatctgcgatgagcccacct
ccggactggactcatttaccgcccacagcgtcgtccaggtgctgaagaagctgtcgcagaagggcaagaccgtcatcctgaccattcatcagccgtcttccgagctgtttgagctctt
gacaagatccttctgatggccgagggcagggtagctttcttgggcactcccagcgaagccgtcgacttcttttcctacgtgggtgcccagtgtcctaccaactacaatccggcggacttt
tacgtacaggtgttggccgttgtgcccggacgggagatcgagtcccgtgatcggatcgccaagatatgcgacaattttgctattagcaaagtagcccgggatatggagcagttgttgg
ccaccaaaaatttggagaagccactggagcagccggagaatgggtacacctacaaggccacctggttcatgcagttccgggcggtcctgtggcgatcctggctgtcggtgctcaa
ggaaccactcctcgtaaaagtgcgacttattcagacaacgatggttgccatcttgattggcctcatctttttgggccaacaactcacgcaagtgggcgtgatgaatatcaacggagcca
tcttcctcttcctgaccaacatgacctttcaaaacgtctttgccacgataaatgtgttcacctcagagctgccagtttttatgagggaggcccgaagtcgacttttatcgctgtgacacatact
ttctgggcaaaacgattgccgaattaccgctttttctcacagtgccactggtcttcacggcgattgcctatccgatgatcggactgcgggccggagtgctgcacttcttcaactgcctggc
gctggtcactctggtggccaatgtgtcaacgtccttcggatatctaatatcctgcgccagctcctcgacctcgatggcgctgtctgtgggtccgccggttatcataccattcctgctctttgg
cggcttcttcttgaactcgggctcggtgccagtatacctcaaatggttgtcgtacctctcatggttccgttacgccaacgagggtctgctgattaaccaatgggcggacgtggagccggg
cgaaattagctgcacatcgtcgaacaccacgtgccccagttcgggcaaggtcatcctggagacgcttaacttctccgccgccgatctgccgctggactacgtgggtctggccattctc
atcgtgagcttccgggtgctcgcatatctggctctaagacttcgggcccgacgcaaggagtag

b) SDM Mutant version of *miniwhite*:

atgggccaagaggatcaggagctattaattcgcggaggcagcaaacacccatctgccgagcatctgaacaatggtgacagcggagcggcttcgcagagctgcattaaccaggg
cttcgggcaggccaaaaactacggcacgctcctgccacccagtccgccggaggactccggttcagggagcggccaactagccgagaacctcacctatgcctggcacaatatgg
acatctttggggcggtcaatcagccgggctccggatggcggcagctggtcaaccggacacgcggactattctgcaacgagcgacacataccggcgcccaggaaacatttgctca
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cacctccggactggactcatttaccgcccacagcgtcgtccaggtgctgaagaagctgtcgcagaagggcaagaccgtcatcctgaccattcatcagccgtcttccgagctgtttga
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ctcaaggaaccactcctcgtaaaagtgcgacttattcagacaacgatggttgccatcttgattggcctcatctttttgggccaacaactcacgcaagtgggcgtgatgaatatcaacgg
agccatcttcctcttcctgaccaacatgacctttcaaaacgtctttgccacgataaatgtgttcacctcagagctgccagtttttatgagggaggcccgaagtcgacttttatcgctgtgaca
catactttctgggcaaaacgattgccgaattaccgctttttctcacagtgccactggtcttcacggcgattgcctatccgatgatcggactgcgggccggagtgctgcacttcttcaactgc
ctggcgctggtcactctggtggccaatgtgtcaacgtccttcggatatctaatatcctgcgccagctcctcgacctcgatggcgctgtctgtgggtccgccggttatcataccattcctgctc
tttggcggcttcttcttgaactcgggctcggtgccagtatacctcaaatggttgtcgtacctctcatggttccgttacgccaacgagggtctgctgattaaccaatgggcggacgtggagc
cgggcgaaattagctgcacatcgtcgaacaccacgtgccccagttcgggcaaggtcatcctggagacgcttaacttctccgccgccgatctgccgctggactacgtgggtctggcc
attctcatcgtgagcttccgggtgctcgcatatctggctctaagacttcgggcccgacgcaaggagtag

start codon

SDM mutation site

Figure 1. Nucleotide sequence of the *miniwhite* gene. a) the nucleotide sequence of the unmodified *miniwhite* gene. The first three nucleotides of the sequence indicate a start codon, and the underlined and highlighted section mid-sequence is the unmodified sequence at the site of SDM. b) the nucleotide sequence of the modified *miniwhite* gene after SDM. The first three nucleotides indicate a start codon, and the underlined and highlighted section mid-sequence indicates the nucleotides which have been mutated relative to the sequence in a).

Case Study #8

ii) Develop a strategy that confirms SDM has successfully mutated the original transgene to the new sequence. You have access to standard molecular lab equipment, including a thermocycler, heat blocks and gel electrophoresis, you have standard lab reagents and the following choice of primers and restriction enzymes.

When describing your protocol – you should clearly detail all equipment and reagents required, but are not required to provide the conditions/settings of any equipment you would use.

Please include a suitable control and provide details of all expected results
(e.g. sizes of amplicon products and restriction digests).

	Primer name	Sequence
Pair 1	mini-white 194-217 FWD 1	ccgagaacctcacctatgcctggc
	mini-white 1372-1393 REV 1	tccgttgatattcatcacgccc
Pair 2	mini-white 270-290 FWD 2	gctggtcaaccggacacgcgg
	mini-white 461-481 REV 2	gcagtcgcatcccggatggcg
Pair 3	mini-white 762-782 FWD 3	aggcactaaccgatccgccgc
	mini-white 1390-1412 REV 3	tcaggaagaggaagatggctccg

Restriction enzymes

HpaI
PvuII
KpnI
EcoRv

Case Study #9

Contributor: Nigel Francis (Cardiff University)

Style of question: #Understanding, #Interpretation, #Analysis, #Application

Level of Study:

- England / Wales 6
- Scotland

Rational

Asking students to engage with the wider literature encourages them to read more broadly around the subject area and therefore gain a more in-depth understanding of the topic. Students are provided with a core text (primary paper) linked to the lecture content and are then examined on their ability to answer interpretive/analytical questions relating to these core papers.

Learning Objective

LO1 Discuss detailed aspects of the immune system and apply this to disease processes in humans
LO2 Analyse and critically evaluate scientific papers that contribute to our current understanding of the immune system in health and disease
LO3 Interpret and explain experimental data leading to the design and justification of experimental approaches to address a current immunological question

Relevant Notes

All papers are provided at the time of lecture delivery, so students can link them to the content as it is taught. The exam is open book, so students can have annotated copies of the papers in the exam. 13 papers were provided to cover 15 lectures, with some papers spanning 2 lectures. Exam consisted of 5 analytical questions, students had to answer 4 or the 5 questions.

Example Question

Paper: Gupta et al. HIV-1 remission following CCR5Δ32/Δ32 haematopoietic stem-cell transplantation. Nature. 568, 244–248 (2019).

Describe how an allogeneic haematopoietic stem cell transplantation (HSCT) containing the CCR5 32/32 mutation would result in the formation of CD4+ T-lymphocytes that were resistant to HIV infection (50%). Identify and explain immunologically the key clinical changes seen in the ‘Essen’ patient as a result of this transplant (30%). What are the key limitations of this study (20%)?

Example Marking Scheme

- HSCs develop into lymphoid progenitors which become CD4+ T-lymphocytes. CCR5 is known to be a co-receptor for HIV-1 viral entry.
- HIV-1 infects CD4+ T-lymphocytes and replicates within these cells
- Increasing viral load leads to a reduction in CD4+ pool and ultimately progression from HIV to AIDS
- Provided native CD4+ T-lymphocytes have been depleted, the HSCT with CCR5 32/32 mutation would generate a long-term pool of CD4+ T-lymphocytes that lack CCR5 and therefore HIV-1 would be unable to infect these cells. As viruses require host cellular machinery to replicate this would result in a reduction in viral load.

Key changes in the patient:
- Reduction in HIV-1 DNA and RNA loads consistent with reduced viral load.
- Reduction in antibody titres, consistent with the reduced presentation of viral peptides to B-lymphocytes
- Reduction in CCR5-tropic viral response, consistent with lack of viral entry and therefore lack of CD4+ and CD8+ activation with an associated reduction in cytokine/chemokine release.

Major weaknesses/limitations:
- Only an 18-month follow-up, potential for long term relapse.
- Graft vs host disease and high toxicity of associated CD4+ CCR5+ depletion.

Case Study #10

Contributor - Dr Ashley Le Vin (University of Glasgow)

Style of question #Problem Solving, #Understanding, #Data Analysis

Level of Study

- England/Wales 6
- Scotland 9/10

Rationale: The idea behind these questions is to challenge how students interpret data analysis outputs. Students are given an output from R (a general linear model) and have to answer a range of problem-solving questions. There is a range of calculations, identifying variables, graph drawing and overall interpretation of the results of the analysis. As the questions are based on a specific analysis output, the answers cannot be easily googled and students must understand how to interpret the data. Additionally, this section of our exam then has a couple of short answer questions based on understanding of data analysis concepts. These questions are easier to google, but a time limit to the exam reduced the chances of this.
(If exams remain online we would like to introduce an element where students are given a dataset and asked to do the actual analysis and then interpret their own data output and create graphs to represent the data.)

Learning Objective To advance skills related to quantitative analysis of data and interpret results obtained.

Relevant Notes* Currently, students have a range of lectures and practical labs using R. The exam is online, open booked but has a time limit to complete it.

Example Question

> **Q1.** A researcher has quantified the diversity (Shannon index) of a mammal community in Serengeti National Park at various distances from a water source (in m) and at different habitat types (bush, grassland, woodland). They are interested in exploring whether the distance from the water source as well as the habitat type has an effect on the diversity of the mammal community.

Analysis of Variance Table

Response: Shannon

	Df	*Sum Sq*	*Mean Sq*	*F value*	*Pr(>F)*
Distance	*1*	*0.7904*	*0.79042*	*7.4432*	*0.007906 **
Habitat	*2*	*3.1768*	*1.58841*	*14.9575*	*3.331e-06 ***
Residuals	*76*	*8.0708*	*0.10619*		

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*Signif. codes:0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1*

Case Study #10

Coefficients:

	Estimate	*Std. Error*	*t value*	*Pr(>|t|)*
(Intercept)	*1.174325*	*0.105617*	*11.119*	*< 2e-16 ****
Distance	*-0.007374*	*0.002605*	*-2.831*	*0.00594 ***
Grassland	*0.177535*	*0.094110*	*1.886*	*0.6305 .*
Woodland	*-0.279436*	*0.097213*	*-2.874*	*0.00525 ***

---

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '*

Based on the above R output, answer all of the following questions:

(Question 1 is 50% of overall Data analysis Grade)

Q1.1 Identify the response and explanatory variables in this analysis.
(2 marks)

Q1.2 What is the total variation (i.e. the Total Sums of Squares) in your response variable?
(2 marks)

Q1.3 On what sample size is this analysis based? *(3 marks)*

Q1.4 What is the R-squared of this model? *(3 marks)*

Q1.5 What percentage of the total variation in the response variable is explained by habitat type? *(4 marks)*

Q1.6 Write down the algebraic structure of the model that is fitted to these data.
(6 marks)

Q1.7 Replace the algebraic representation of the coefficients with their numerical counterparts in the output above in Q1.6. *(7 marks)*

Q1.8 What is the predicted value of Shannon for a community that is found at 33m distance from the water source and on a habitat dominated by bush?
(7 marks)

Case Study #10

Q1.9 Sketch in one graph the relationships between the response and explanatory variables. *(7 marks)*

Q1.10 Write a short and formal 'results' paragraph suitable for a scientific report citing the appropriate statistical support for the findings of this study.

(8 marks)

Q2. This question is made up of *two* parts (Q2.1 – Q2.2).

(Question 2 is 50% of overall Data analysis Grade, both parts of the question are equally weighted)

Q2.1 What does the 't-value' associated with each coefficient in a model output represent?
Q2.2 Why do we aim to maximise the residual degrees of freedom and how is it possible to achieve that?

Case Study #11

Contributor David Smith (Sheffield Hallam University)

Style of question #ProblemSolving #ExperimentalDesign #Creative

Level of Study

- England / Wales 6
- Scotland 9/10

Rationale The highest levels of learning require students to create. To do this they must draw on the core concepts and ideas learned during the module. To achieve this, open-ended questions can be used in which multiple correct ideas are accepted. The challenge for the marker is that there is no predetermined correct answer and many possible solutions. Set real situations the students would face on graduation or problems they are likely to have to solve.

Learning Objective Students will be able to apply their knowledge and understanding to generate unique solutions to a given problem.

Relevant Notes Marking schemes need to be flexible and adaptable, assessing the idea and feasibility of what's being suggested.

Example Question The example below is drawn from the final paragraphs of a research paper (research interests of the teaching team have also been used). Typically, within the Biosciences research papers, these paragraphs suggest an area of study or a new direction for the investigation. Students are required to suggest potential experiments to address the problem.

Within the paper discussion (Limatola et al. 2018), the authors comment on the effects of post-translational modifications on proteolytic processing of α-synuclein. Set out a detailed experimental plan to determine if phosphorylation of these Tyrosine residues is critical for the proteolytic processing of α-synuclein.

Example Marking Scheme

Pass – attempt to answer question, relevant methods present with some form of description that may contain errors or misunderstanding.
5 – attempt to answer question, relevant methods present with some form of description that is correct.
6 – good attempt to answer question, relevant methods present with some form of detailed description that is correct.
7 – good attempt to answer question, relevant methods present with detailed description that is correct and presented in a logical work flow.
(note here the shift to the high end by the addition of expected outcomes)
8 – excellent attempt to answer question, fully integrated methods present with detailed description that is correct plus logical workflow and expected outcomes.
9 – excellent attempt to answer question, extensive methods present with detailed description that is correct plus logical workflow and expected outcomes.
10 – outstanding attempt to answer question, extensive methods present with fully detailed description that is correct plus logical workflow and expected outcomes.

Case Study #12

Contributor: Dr Stephany Veuger (Northumbria University)

Style of question: #Scenario #Bioethics #CaseStudy #ShortAnswer #Understanding, #Interpretation,

Level of Study

- England / Wales 6
- Scotland 9/10

Rationale: This exam question was used in a final level 6 exam in a drug design and development module which is an optional module for biomedical science students. The exam is an online timed assessment (restricted). There are 6 SAQs of which students need to choose and answer 4.

In the module, students are introduced to a range of issues in drug discovery starting with selecting a disease through to identifying a disease target and the type of molecules to be utilised. Topics include principles of clinical trials. Tutor-led workshop sessions offer opportunities for free exchange of knowledge and views on contemporary topics such as bioethics. This scenario-based question aims to test students' knowledge and understanding of ethical concepts and principles relating to developing drugs and medicines. The question introduces and outlines a clinical scenario based on possible real-life events and considerations that clinicians must ensure they take.

This structured short-answer question begins by presenting the student with information that is related, but not identical, to that presented in class. Students are asked to answer the question and its subparts in no more than 500 words. A total of 25 marks are assigned to each question. Students are advised to spend around 20 minutes on the whole question

Learning Objective: The aim of the module is to introduce students to how drugs interact with and affect their target areas in the human body, the identification of lead compounds and the development of these compounds into drugs that are introduced into the clinic.

Notes: Students receive 2 x 2-hour workshops on Bioethics – these aim to use/apply some core bioELSI principles and theory which could/should be used to guide ethical biomedical/ clinical research/practice. This structured short-answer question begins by presenting the student with information that is similar, but not identical, to that presented in class workshops.

Case Study #12

Example Question:

MHT and her parents have been approached about her participation in a clinical trial of a new asthma medication to assess its safety and efficacy in treating children. This medication is taken once daily as a flavoured chewable tablet and works by a different mechanism than inhaled medications. It has not yet been studied in children, but 3 trials have been completed in 550 adult asthmatic patients. Adult studies show the new experimental drug significantly improves asthma in some patients and has very few side effects (side effects are limited to occasional nausea, headache, and dizziness and were also noted at the same frequency in the placebo group).

If MT participates in this trial, she will be on the study protocol for 14 weeks. Weeks 1- 2 will include assessment to assure MT's asthma is well controlled at the time she enters the experimental phase. The trial is blinded, so, during weeks 3-14, MT will be randomized to receive either standard treatment, the experimental drug plus her bronchodilator inhaler as needed, or a placebo plus her bronchodilator inhaler as needed. Neither MT, her parents, or her doctor will know which medication she is receiving during the trial. MT will have to attend a trial clinic 6 times to assess her response to treatment and evaluate for any adverse events. During each visit, breathing tests will be done and blood will be drawn for safety tests and to measure the amount of study drug in her blood.

MTs parents will be reimbursed for transportation costs to attend the required trial medical visits and MT will also receive £40 for each trial visit - a total of £240 if she completes the entire protocol.

MT and her parents have been asked if MT can be enrolled on this trial.

[1] Summarise the ethical best practice associated with enrolling MT onto this trial. In your answer, include reference to the main ethical principle that underpins the obligation of trial teams to ethically enrol participants.
[10 marks]

[2] What are the ethical issues associated with offering trial participants financial rewards for enrolment? Do you think the offer of £40 for each study visit (to a total of £240) to MT for her participation is ethically acceptable? [10 marks]

[3] Briefly explain why placebos are both important, but ethically problematic in clinical trials. Is the use of a placebo as part of a blinded design ethically acceptable in this trial?
[5 marks]

Case Study #12

Model Answer/mark scheme

[1] Principle of autonomy – obligation to respect decisions of competent individual [2 marks]

1 mark for each point, to total of 8 (total 10 for this section)

- Informed consent is best practice
- Participant information must be provided in advance,
- PI must be in lay language, explain exactly what is involved (requirements, risks and perceived benefits, and how to withdraw from study etc.)
- MT and parents must have opportunity to ask Qs/ clarify understanding before enrolling
- MT is a child (14) = legally non competent = ethically and legally not permissible for her to give consent
- MT should be asked to give assent
- and parents must give informed consent
- participation should be voluntary (free from coercion/ pressure etc.)
- consent/ assent must be documented/ recorded
- capacity to withdraw consent/ assent / from the trial at any time, without prejudice
- debrief opportunity should be provided

[2] What are the ethical issues associated with offering trial participants financial rewards for enrolment? Do you think the offer of £40 for each study visit (to a total of £240) to MT for her participation is ethically acceptable? [10 marks]

2 marks for each relevant point, to max 5

- a large financial inducement for participation could be considered coercion (non-voluntary participation)
- a small financial 'thank you' acceptable/ not considered coercion
- coercion depends on context;
- the money involved here likely not coercive to parents (but could be e.g. if on benefits/ single parent)
- £40 for each visit (£240 in total) could be considered coercive to a MT/14 year old, especially for continued participation/ not withdrawing (as £40 for each visit)
- money should be given to (and not taken from) MT
- more ethical if money is not advertised as up front inducement, but given as end thank you/ reward

[3] Briefly explain why placebos are both important, but ethically problematic in clinical trials. Is the use of placebo as part of a blinded design ethically acceptable in this trial? [5 marks]

- importance: efficacy beyond placebo is key outcome measure for experimental drugs/treatments
- · ethical issue:
  - placebos involve deception (autonomy)
  - patients may not receive the most effective treatment (beneficence & non malfeasance)
- placebos may only be used if participants are informed and agree to their use, as in this trial
- also frequent assessment of the impact on participant health built into the study design

Case Study #13

Contributor: Dr Stephany Veuger (Northumbria University)

Style of question: #Scenario #CaseStudy #Application #Interpretation,

Level of Study

- England / Wales 6
- Scotland 9/10

Rationale: This exam question was used in a final level 6 exam in a drug design and development module which is an optional module for biomedical science students. The exam is an online timed assessment (restricted). There are 6 SAQs of which students need to choose and answer 4.

In the module, students are introduced to a range of issues in drug discovery starting with selecting a disease through to identifying a disease target and the type of molecules to be utilised. Topics include pharmacokinetics and pharmacodynamics: Important parameters measured relating to ADME Students are presented with a problem.

Questions are problem-based. Each problem requires the application of theoretical knowledge, therefore, students cannot easily google answers. Students are asked to answer the question and its subparts in no more than 500 words. A total of 25 marks are assigned to each question. Students are advised to spend around 20 minutes on the whole question.

Learning Objective: Students will be able to apply taught theory to solve new problems.

Notes: The aim of the module is to introduce students to how drugs interact with and affect their target areas in the human body, the identification of lead compounds and the development of these compounds into drugs that are introduced into the clinic. The problems presented work well when related to scenarios and examples provided in their taught lecture content

Students have a two-hour lecture/tutorial on ~PK/PD which is followed up with an example and worked answers provided 2 weeks later. Students are provided with a formula list in the exam.

Case Study #13

Example Question:

A. Drug A is administered orally and taken up at a rate of 1.5 h^{-1}. Intravenous injection of the same drug showed that is has a half-life of 2.1 hours.

At what time after ingestion (two significant numbers) does the plasma concentration of drug A reach its maximum level (**10 marks**).

B. Drug A has a hepatic drug extraction factor of 0.37 and an apparent volume of distribution of 0.11 L
kg-1.

What is the maximum plasma concentration drug A can reach (in µg L^{-1}) when 300 µg of drug A is orally administered to an 80 kg-heavy patient (give 2 significant numbers) (**15 marks**).

Formula list for AP0611 exam component 2

Pharmacokinetic functions for plasma concentration in time ($C_P(t)$) of drugs administered:

As IV bolus

$$C_P(t) = C_P(0) \times e^{-k_{el} \times t}$$

As IV infusion

$$C_P(t) = \frac{k_0}{k_{el}} \times (1 - e^{-k_{el} \times t})$$

Orally

$$C_P(t) = \frac{F \times D(0)}{V_d} \times \frac{k_{ab}}{k_{ab} - k_{el}} \times (e^{-k_{el} \times t} - e^{-k_{ab} \times t})$$

The time at maximum plasma concentration (t_{max}) after oral administration:

$$t_{max} = \frac{\ln k_{el} - \ln k_{ab}}{k_{el} - k_{ab}}$$

Case Study #13

MODEL ANSWER

A. Acknowledge that this time is called and can be calculated from the elimination rate () and the uptake rate () according to the following formula (**4 marks**):

Show how can be calculated from the half-life given via (**3 marks**):

Show the filled in formula and final outcome (**3 marks**):

B. Define the formula to calculate the plasma concentration at a given time () for an orally administered drug (**3 marks):**

Acknowledge that and that and are known from the calculation shown above (**2 mark**)

Bioavailability can be calculated from the hepatic drug extraction factor using: (**3 marks**)

The total dose administered (**1 mark**)

The apparent volume of distribution is given as a value normalized for body weight, so the volume of distribution relevant for the calculation for an 80 kg-heavy patient is (**3 marks).**

Fill in all the variables in the formula and calculate **(3 marks)**

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