

#### **Appendix 4. Example of responses to an exam question and the points awarded.**

This question appeared on Exam 3 and was worth a total of 10 (out of 100) points.

question: You have cloned a gene encoding a protein never previously described. When you express a GFP (green fluorescent protein)-tagged version of this protein, you observe that it resides in the Golgi.

Where was this protein translated?

You believe that the first 10 amino acids encoded by the gene are a signal sequence. How could you prove that these amino acids were **necessary** for directing this protein to the Golgi?

How could you prove that these amino acids were **sufficient** for directing this protein to the Golgi?

Student #1 response: "This protein was translated in the endoplasmic reticulum."

"You could use a restriction endonuclease to extract this part of the coding DNA sequence or alter it in some way and then observe with the GFP where the protein is directed. If its is never directed in the right place, then the amino acids are a necessary signal sequence."

"To prove that these amino acids were sufficient, you could extract only the coding sequence for the signal sequence from the DNA. You would then insert it into a specially prepared protein-coding sequence where the signal sequence has been removed. After also tagging it with a GFP, you would see if this new protein is always directed to the Golgi. If not, then this signal sequence alone is not sufficient for directing the protein."

Points awarded: 10 points

Student #2 response: "endoplasmic reticulum"

"You would need to use an endonuclease to cut that specific sequence of 10 amino acids out of the sequence and then observe the location of the GFP protein. If it is not within the Golgi, they were necessary for directing effects."

"If you had another known signaling sequence that directed this protein to the Golgi, you could separately tag the two sequences and see if a sufficient amount of the new protein ended up in the Golgi or if another amino acid sequence is more efficient."

Points awarded: 8.5 points – The student lost points on the last part of the question because the experiment proposed would not clearly demonstrate sufficiency.

Student #3 response: "the nucleus"

"To test this, we could eliminate the first 10 amino acids and detect whether it would still appears (resides) in the Golgi ( the rest of the amino acid)."

"To test sufficiency, eliminate the rest of the amino acids (leaving only the first 10) and see if they reside in the Golgi."

Points awarded: 7 points – The student could not recall the factual information that Golgi proteins are translated in the endoplasmic reticulum, but did demonstrate a fundamental understanding of how experiments show whether an element is necessary or sufficient.

Student #4 response: "The protein was translated in mitochondria."

"It can be determined if these amino acids were necessary for directing the protein to the golgi by studying if the protein was transported form the outer to inner membrane or not. This will determine if the protein was moved from the cytosol into the matrix or not."

"It can be proved that these aa's were sufficient for directing the protein to the golgi because once the protein has entered the golgi and found the best pathway to reach the extracellular space it is know that the amino acids were sufficient."

Points awarded: 0 points – The student demonstrated neither factual nor conceptual knowledge of protein transport and localization.