Purpose: This assignment builds on Long Assignments #1 and #2 where you were asked to discuss the research goals of PEBL for this semester and describe the results of some of your discoveries to date. The purpose of this assignment is for you synthesize all that you have learned this semester by (a) summarizing the full results from the characterization of your variant, (b) examining the validity of your original hypothesis (LA#1) against the data you have collected, (c) evaluating your work against the goals of ***all teams*** in your PEBL section, and (d) reflecting on implications of and for the measured outcomes in regards to the overall question of PEBL.

Length: 1500 (minimum) and 2000 (maximum), figures excluded, 1-inch margins all around, 12 pt font Times New Roman.

Logistics: Consider the conclusions you are able to draw from your results obtained in Meetings #10 - #12 and contemplate their implications. In Meeting #13, you will deliver and hear presentations on all 6 proteins studied by your PEBL section. This will provide an opportunity for you to collect information about all the variants studied in your section. By midnight three days after Meeting #13, upload a *detailed outline* of LA #3 to Gradescope (see attached example). The outline will be graded similarly to the Quick Checks. All outlines will be reviewed and used to create one global feedback document for all students. If you fail to upload an outline, your LA #3 may be penalized. The **final** LA #3 (graded) must be submitted to Turnitin.com via Blackboard no later than Tuesday, May 10th.

The final assignment should be composed of multiple paragraphs in an essay-like form and clearly present the important components below. You are not restricted to a specific number or length of paragraphs; however, (a) each paragraph should contain a single idea, (b) one idea should not be broken up over multiple, 1-2 sentence paragraphs, (c) paragraphs should not be separated with titles or section headers.

Goals and motivation:

- Introduce and explain the goals and project of PEBL this semester.
- Provide an explanation for why this project is a worthwhile endeavor. This will provide context for the motivation behind the class project and set the stage for why your variant was studied.
- Introduce and describe your mutation(s). Discuss how the characterization of your variant can inform us about proteins in general and how your protein fits into the larger class project.

Individual variant:

- You have performed multiple experiments to examine different properties of your protein. Provide a complete, yet concise, analysis of your data from Labs 10 – 12 to cover each of the three physical

properties of the protein you characterized. You may find it helpful to address one experiment or one protein aspect at a time and to include in-text references to the relevant figures/tables when appropriate.

- For each experiment, present the **key, relevant** data/values for your protein. Every experiment has limitations and every measurement has uncertainty so be sure to discuss any noise in the data or other possible sources of error where appropriate.
- Additionally, provide an interpretation of your observations and what can be concluded from the experiment. Describe how your mutation affected the relevant property of the protein being examined in each experiment by comparing your variant against other control proteins (*not other teams!*) and/or other conditions. Address any noise or anomalous data points when considering the impact of your mutation.
- Combining your analysis of the experiments for each property examined, evaluate the extent to which your original hypotheses from LA#1 were supported or refuted by the data you collected. Propose a reasonable biophysical mechanism that could explain why your protein behaves as you observed.

Class project:

- Your variant was only one small piece of the larger class project. Review the data available from all 6 teams and decide which results are relevant to the class project this semester. In your writing, ***report only the salient results from each team*** and provide an interpretation of what these values mean within the context of the project. Be sure to address any outliers or significant noise in any of the data sets and refer to relevant figures/tables when appropriate using in-text references.
- Consider the collective sets of data and synthesize an evaluation of them within the context of the initial hypothesis and goal for the class project. This is where comparisons of all 6 variants and the background (7 proteins total) against each other are most helpful. You should assess how well did the overall hypothesis of PEBL this semester stand up against the actual results and the degree to which the class as a whole succeeded in achieving the initial goal. Ground your evaluation in what you have learned about biophysical theory and proteins at a molecular level.

Summary:

- Using what you have learned in class from the background material, discussions, and bench work, conclude the major findings from the data you presented and trace the implications of these

conclusions about proteins beyond the classroom. There is also merit in pointing out what *cannot* be determined by these data at this time. This is where you can make connections from one specific lab course to whole industries or populations and pose new directions for this research project to continue.

Figures:

- Given the amount of data collected by all of the teams, it would be unwieldy to display all of it. Choose the relevant data sets that support your interpretations and discussions and create at most 1 data table and at most 2 figures (each may include 1 – 4 panels).
- Your figures and table should be clearly labeled and presented in a manner that is easy to understand (i.e. uncrowded, legible text, distinct data sets, etc.) with a separate title and descriptive caption below the image. These should appear at the end of your document, after the text, **and** be referenced as necessary in your paragraphs as in-line references. The weekly reading materials have many good examples of properly formatted figures and how to reference them in text.

Assessment: This assignment will be worth 15% of your grade. A **detailed outline** (graded on completion) should be uploaded to Gradescope within 3 days of the presentations; failure to do so will lead to deductions on your LA #3 component. The **final LA #3** (graded) must be submitted to Turnitin.com via Blackboard no later than Tuesday, May 10th. Your evaluation will take into account:

(a) the completeness of your explanation (e.g. the presence of all components outlined in the assignment above);

(b) the coherence, clarity, and logic of your prose and figures (an intelligent non-specialist should be able to understand your work at the sentence level, and overall); and

(c) the articulation of the conceptual implications of your work (e.g. your ability to probe the relationship between your questions and hypothesis, and the questions and hypothesis PEBL asks this semester, as well as the course's broader frames of inquiry).

Assignment criteria			
	Unsatisfactory	Satisfactory	Excellent
Goals and hypotheses	○ Missing introduction of broader course goals or contains significant errors or omissions	○ Introduces the broader goals of PEBL with minor errors or omissions	○ Accurately introduces and explains the **overarching goals** that PEBL seeks to achieve
	○ Examples for project motivation are absent, are hindered by major inaccuracies, or have no connection to the research project	○ Includes real world examples to contextualize the project, though the connection may be weak or underdeveloped	○ Provides clear reasons for why protein stability, structure and function are important with 1 or more real world examples.
	○ Introduction to the semester research project and the reasoning behind the mutation choices is missing or contains significant errors OR connection between the project and mutations is absent or hindered by major errors	○ Introduces the semester research project and the reasoning behind the mutation choices with minor errors OR the connection between the project and mutations is tenuous	○ Accurately introduces the **research project** for the semester and how the theme/types of mutations chosen factor in.
	○ Introduces the specific variant, but the description contains significant errors or gaps OR omits the introduction of the variant	○ Introduces the specific variant, but the description is shallow or contains minor errors (e.g. only notes new residue properties but not original)	○ Introduces the **specific variant** the student will examine with a full description of the mutation(s) including but not limited to environment, evolutionary conservation, and side chain properties.
	○ Fails to explain the individual variant's role in the class project or description is hindered by significant inaccuracies	○ Description of the variant's role is present, but contains minor inaccuracies or is underdeveloped	○ Accurately and fully describes the individual **variant's role in the class research project**.
Individual variant characterization			
Individual outcomes	○ Discussion of the mutation's effect on structure is missing OR contains significant inaccuracies/is unsupported by appropriate data OR important comparisons are omitted	○ Discussion the mutation's effect on structure is supported by relevant data, but contains minor errors OR is underdeveloped, missing some details or comparisons	○ Discusses the mutation's effect on **Structure** using the appropriate experimental data in support (e.g. the shape of the far-UV spectra)
	○ Discussion of the mutation's effect on function is missing or contains significant inaccuracies OR important comparisons are omitted	○ Discussion the mutation's effect on function, but contains minor errors OR is underdeveloped, missing some details or comparisons	○ Discusses the mutation's effect on **Function** with respect to environmental pH and cofactor presence and identity.
	○ Discussion of the mutation's effect on stability and/or cooperativity is missing OR discussion is hindered by significant errors/is unsupported by appropriate data OR important comparisons are omitted	○ Discussion of the mutation's effect on stability and/or cooperativity is supported by relevant data, but may contain minor errors OR is underdeveloped, missing some details or comparisons	○ Discusses the mutations effect on **Stability** using the appropriate experimental data in support (e.g. dG, Tm and pHmid) and **Cooperativity**.
	○ Frequently or consistently misreferenced figures/table or fails to reference figures/table appropriately	○ Figures and table maybe be referenced inconsistently or in inappropriate locations or manners.	○ Descriptions of data or comparisons between proteins/conditions contain appropriate references to **figures/table**
	○ Omits the discussion of the reliability of data and the impact of noise/outliers on data analysis for many or all experiments OR discussion is hindered by significant inaccuracies	○ Addresses the reliability of data and the impact of noise/outliers on analysis for *most* experiments OR discussion contains minor inaccuracies or gaps	○ Discusses the **reliability** of observations/measurement by including the **uncertainty of each measurement** and the **impact of noise/outliers** on data interpretation
Evaluation of individual outcomes	○ Fails to state the original hypothesis for *each* property of SNase OR hypotheses contain major inaccuracies.	○ Original hypothesis for each property of SNase is stated, but may be unclear or vague.	○ For each property of SNase, **states the original** hypothesis
	○ Fails to evaluate each property of SNase OR evaluations are hindered by major errors or omissions.	○ Evaluation addresses all relevant data for each property, but may be underdeveloped or contain minor errors OR evaluations omit some relevant data that support or refute the original hypothesis	○ Addresses all relevant data that both support or refute the hypothesis for each property of SNase
	○ Fails to include a biophysical reason/molecular mechanism for all of the variant's behavior OR reasoning is implausible or hindered by major errors and omissions	○ Provides a reasonable biophysical reason/molecular mechanism for variant behavior in total, but may be underdeveloped or contain minor errors	○ Provides a reasonable **biophysical reason**/molecular mechanism for the variant behavior in total and is grounded in biophysical fundamentals and basic theory.
	○ Discussion of the limitations of evaluation is superficial or absent OR discussion does not address most of the data	○ Discusses the limitations imposed by noise or outliers, but may contain minor errors or gaps	○ Discusses the **limitations** of evaluation by including the **impact of noise/outliers** on data interpretation

Class research project

	Unsatisfactory	Satisfactory	Excellent
Section outcomes	○ Fails to discuss the main finding(s) of the relevant property for <u>each</u> team OR discussion contains major errors.	○ Discusses the main finding(s) of the relevant property for each team, though discussion may contain minor errors or omissions	○ Discusses the **main finding(s)** of the property relevant to the research project for <u>each</u> team and incorporates appropriate data/values as support
	○ Frequently or consistently misreferenced figures/table or fails to reference figures/table appropriately	○ Figures and table maybe be referenced inconsistently or in inappropriate locations or manners.	○ Descriptions of data or comparisons between proteins/conditions contain appropriate references to **figures/table**
	○ Omits the discussion of the reliability of data and the impact of noise/outliers on data analysis for many or all teams OR discussion is hindered by significant inaccuracies	○ Addresses the reliability of data and the impact of noise/outliers on analysis for <u>*most*</u> teams OR discussion contains minor inaccuracies or gaps	○ Discusses the **reliability** of observations and measurements by including the **uncertainty** of each measurement and the **impact of noise/outliers** on data interpretation
Evaluation of section outcomes	○ Evaluation fails to mention the original hypothesis of this semester's research project.	○ Evaluation obliquely or incompletely references the original project hypothesis.	○ Evaluation always references the original hypothesis of this semester's research project explicitly
	○ Evaluation fails to address the entirety of the original hypothesis of this semester's research project OR is hindered by major errors or omissions.	○ Evaluation incorporates all relevant data, but may be underdeveloped or contain minor errors OR omits some data that support or refutes the original project hypothesis.	○ Evaluation incorporates the relevant data that <u>both</u> **supports and refutes** the stated hypothesis.
	○ Fails to include a biophysical reason/molecular mechanism for the observed behavior of SNase within the context of the research project OR reasoning is implausible or hindered by major errors and omissions	○ Provides a reasonable biophysical reason/molecular mechanism for the observed SNase behavior, but may be underdeveloped or contain minor errors	○ Proposes a reasonable **biophysical reason/**molecular mechanism for the observed behavior of SNase within the context of the research project that is grounded in biophysical fundamentals and basic theory.
	○ Discussion of the limitations of evaluation is superficial or absent OR discussion does not address most of the experimental data	○ Discusses the limitations imposed by noise or outliers, but may contain minor errors or gaps	○ Discusses the **limitations** of evaluation by including the **impact of noise/outliers** on data interpretation

Wrap up

	Unsatisfactory	Satisfactory	Excellent
Summary	○ Fails to review the main findings of the individual variant protein properties characterized OR review contains major errors or contradicts earlier statements about the variant protein properties.	○ Reviews the main findings of the individual variant characterization with minor errors or omissions.	○ Fully reviews the main findings of the **individual** variant characterization.
	○ Summary of the main finding(s) is absent or incomplete OR summary contains major errors or contradicts earlier statements about SNase	○ Summarizes the main finding(s) for all portions of the research project with minor errors or omissions	○ Summarizes the main finding(s) for all portions of the **class** research project
	○ Connections to the broader scientific world are absent or hindered by major inaccuracies.	○ Identifies connections between in-class investigations and the broader scientific world, though connection may be tenuous or superficial.	○ Identifies meaningful **connections** between in-class investigations and the broader scientific world
Support with figures	○ Figures are missing or too difficult to interpret and/or units are absent	○ Figure data may be difficult to see due to style choices (color/size) or inappropriate axes ranges; May be improved with minor changes.	○ **Figures** are relevant, clear, have distinguishable data sets, and appropriately sized texts and symbols; Axes have appropriate ranges and units.
	○ Table is missing or too difficult to interpret OR units (or sig figs) are absent or inappropriate	○ Table has insufficient organization for its size or complexity; Units & sig figs are present and appropriate.	○ **Table** is organized to clearly relate data; Units & significant figures are present and appropriate
	○ Figures or table lacks captions and/or informative titles.	○ Figure/table captions are present, but incomplete or includes details/analysis that should be in the text; Titles are present but uninformative.	○ Each figure/table has a separate descriptive, informative title (i.e. not just “Figure 1”) and caption that is concise and fully describes the data presented without analysis.
	○ A figure or table is embedded within the paragraphs.	○ Figures/table appear after the text, but in a disorganized manner	○ Figures/tables appear after all paragraphs in an organized manner.

Global criteria			
	Unsatisfactory	Satisfactory	Excellent
Analysis and context	○ Analysis frequently lacks a clear logical connection to previous ideas.	○ Logical reasoning is generally explicit and sound but fails to extend ideas beyond what is presented in class.	○ Logical reasoning extends ideas presented in class in an original way.
	○ Most points need further explanation or support; lack of contextualization impedes readers' understanding.	○ Analysis is generally clear, but may often benefit from further support, explanation, or contextualization	○ Each point is fully explained, supported, and contextualized as appropriate for audience who is scientifically literate but not expert in biophysics.
	○ Discussion of key ideas is missing or contains major inaccuracies.	○ Most concepts are addressed, but some key ideas are discussed superficially or with minor inaccuracies.	○ All key concepts are fully addressed
	○ Extraneous or inaccurate material is frequently used to support arguments	○ Supporting statements are incomplete or contain extraneous material not relevant to the argument being made.	○ Supporting statements are connected to the main ideas of the paragraph and overall assignment without extraneous material.
Coherence	○ Order of ideas within paragraphs is jumbled or illogical to the point that it obscures the overall argument.	○ Overall organization is present, but the argument(s) could be improved by minor reordering.	○ Logical order of ideas within and between paragraphs where each idea flows naturally into the next.
	○ Transitions within or between paragraphs are very weak or absent.	○ Transitions within or between paragraphs are present, but may be rough.	○ Graceful transitions within and between paragraphs.
	○ Ideas often repeat or may contradict information found elsewhere in the text.	○ Ideas generally build on each other with only minor repetition or gaps.	○ Ideas build on each other without repetition or gaps.
Style and mechanics	○ Numerous spelling or grammatical errors suggesting no proof reading was done	○ Few, minor spelling or grammatical errors	○ No spelling or grammar errors.
	○ Frequent awkward sentence construction OR imprecise use of language sufficient to obscure/impede comprehension.	○ Writing is generally clear, but may contain some awkward or imprecise use of language.	○ Writing demonstrates exceptional clarity and precision of language.
	○ Submission contains more than 2 figures OR figures are composed of more than 4 panels.	N/A	○ Submission contains no more than 2 figures with no more than 4 panels per figure
	○ Submission contains more than a single table.	N/A	○ Submission contains no more than a single table
	○ Does not follow instructions for formatting OR is missing required components of the assignment	○ Meets formatting and other requirements outline in assignment description, but may employ stylistic choices that impede understanding (i.e. many unnecessary short paragraphs)	○ Meets formatting and other requirements outlined in assignment sheet; assignment appears polished.
	○ Word count exceeds the limit by +/- 10%	○ Word count exceeds the limit but is within +/- 10%	○ Meets word limit of assignment