I. INTRODUCTION

A. General philosophy. As stated in the Academic Bulletin, the Senior Project "is not a mere report or semester paper, but a significant piece of independent study, research, or creative work." Indeed, a mandatory comprehensive senior research project is unusual among liberal arts colleges, and this experience distinguishes Allegheny graduates as they embark on professional careers. More importantly, the successful completion of an independent research project is a milestone in personal development, with merit transcending the context of vocational utility.

Students are fully responsible for the successful completion of the project, including literature research; documentation and interpretation of results; procurement, proper maintenance, and (in some cases) construction of equipment; troubleshooting; and the deft redirection of approaches not yielding desired results. This is a never-ending cycle requiring constant initiative.

Of course, the research advisor is an integral part of this cycle, but the student should not expect to wait upon the advisor to issue directives. Rather, the advisor should be viewed as an expert resource from whom guidance about specific research issues may be obtained. The advising relationship is a complex dynamic, however, and chemistry faculty have differing styles, which reflect the diversity of approaches in the discipline. Students are therefore encouraged to be mindful of this when choosing their Senior Project advisor.

B. Goals and Behaviors. The Chemistry Department has defined specific goals for the Senior Project, which include:

- exposing the student to cutting-edge research techniques in chemistry
- beginning the development of the student's ability to ask interesting and well-defined scientific questions
- furthering the development of the student's ability to work independently
- engaging the student intellectually in a multi-dimensional chemical investigation

Students completing a Senior Project should therefore exhibit a variety of observable behaviors, which are detailed in the attached rubric.

C. Modification for the 2020-2021 academic year. In order to accommodate the flexibility that may be required during a global pandemic, the Senior Project for the 2020-2021 academic year has been altered from a research paper into an original Grant Proposal in consultation with the research advisor. Grant writing skills are paramount to a successful career in research chemistry and vital to keeping the science funded. The goal of the project is to identify an unanswered question, in consultation with the research advisor, in the chemical sphere of knowledge and convince the reviewers (faculty advisor and committee members) that it is both a question worth answering and a question that the individual student is prepared to answer experimentally. It is important that the student is able to demonstrate that the proposed project is feasible. To this end, grant writers include preliminary results to support their hypothesis and demonstrate their capability to complete the proposed project. Proposals submitted under the 2020-2021 senior comprehensive project must include preliminary results. These preliminary results may involve lab experiments, computational data, or original literature data analysis. Analysis of concepts from the literature is expected in all proposals, but original data analysis from the literature is expected if experimental or computational data is absent. Original data analysis will vary by subdiscipline and topic, so the exact form should be determined in consultation with the research advisor. The balance of original data and original analysis appropriate for each proposal will be determined in collaboration between the student and advisor. Proposals can range from largely experimentally-driven or computational to entirely literature-based analysis and will be treated equally in review and evaluation.

Regardless of the extent of original data in the final proposal, students will be expected to demonstrate a detailed understanding of the techniques assumed in the proposal.
II. LOGISTICS
A. Academic Credit. Chemistry has a two-semester Senior Project. Students sign up for 2 hours in the fall (CHEM 600), followed by 4 hours in the spring (CHEM 610). Students receive grades for both the fall and spring semester courses.

B. Scope of Project. The Senior Project must: a) exhibit scientific merit, b) contain a body of work appropriate for a senior-level research experience, and c) fall within the realm of at least one faculty member's area of expertise. The exact scope of the project is defined collaboratively through discussion between the student and the research advisor.

C. Choice of Research Advisor. During the Junior Seminar, faculty members present research overviews of current projects, after which students submit three possible choices for a Senior Project advisor. Assignments are then decided by the department as a whole. Once assignments are made, students are encouraged to be in contact with their advisors as soon as possible.

D. The Senior Project Committee. Each Senior Project is evaluated by a three-member committee. The first reader is the student's research advisor; two additional readers are assigned to the student by the department. The written and oral presentations of the project should conform to the format and expectations of the first reader's subdiscipline; however, care must be taken so that the project is presented to an audience of non-specialists. All committee members have significant input in evaluating the project.

E. Biochemistry Majors & Joint Senior Projects. The goals, behaviors, appropriate topics, and meeting schedules of biochemistry majors, self-designed majors, and joint senior projects must conform to the department in which the primary research advisor is a member. Furthermore, the student is expected to abide by the guidelines of the specific group in which they are working.

Biochemistry majors wishing to complete a Senior Project in the Chemistry department must have completed the Chemistry Junior Seminar. The research advisor is assigned through the Junior Seminar, as described above. The second reader, who must be a Biochemistry faculty member outside the Chemistry department, is assigned by the Biochemistry program director. The third reader is assigned by the Chemistry department.

III. SPECIFIC GUIDELINES
A. Scope. Anything presented as "Preliminary Results" must be from research carried out by the student during the senior academic year. Work from summer research or previous independent study—or work by other students—may be included in the proposal, but must be presented as "Background" or "Previous Work" and must be cited accordingly. These results will not be considered for the purposes of evaluating the progress of the project.

B. Audience. Students are reminded that their Senior Project board is composed of chemists, but not specialists. Information should be communicated in a way that is understandable to a general scientific audience and not heavily laden with discipline-specific jargon.

C. First Written Document (Proposal Prospectus). This document has many functions, and it should address three main topics. A prospectus, or pre-proposal is a condensed version of a proposal. The main goal of the document is to convince reviewers that you have a fundable idea worth expanding into a full proposal. Feedback from a prospectus is typically constructive and intended to help strengthen the proposal.

An 'Introduction and Background' section should present the reader with the general research question being addressed in the proposal. It should provide a selective but thorough review of the relevant previous work in the field and should hint at the student's comprehensive knowledge. In addition, it should show how the student's research question fits into this global picture. More importantly, it should naturally substantiate the motivation behind the proposed research (i.e., why is it interesting?). Biochemistry majors should clearly address the biological significance of their proposal with specific examples.

The student should include a 'Assumptions and Justification' section. This section should provide an argument to support your research question, including evidence that the project is feasible and based in chemical principles. This section should anticipate and address potential conflicts with
existing theory and literature. Any assertions or assumptions that the project builds on should be clearly identified. Where possible, verification of the assumptions should be provided either experimentally or from the literature. Assumptions that will be tested during the Spring semester should be clearly explained. Any experimental supporting information (data, spectra, etc.) should be included and clearly labeled.

Finally, a 'General Research Plan' section should outline how the project is to be carried out, and it should include any references that support the proposed work. This requires an understanding of the strengths and limitations of the techniques proposed. Proposed research should only include techniques and instrumentation available at Allegheny College. Any experiments already completed or that are planned for the Spring semester should be clearly identified and outlined. This portion should also include any contingency plans—in other words, how might the project be modified if Plan A doesn’t provide the desired outcome?

The report should also include a thorough 'Works Cited' section. Plagiarism and proper citation requirements can be difficult to identify by oneself in grant proposals and literature reviews. Students are encouraged to consult their advisor if they are at all unsure about what constitutes plagiarism or have questions about academic integrity.

D. First Oral Presentation. The first oral presentation will be conducted remotely. The student should prepare a ca. 20-minute PowerPoint presentation giving a condensed background of the topic and focusing primarily on the project justification. The talk should start from the premise that the committee has read the Prospectus (i.e., not simply rehash the written work), but it should still be cohesive and understandable on its own merit. The committee will serve as Reviewers of the proposal prospectus and provide constructive feedback on the likelihood of success. Reviewer comments should be considered and addressed in the final proposal.

Students may be interrupted during their presentations for points of clarification. Authors of hastily prepared or poorly organized presentations and/or prospectus may expect more interruptions. At the conclusion of the formal presentation, students should be prepared for in-depth questions about any and all aspects of the project, which may include experimental design issues, interpretation of data, literature background, or basic chemistry concepts related to the project.

E. Final Written Document (Grant Proposal). The final grant proposal should address four areas with roughly equal attention and be structured similar to the following:

a) Background and Significance. This section functions similar to an introduction, but with a strong focus on the broad goals and questions your proposal addresses. There should be enough relevant literature discussion so that the reviewers understand the motivation for the proposed project and what prior work applies. Just as in the prospectus, biochemistry majors should clearly address the biological significance of their proposal with specific examples.

b) Specific Aims. This is arguably, the most important section of a grant proposal, and consists of 2-3 specific experimental goals or aims. Each aim should answer a small question that sheds light on the larger question from the Background and Significance. The aims should be listed clearly and labeled as Specific Aim 1, 2 and 3 with an explanation of the connection to the broader question and an indication of the strategy proposed to accomplish the aim.

c) Preliminary Results and Analysis. This is the scientific foundation of your proposal. The assumptions identified in the prospectus should be supported in this section. This can be accomplished with original experimental data accompanied by the appropriate interpretation and analysis, or original analysis of literature data and experiments. Additionally, any work already completed to advance the research goals should be included and discussed. The significance of all results with respect to the broad goals of the proposed project should be discussed.

d) Experimental Design. This section discusses how the research will be implemented and should be much more detailed than the
general research plan in the prospectus. Students must convince the reviewers that they have a realistic and thought-out plan to accomplish their specific aims in this section. The section should include detailed plans and justifications for experiments and instrumentation needed, including reagents and the necessary control experiments. Any technique or experiment proposed should be explicitly linked to a specific aim, and the expected outcomes and relevant metrics should be discussed.

e) References.

F. **Final Oral Presentation.** The same guidelines apply as for the first oral presentation, except the focus is almost entirely on feasibility of the proposed research. If addressed at all, only enough introductory material should be included to contextualize the rest of the talk. **Students are expected to address any reviewer comments from the prospectus and should be prepared to discuss the timeline of their proposed research.** Where appropriate, results should be supported with experimental data or original analysis.
IV. EXECUTION OF THE PROJECT

A. Meetings. Research advisors' styles vary from more directive to more "hands-off", reflecting the diversity of environments within the discipline. Students are encouraged to consider this aspect in their choice of advisor. In all cases, however, responsibility for successful completion of the Senior Project lies with the student.

Some advisors have required weekly group meetings. The format of these meetings varies, but can include opportunities for students to engage the rest of the group in their project and/or to review literature that is relevant to the entire group. These meetings might also provide an opportunity for students to speak both formally and informally and to show adequate intellectual engagement with their chosen field of study. In contrast, some advisors have no formal meetings with students. Some advisors schedule weekly meetings with students one-on-one and some schedule one-on-one meetings only as the need arises. There are no formal meetings with second and third readers.

B. Calendar & Deadlines

1. First Oral Presentation. Students present progress to date and summarize their plan for the spring semester. They also defend their written proposal prospectus (see below). Presentations are scheduled beginning the Monday after Thanksgiving.

2. Written Proposal Prospectus. Students submit a well-written report providing motivation for the project and placing the project in the context of other work in the field. Students must submit an electronic copy of the prospectus (in PDF format) to their “Chemistry Senior Project” Sakai drop box by 4:00 pm on Tuesday of Thanksgiving week. It is the student’s responsibility to verify that the file has been properly transferred to the Drop Box folder. Not submitting the Progress Report on time will result in a failing grade for the first semester of the Senior Project.

3. Final Oral Presentation. Students present and interpret the results of their research project and explain the significance of their work. They also defend their final grant proposal (see below). Presentations are scheduled for the last two full weeks of classes.

4. Grant Proposal. Students must submit an electronic copy of the proposal (in PDF format) to