



POLICIES AND PROCEDURES FOR CERTIFYING BACHELOR'S DEGREES IN BIOCHEMISTRY & MOLECULAR BIOLOGY

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ASBMB DEGREE CERTIFICATION PROGRAM IN BIOCHEMISTRY & MOLECULAR BIOLOGY

Biochemistry and Molecular Biology are distinguished by their focus on information flow, structure, function and mechanism within overarching biological contexts.

INTRODUCTION

The goals of the ASBMB degree certification program are to provide:

- a national, outcomes-based mechanism by which students receiving a B.S. or B.A. in Biochemistry & Molecular Biology or closely related major¹ are given an opportunity to have their degree **certified** by The American Society for Biochemistry and Molecular Biology (ASBMB).
- a vehicle for **recognizing** undergraduate BMB programs whose features and infrastructure fulfill the basic expectations of the ASBMB.
- access to an independently constructed and scored instrument for assessing student achievement and program effectiveness.

BACKGROUND

A certification program for bachelor's degrees in Biochemistry and Molecular Biology¹ (BMB) constitutes a powerful vehicle by which the **ASBMB** can:

- *actively* and *visibly* promote excellence and innovation in undergraduate BMB education.
- *connect* with and *recruit* aspiring young biochemists and molecular biologists on a nation-wide scale.
- raise the *profile* and enhance the *relevance* of our society among STEM educators.
- raise the *profile* and *relevance* of our society in the private sector, where employers are often frustrated by the heterogeneity in knowledge and skills exhibited by graduates of different BMB programs.

For **students**, receipt of a certified degree will affirm to prospective graduate and professional schools or potential employers that the recipient in question has:



- matriculated through a program whose curriculum and infrastructure meet the basic expectations of the ASBMB, and
- demonstrated a grasp of fundamental concepts and critical reasoning skills on the ASBMB Evaluation Instrument. Certification will provide students graduating from diverse programs an opportunity to demonstrate their competitiveness with peers from across the nation.

For BMB **educators**, access to an independent, nationally-recognized evaluation tool will materially assist them in meeting the growing demand from collegiate accrediting bodies, university administrators, etc., for regular outcomes assessment. Independent assessment will, in turn, assist them in pinpointing strengths and weaknesses in their curriculum.

In order to have their degree certified by the ASBMB, a student must:

- earn a B.A., B.S. or equivalent degree from an ASBMB-recognized program, and
- exhibit acceptable performance on an assessment instrument provided by the ASBMB.

Students who exhibit exceptional performance on the assessment instrument will be recognized as having graduated *with distinction* by the ASBMB.

CHARACTERISTICS OF AN ASBMB-RECOGNIZED PROGRAM

INTRODUCTION

Key characteristics of an ASBMB-recognized program are described in the sections below. The ASBMB recognizes that many programs (particularly at smaller schools) may not be able to incorporate all of these characteristics exactly as described. Consequently, the matrix shown in Appendix I has been designed to aid evaluators in examining individual programs from a holistic perspective.

INSTITUTION

An ASBMB-recognized program must be located within an institution of higher learning that has been accredited by the pertinent national or regional body. The college or university must articulate policies intended to foster an institutional culture that values diversity in all dimensions and provide mechanisms for promoting a safe, supportive, and welcoming learning environment for all students and faculty. Classrooms, teaching laboratories, and research spaces should be safe² and equipped with the supplies and instrumentation needed to perform modern biochemical and molecular biological analyses and manipulations. Courses should be offered on a regular



schedule with sufficient frequency and seating capacity to prevent unnecessary delays in the timely completion of a BMB degree. Access to information resources that provide breadth, depth, and currency of scientific content that includes, but is not limited to, major peer-reviewed BMB journals must be provided for faculty and students. Career advising resources should be available on campus.

The institution should afford BMB faculty regular opportunities to engage in professional development activities such as sabbatical leave, attendance of professional conferences and workshops, participation in research, publication in the refereed research literature, and/or attendance of continuing education workshops and courses.

FACULTY MEMBERS

The faculty of an ASBMB-recognized program must be sufficient in number as well as breadth, depth, and diversity of experience and expertise to provide a well rounded, fundamentally sound educational program for BMB students. BMB faculty should possess a Ph.D. or other advanced degree (e.g. M.D., M.D./Ph.D., D. Phil.) in biochemistry, molecular biology, or a closely related discipline as well as a demonstrated track record of teaching and research in BMB.

The recommended threshold for a BMB program is three or more contributing faculty members. While these faculty members may not necessarily be assigned exclusively to the BMB program, each should play a clearly defined role in the instructional and advising missions of the program.

CURRICULUM

Introduction

The ASBMB believes that students are best served when programs focus on the development of durable, translatable skills and fundamental knowledge rather than the rote accumulation of detailed facts. Program effectiveness also is materially enhanced when guided by a set of clearly-stated educational objectives. One important contributor to the development of capable life long learners in BMB is the establishment of a strong grounding in its core concepts. This firm foundation should be nurtured through a continual, progressive emphasis on critical reasoning skills, experiential learning, and the ability to communicate information and concepts in a clear, accurate, and organized form using both the written and spoken word.

Since both our discipline and educational best practices are subject to continual change and innovation, the recommendation regarding curriculum outlined below intentionally avoids providing a list of “required” courses. Such a prescriptive, topics-based approach runs counter to ASBMB’s desire to focus on outcomes as well as our intention to provide the members of the educational community free reign to apply their creativity and experience to the continual improvement of BMB pedagogy.



Core Concepts and Learning Objectives³

An ASBMB-recognized program should be able to relate each element of its BMB curriculum to one or more of the core concepts listed below and their related learning objectives (For reasons of space, sample learning objectives are provided in Appendices II – V):

1. Energy is Required by and Transformed in Biological Systems.
2. Macromolecular Structure Determines Function and Regulation
3. Information Storage and Flow Are Dynamic and Interactive.
4. Discovery Requires Objective Measurement, Quantitative Analysis, & Clear Communication.

The curriculum should present these core concepts in a manner that illustrates the pervasive role that *Evolution* plays in shaping the form and function of all biological molecules and organisms.

Experiential learning

An ASBMB-recognized program requires participating students to engage in a cumulative total of **400 or more contact hours⁴** of direct, hands-on laboratory experience in STEM areas⁵ over the course of the degree program. It is recommended that at least one of these experiences be research/inquiry-based. Under certain circumstances⁶ undergraduate research, internship activities, independent and team projects, *in silico* research, etc., can substitute for more traditional laboratory courses. Regular, explicit attention should be devoted to the topic of laboratory safety, including the recognition of common laboratory hazards, responsible laboratory practices, and methods and equipment used for the prevention of, protection from, and response to incidents involving potential hazards². Regular, explicit attention should also be devoted to the principles of ethical conduct of research and scholarship, including plagiarism and appropriate citation, qualifications for authorship, appropriate application of image and data manipulation techniques, confidentiality, etc.

Communication skills

Oral and written communication skills represent important elements in preparing students for long-term professional success. The required curriculum of an ASBMB-recognized program should afford students training in written and electronic communication practices, including:

- reading and consistently adhering to standard laboratory operating procedures
- maintaining complete and accurate records, including laboratory notebooks
- preparing complete and lucid laboratory reports



Other potential activities include preparing research proposals or grant applications, writing intensive projects, constructing or contributing to web pages or blogs, etc.

An ASBMB-recognized program should also afford students opportunities to develop oral communications skills. Methods for achieving this may include but are not limited to:

- poster presentations
- oral reports
- oral examinations
- team projects
- classroom discussions

Presentations of posters and talks at meetings and conferences should provide particularly rich experiences for participating students.

Teamwork skills

The increasingly interdisciplinary nature of science and engineering demands that BMB graduates be prepared to work in a diverse, team-oriented environment. An ASBMB-recognized program therefore should afford students the opportunity for training and participation in team activities.

Undergraduate research, cooperative experiences, and internships

While it is desirable that every BMB major be given the opportunity to participate in research or related activities in an active research laboratory or other professional setting, ASBMB recognizes that the large number of students enrolled in many BMB programs renders 100% student participation impractical. Nonetheless, mechanisms by which advanced students and those drawn from groups historically underrepresented in science, technology, engineering, and mathematics can further enrich their academic experience through direct participation as the member of an active research group or other professional entity are deemed an essential feature of a recognized program. Some examples of such entities include quality assurance/quality control laboratories, analytical laboratories, and production units.

If the necessary research infrastructure to support undergraduate research is lacking within the host institution, it is expected that the program will provide and advertise mechanisms for assisting students in obtaining experience through internship, co-op, or summer research programs at other institutions.



APPLYING FOR ASBMB-RECOGNIZED STATUS

APPLICATION CONTENTS

Undergraduate degree programs or departments seeking recognized status from the ASBMB should submit an electronic document in .pdf format to wzhao@asbmb.org. The application should provide the following information:

Institution

- The name of the degree program and the identity of the participating unit(s).
- Contact person.
- Letter of support from the Dean or equivalent institutional authority.
- Number of BMB degrees awarded each year for the preceding five years.
- Description of instructional facilities, including teaching and research laboratories, major instrumentation, and safety infrastructure.
- Evidence of institutional value and support for diversity of faculty and students
- Description of information resources and, where applicable, library facilities.
- Description of professional development programs and opportunities for BMB faculty.
- Description of course availability: timing and capacity.
- Description of safety program as it relates to BMB faculty and students

Faculty

- List of all faculty directly participating in the delivery of the BMB bachelor's degree program. Please include rank, unit affiliation, curriculum vitae, role in the program, approximate time commitment to the program.
- Names and affiliations of any additional faculty or other key personnel relevant to the program, such as faculty who sponsor undergraduate research experiences for BMB majors.

Curriculum

- Statement of educational goals for BMB majors and outline of overall educational approach/philosophy (limit one page).
- Brief description of the curriculum for BMB majors, including required courses and electives, and a short description of how each relates to the core concepts.
- Description of required STEM experiential learning component, including laboratory classes or equivalent, including contact hours (400 minimum).
- Description of undergraduate research opportunities, coop, and/or internship programs available to BMB majors and/or mechanisms for assisting students in obtaining such opportunities.
- Description of how the BMB program promotes communication skills



- Description of how the program fosters the development of teamwork skills
- Description of academic and career advising resources and programs.
- Brief description of the internal assessment methods used by the BMB program.

EVALUATION PROCESS

A committee of five ASBMB faculty and two industry representatives will be appointed by the chair of the Education and Professional Development (EPD) committee to oversee the evaluation of applications for ASBMB-recognized status. Applications will be evaluated twice each year on an advertised schedule determined by the committee. The chair of the committee will assign each application to an individual committee member for initial review. This evaluator will determine whether the application is complete and ready for consideration by the full committee. If significant omissions or deficiencies are evident they may immediately return the application to the applicants with a statement of suggested revisions. Those applications that pass initial review will then be distributed to the full membership of the committee.

Twice each year, the members of the accreditation committee will convene in person or by tele- / video- conference to evaluate applications. The matrix shown in Appendix II will be used to guide the evaluation process. Acceptance or rejection of an application will require a majority vote of the participating members. A quorum of five will be required for voting purposes.

FEEDBACK

Programs will be informed of the outcome of their application no later than six months following the applicable submission deadline. Notification will be accompanied by a written summary of the perceived strengths and weaknesses of the program.

APPEALS PROCESS

Unsuccessful applicants can resubmit a revised application at the next convenient deadline. It is recommended that resubmitted applications include a letter briefly outlining their response to the prior evaluation summary.

MAINTENANCE OF RECOGNIZED STATUS

Recognized status is conferred for a period of seven years. At the end of this time, an application for continuation of recognized status should be submitted to ASBMB. The format and evaluation process for renewal applications will be identical to those for an initial application.



ASBMB DEGREE CERTIFICATION PROCESS

Once a program has been approved as an ASBMB-recognized program, its students become eligible for an ASBMB-certified degree. To qualify for degree certification students must a) be in their final year of study for their BMB degree and b) exhibit a satisfactory performance on the ASBMB assessment instrument.

Eligible programs will administer the ASBMB assessment instrument to BMB students during their final year of study. The examination will be provided in electronic form to the designated contact person for each ASBMB-recognized program. This person will arrange for a staff member to print hard copy versions of the assessment instrument sufficient to provide one copy for each eligible student (with appropriate accommodations for students with disabilities). Both the electronic and hard copy versions of the assessment instrument should be kept in a secure place until immediately prior to the examination period. Students and faculty should NOT read any portion of the instrument prior to the exam period.

Ideally, all eligible students should take the assessment instrument on the same day, preferably at the same time. Answers should be written in pencil. Faculty should proctor the exam and be ready to assist students with questions intended to clarify content. However, proctors should refrain from providing “hints”, etc. designed to direct the student toward possible answers.

At the end of the exam period, the proctors will collect all copies of the assessment instrument and mail them to the ASBMB at the following address.

ASBMB
11200 Rockville Pike
Suite 302
Rockville, MD 20852

Applications will be scored by a committee of ASBMB members using rubrics provided by the authors of the respective questions. Each student response will be scored by three or more independent evaluators. Any items exhibiting unusually disparate scores will be investigated by a team of two additional evaluators. The members of the committee will be selected to insure both individual diversity as well as balance by region and institutional classification. Every evaluator will participate in a training experience to enhance uniformity of scoring.

ASBMB will compile all scores, determine cutoffs for certification and certification with distinction, and report this information to students and their instructors. In addition, each program will receive a report of the aggregate scores achieved by their students on each question.



FOOTNOTES

¹In addition to the obvious majors — Biochemistry, Biological Chemistry, Molecular Biology, or Biochemistry & Molecular Biology — we recognize that similar core content is often delivered by majors with names such as Biophysics, Chemical Biology, Molecular & Cellular Biology, etc. Hence, ASBMB considers it inadvisable to be overly reliant on labels in identifying relevant degree programs.

²For more information on laboratory safety, see www.cdc.gov/niosh/docs/2007-107/pdfs/2007-107.pdf and <http://chemical-safety.com/labsafety.htm> and societyforscience.org/isef/rules/rules11.pdf and <http://www.cdc.gov/biosafety/publications/bmb15/BMBL.pdf>.

³These core concepts were developed through a multi-year series of workshops supported by a grant from the NSF. At these workshops members of the BMB community were invited to develop a list of core concepts that defined and distinguished Biochemistry and Molecular Biology from other STEM disciplines, as well as a series of learning objectives for each.

⁴STEM lab contact hours required by several BMB programs:

Minnesota State – 819	Montclair State – 420
Nebraska – 450	Missouri Western State – 750
St John's/St. Benedict's – 633	UW La Crosse – 855
UW Madison – 390	U. Mich. Dearborn – 633
Virginia Tech – 540	Wellesley – 450

⁵STEM areas include Biology, Chemistry, Biochemistry, Molecular Biology, Physics, Engineering, Mathematics, and Computer Science.

⁶*in silico* laboratory experiences can be included in the required laboratory experience hours only when the subject matter is appropriate for active learning. Some examples of appropriate subject matter include bioinformatics analyses and structural modeling. Simulated laboratory activities or demonstrations, online or otherwise, will not be counted towards the required laboratory experience hours. The accreditation sub-committee of the ASBMB EPD will be the final arbiter of whether a particular laboratory experience is included in the required hours.



APPENDIX I

MATRIX FOR EVALUATING APPLICATIONS FOR ASBMB-RECOGNIZED STATUS

	Outstanding / Innovative	Strong	Appropriate	Improvement Needed	Unsatisfactory
INFRASTRUCTURE					
Faculty - number					
Faculty - qualifications					
Laboratory facilities					
Classroom facilities					
Administrative support					
Institutional support					
Faculty scholarship & research					
Professional development activities for faculty					
Evidence of institutional support for diversity					
Course capacity and timeliness					
CURRICULUM					
Core curriculum - breadth					
Educational Goals					
Core curriculum - quality					
Experiential learning - breadth					
Experiential learning – inquiry components					
Safety component					
Ethical conduct of research					
Internship / research opportunities					
Communications skills					
Teamwork skill opportunities					
Assessment methods					
Academic advising					
Career advising					

APPENDIX II

SAMPLE LEARNING OBJECTIVES FOR CORE CONCEPT 1¹: ENERGY IS REQUIRED BY AND TRANSFORMED IN BIOLOGICAL SYSTEMS².

1. Given³ knowledge of common mechanisms of regulation for biomacromolecules, students should be able to predict the sites and nature of regulation in pathways that transform energy.
 - a. Given⁴ the diagram of a metabolic pathway, students should be able to **describe**⁵ how that pathway is regulated.

Expectation: Students should be able to compare and contrast regulatory mechanisms of a particular pathway.
 - b. Given a description of a known regulatory molecule, students should be able to **predict** how pathway(s) would respond to changes in regulator levels.

Expectation: Students should be able to predict pathway flux regulated by a single macromolecule.
2. Given a knowledge of the basic structure of fatty acids, triglycerides, nucleotides, and carbohydrates; students should be able to compare and contrast the synthesis, storage, and transformation of macromolecules from which living organism harvest derive energy.
 - a. Given a diagram depicting the structures of glucose and a fatty acid, students should be able to **compare** their oxidation level with the relative energy stored.

Expectation: Students should be able to compare their relative state of oxidation and predict which has more reducing capacity.
 - b. Given a diagram describing the pathways of synthesis and degradation of a high energy molecule (e.g., glycolysis and gluconeogenesis), students should be able to **predict** the relative input or output of energy molecules for each pathway.

Expectation: Students should be able to predict the requirement for more energy molecules in the synthesis of a high energy molecule as compared to the net generation of high energy molecules for degradative pathway.

3. Given a macromolecule, students should be able to explain the contribution of entropy, enthalpy and temperature of a macromolecule and water (associated and in bulk solvent) in a folded versus unfolded state.

- a. Given: A macromolecule, students should be able to **identify** covalent and non-covalent interactions that affect the conformation of the macromolecule.

Expectation: Students should be able to identify covalent and non-covalent interactions that affect primary, secondary, tertiary and quaternary structure.

- b. Given: Covalent and non-covalent interactions, students should be able to **predict** the affect of making or breaking those interactions on the conformation of a macromolecule.

Expectation: Students should be able to relate the entropy, enthalpy and temperature of covalent and non-covalent interactions on the conformation of the macromolecule.

- c. Given: A macromolecule, students should be able to **describe** the effect of water on the conformation of that macromolecule.

Expectation: Students should be able to identify covalent and non-covalent interactions of water that affect primary, secondary, tertiary and quaternary structure of water and a macromolecule.

4. Given a biological example, students should be able to explain how thermodynamically unfavorable processes can occur.

- a. Given: Standard reduction potentials, students should be able to **explain** electron flow.

Expectation: Students should be able to identify electron donators, carriers and acceptors of electron flow.

- b. Given: An understanding of bond energy, students should be able to **relate** oxidation state to photosynthesis and/or respiration.

Expectation: Given molecules in different oxidized states, students should be able to identify bonds that require the most energy to break.

- c. Given: An example of transport, students should be able to **predict** the thermodynamic elements that drive transport.

Expectation: Given a transport process and an unfavorable reaction, students should **deduce** that an additional, thermodynamically favorable element (e.g. ATP hydrolysis) be used to facilitate the unfavorable reaction to become favorable.

5. Given an enzyme reaction, students should be able to differentiate the effect of an enzyme on the change in free energy of a reaction versus the change in transition state free energy.

- a. Given: An energy diagram of an enzyme reaction, students should be able to **predict** the change in that diagram if an enzyme were present.

Expectation: Students should be able to predict the change in an energy diagram by an enzyme's presence.

- b. Given: An enzyme mechanism, students should be able to **explain** the affect on free energy of the bond formation and breaking in the mechanism.

Expectation: Students should be able to explain the affect on free energy of covalent and non-covalent interactions of an enzyme mechanism.

6. Given entropy, enthalpy and temperature, students should be able to justify why evolutionary selection is constrained by the laws of thermodynamics.

- a. Given descriptions of the tertiary structure two homologues of an enzyme, one from a thermophilic organism and one from non-thermophile, students should be able to **predict** the differences in bonding responsible for the greater temperature stability of the thermophilic homologue.

Expectation: Students should be able to predict that the thermophilic enzyme is stabilized by a relatively larger number of hydrogen bonds and salt bridges [Note: the strength of hydrophobic interactions decreases with temperature.].



- b. Given: Two sequences of DNA, students should be able to **predict** a higher or lower temperature required for denaturation.

Expectation: Students should be able to predict that the GC-rich nucleic acid will exhibit the higher melting temperature and correctly explain the reason why.

FOOTNOTES:

¹The list of Core Concepts described herein is not intended to be dogmatic. On the contrary, as new discoveries are generated in Biochemistry and Molecular Biology, they shall evolve to incorporate new knowledge, either by the addition of new entries or the modification or replacement of the current ones.

²Learning objectives are numbered. Letters indicate examples of specific performances related to that learning objective. The set of learning objectives described herein constitutes a work in progress. As such, it will be subject to continual updating to incorporate lessons learned and to accommodate new knowledge in the field.

³We welcome feedback from the BMB community. However, we ask those persons wishing to contribute suggestions for new or modified learning objectives and related examples to conform to the “given / should be able / expectation” format used herein.

⁴The material in the subheadings is intended to clarify and amplify each learning objective by providing one or more specific examples of the types of knowledge and skills that fall under this learning objective.

⁵The words highlighted in **bold type** are key words from Bloom’s taxonomy ([Bloom, B. S.](#), Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. *Taxonomy of educational objectives: the classification of educational goals; Handbook I: Cognitive Domain* New York, Longmans, Green, 1956.), a system for classifying educational activities and questions within a hierarchy of Learning Domains. A chart listing relating specific verbs to specific learning domains is provided in Appendix VII.

APPENDIX III

SAMPLE LEARNING OBJECTIVES FOR CORE CONCEPT 2¹: MACROMOLECULAR STRUCTURE DETERMINES FUNCTION AND REGULATION².

1. Given³ the knowledge of bio macromolecules, students should be able to identify, draw (sketch) and know properties (functions) of bio macromolecules.
 - a. Given⁴ the primary structure of either a protein or a nucleic acid, a student will be able to **identify**⁵ the covalent bond that joins the monomer units and **notate** key features of the bond or macromolecule.

Expectation: Students will correctly identify the peptide bond in a polypeptide, the phosphodiester bond in a polynucleotide, and the glycosidic bond in a carbohydrate.
 - b. Given: A description and image of a complex carbohydrate (including glycoproteins and proteoglycans), a student should be able to **summarize** the molecular function of that macromolecule.

Expectation: The summary will include major points for the complex carbohydrate and include functions described at a mechanistic/chemical level.
 - c. Given: A description and diagram of a lipid membrane, students will be able to **predict** the impact of altering physical and chemical characteristics of the membrane in terms of fluidity and function.

Expectation: Students will correctly identify the impact of changes in membrane construction.
2. Given a list of macromolecules, students should be able to devise an experiment on how they interact or interpret results of experiments on their interactions.
 - a. Given: Structure of a macromolecule or a macromolecule binding another compound/macromolecule, students will be able **identify** and **analyze** forces involved in interactions within the macromolecule, a binding partner or ligand.

Expectation: Students will be able to correctly identify the intra and intermolecular forces maintaining structure. Students will also predict possible interactions with another macromolecule or ligand.

- b. Given: A figure depicting the key structural features of a biological complex, students will **hypothesize** forces stabilizing the structure and **design** an experimental test to evaluate the potential contributions of each force to stabilizing its structure.

Expectation: Students should hypothesize and reasonably create an experiment to examine these effects.

- c. Given: A description of a range of known inhibitors with graphs of their kinetics (velocity vs substrate concentration) and secondary kinetic plots of these enzymes on a common enzyme, and an unknown small molecule, students should be able to **distinguish** the type of regulation by the known inhibitors on the enzyme and **differentiate** the distinction between the sites of action of the inhibitors. Students should also **create a hypothesis** and **design** an experiment to determine the nature of the unknown inhibitor.

Expectation: Students will correctly identify the inhibitors and describe the actions of the shown inhibitors. Students will also be able to create a hypothesis and design an experiment with critical elements that would identify the type of inhibitor the unknown molecule was.

- d. Given: A protein whose function is allosterically controlled, a description of the function of the protein and either biophysical or kinetic evidence of a small molecule which impacts the cooperativity of the protein. Students must **evaluate** the structural and kinetic impact of the regulatory molecule(s) on the output of the protein.

Expectation: Students must determine the cooperativity in terms of subunit-subunit interactions and their impact on protein function.

- e. Given: Data describing the effects of deletion mutations targeting the promoter region of gene A that has been linked to reporter gene B on transcript levels for each.

Students must **interpret** the data and **hypothesize** which region of the promoter is important for full transcription. Students should be able to **design** an experiment to determine where the protein(s) would bind.

Expectation: Students will correctly identify the region(s) of the promoter important for transcription. They should design an experiment that would include assays, such as *in situ* mutations and mobility shift assays, to determine the exact sequence where the protein(s) bind.

3. Given structural changes of a macromolecule, students should be able to predict the impact of structural substitution would have on macromolecule structure and function.
 - a. Given: The structure of a macromolecule bound to either a small ligand or to another macromolecule along with a brief description of the macromolecule's function, students should be able to **assess the effect** of a mutation on structure and function of that macromolecule. Students should also be able to **design** an optimal ligand or binding partner for the mutant macromolecule.

Expectation: Students should be able to identify the impact of the mutation on binding with specific biochemical detail. Students should also be able to design specific changes to an existing ligand/binding partner or create a new ligand/binding partner that would correctly interact with the mutant macromolecule.

4. Given experimental data, students should be able to assess how enzymes facilitate biochemical reactions.
 - a. Given: The reactions catalyzed by two or more enzymes that use a common metabolite as substrate, along with their respective V_{\max} and K_m values, students will **compare** these constants to conclude the flux of substrate.

Expectation: Students will predict the relative proportions of substrate flow through each enzyme.

- b. Given the occurrence of an unknown disease which impacts either the concentration of the metabolite or one or more of the constants for the enzymes. They will **deduce** the impact of the disease on metabolism.

Expectation: Students will predict the impact of the presented disease on metabolic

flow.

- c. Given a model of an enzyme active site and a description of the reaction it catalyzes, students should be to **propose** a plausible reaction mechanism and **predict** the impact of mutations thereupon.

Expectation: Students should be able to correctly identify the key amino acid residues of catalysis and formulate the reaction mechanism. Students should also correctly state the impact of the mutation on catalytic function.

5. Given that evolutionary forces such as gene duplications and genomic mutations can provide changes in protein structure(s) and function(s) students should be able to **explain** how protein structures might change while retaining an evolutionarily conserved function.
- a. Given an example of a protein family (e.g. kinases, hemoglobin, immunoglobulin, serine proteases) students will be able to **discuss** how the family arise from duplication of a primordial gene and will be able to discuss how the mutation of the duplicated gene(s) lead to a gene/protein with unique function(s).

Expectation: Students will correctly identify the gene (or exon) duplication. They should expand to include how the new gene(s) can be spatially or temporally expressed and how it is functionally conserved.

- b. Given information of the degree of sequence divergence amongst a family of proteins students will determine their phylogenetic relationship to one another.

Expectation: Students will correctly construct the correct tree.

FOOTNOTES:

¹The list of Core Concepts described herein is not intended to be dogmatic. On the contrary, as new discoveries are generated in Biochemistry and Molecular Biology, they shall evolve to incorporate new knowledge, either by the addition of new entries or the modification or replacement of the current ones.

²Learning objectives are numbered. Letters indicate examples of specific performances related to that learning objective. The set of learning objectives described herein constitutes a work in



progress. As such, it will be subject to continual updating to incorporate lessons learned as well as to accommodate new knowledge in the field.

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APPENDIX IV

SAMPLE LEARNING OBJECTIVES FOR CORE CONCEPT 3¹: INFORMATION STORAGE AND FLOW ARE DYNAMIC & INTERACTIVE².

1. Given³ an understanding of replication, transcription and translation, students should be able to determine how changes in DNA sequence affect the amino acid sequence of the protein it encodes.
 - a. Given⁴ a DNA sequence and a codon usage chart, students will be able to **identify**⁵ the corresponding protein sequence coded for by the DNA sequence.

Expectation: Students will be able to determine a protein sequence from a DNA sequence with the assistance of a codon usage chart.
 - b. Given a list of changes in a particular DNA sequence, students should be able to **predict** how the protein sequence will be affected.

Expectation: Students will be able to distinguish between silent mutations, missense mutations and nonsense mutations.
 - c. Given a list of DNA repair enzymes and a list of polypeptide repair enzymes, students will **explain** the apparent quantitative discrepancy between the two.

Expectation: Students will be able to cite at least two of the following concepts in their explanations: most proteins are transient and replaced by new, undamaged copies on a regular basis; cells contain only a single copy of their DNA whose accuracy is essential to survival; the nucleotide bases of DNA render it much more vulnerable to damage, especially by UV radiation.

2. Given an understanding of common mechanisms of gene regulation, students will be able to explain or predict changes in transcription in response to biologic variables.
 - a. Given an understanding of signal transduction cascades, students will be able to **relate** how activation of a transmembrane receptor results in transcriptional regulation of specific genes.

Expectation: Students will be able to describe the mode of action of at least three of the following: second messengers, protein kinases, protein phosphatases, transcription

factors, and transmembrane receptors in a signaling cascade.

- b. Given a list of modifications to chromatin and their effect on the transcription of an associated gene, students should be able to **appraise** whether and, if so, how expression of that gene will compare in cells whose DNA or chromatin proteins differ in their state modification.

Expectation: Students will be able to correctly identify the cell that exhibits the highest level of gene transcription or, where applicable, recognize that both cells will exhibit similar levels of transcriptional activity.

3. Given an understanding of genetic information transfer, students should be able to explain the role of RNA in the flow of genetic information.

- a. Given an understanding the role of RNA in transmitting information, students will be able to **describe** the reason why proteins are produced using an RNA intermediate as opposed to translating directly from DNA.

Expectation: Students will be able to formulate a correct response that cites two or more of the following concepts: greater chemical stability of DNA versus RNA, ability to move transcript to region of cell where translation will be most beneficial, such as to the endoplasmic reticulum, the ability to dispose of the transcriptional template when no longer needed without losing the information it encodes, greater variety of gene products that can be generated by alternative mRNA splicing without impacting the archival copy.

- b. Given an understanding of RNA splicing, students will be able to **report** how one gene can result in the production of multiple RNA sequences and multiple protein products.

Expectation: Students will be able to identify the number of potential protein products given a specific number of 5' and 3' splice sites within a DNA sequence.

4. Given an understanding of evolution and natural selection, students should be able to make predictions on how environmental factors will affect information flow over generations.

- a. Given: A known selection pressure, students should be able to offer a plausible **prediction** as to how changes in DNA and the corresponding protein can enable the organism to adapt.

Expectation: Students will describe mechanisms by which mutations that stimulate the expression of one or more defense proteins (such as antibiotic kinases, arsenate reductases, multidrug exporters, etc.) or, alternatively, offer a feasible description of how a mutation to the gene encoding an exiting protein can lead to the emergence of a new enzymatic or other function.

- b. Given: DNA and protein sequence comparisons between multiple organisms, students should be able to **catagorize** these organisms based on sequence similarity.

Expectation: Students should be able to identify sequence identities and similarities with and determine an order of relationship corresponding to the highest number of sequence identities.

5. Given an understanding of commonly encountered signal transduction mechanisms, students will be able to predict or design models for information transfer cascades.

- a. Given a schematic diagram of a feasible, but flawed, feedback regulatory loops the student should be able to **revise** the scheme to achieve better signaling processes and **explain** how the suggested change yields improved regulatory control.

Expectation. Students will be able to identify the suboptimal features and suggest two improvements and correctly explain the improvements in performance that will result.

- b. Given an understanding of covalent modifications commonly utilized to modify the properties of proteins participating in sensor response (signal transduction) cascades, students should be able to **identify** and **confirm** the differences between an irreversible mechanism (Zymogen activation) and a reversible one (phosphorylation-dephosphorylation, acetylation-deacetylation).

Expectation. Students will correctly identify the reversible and irreversible modifications and explain either that reversible modifications permit bidirectional regulation or the ability to rapidly reset the signal-response cascade to a “ready” state.

- c. Given an understanding of metabolic regulation and gene regulation, a student should



be able to **formulate** a position on the issue of whether these represent two distinct forms of regulation.

Expectation: Students taking pro or con positions (either is acceptable) will provide one relevant, factually correct statement in support of their position.

FOOTNOTES:

¹The list of Core Concepts described herein is not intended to be dogmatic. On the contrary, as new discoveries are generated in Biochemistry and Molecular Biology, they shall evolve to incorporate new knowledge, either by the addition of new entries or the modification or replacement of the current ones.

²Learning objectives are numbered. Letters indicate examples of specific performances related to that learning objective. The set of learning objectives described herein constitutes a work in progress. As such, it will be subject to continual updating to incorporate lessons learned as well as to accommodate new knowledge in the field.

³We welcome feedback from the BMB community. However, we ask those persons wishing to contribute suggestions for new or modified learning objectives and related examples to conform to the “given / should be able / expectation” format used herein.

⁴The material in the subheadings is intended to clarify and amplify each learning objective by providing one or more specific examples of the types of knowledge and skills that fall under this learning objective.

⁵The words highlighted in **bold type** are key words from Bloom’s taxonomy ([Bloom, B. S.](#), Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. *Taxonomy of educational objectives: the classification of educational goals; Handbook I: Cognitive Domain* New York, Longmans, Green, 1956.), a system for classifying educational activities and questions within a hierarchy of Learning Domains. A chart listing relating specific verbs to specific learning domains is provided in Appendix VII.



APPENDIX V

SAMPLE LEARNING OBJECTIVES FOR CORE CONCEPT 4¹: DISCOVERY REQUIRES OBJECTIVE MEASUREMENT, QUANTITATIVE ANALYSIS, AND CLEAR COMMUNICATION².

1. Given³ an appropriate question and a working knowledge of BMB, students should be able to formulate hypotheses, design experiments, and assess the quality of experimental design.

a. Given⁴ an experiment result, design, or hypothesis, students should be able to **design**⁵ appropriate positive and negative controls.

Expectation: Students should be able to design and correctly label both the positive and the negative control.

b. Given an experimental observation or set of observations, student should be able to **develop** and **state** a testable hypothesis and describe an experimental approach to test the hypothesis.

Expectation: Students should be able to state a scientifically reasonable hypothesis and a technically a feasible approach.

2. Given a fundamental understanding of BMB concepts, students should be able to formulate experiments and assess the quality of experiments addressing molecular structure, assays of biological function, and isolation/ separation of biomolecules.

a. Given an understanding of the properties of buffers and the concept of molarity, students should be able to **formulate** buffers, **assess** buffering capacity, **produce** stock solutions, and **construct** dilutions.

Expectation: Students should be able to identify the appropriate buffering component(s) and calculate the appropriate concentrations.

b. Given the final Molar concentrations of a complex solution students should be able to

determine the amounts needed to prepare the concentrated stock solution from starting materials (solid or liquid), and make a dilution from the stock solution to a specified working concentration.

Expectation: Students should be able to accurately perform the calculations.

- c. Given a hypothesis, students should be able to **state** a physical property that would form the basis of an experimental test and **justify** its use to test the hypothesis.

Expectation: students will state an appropriate physical property and synthesize a valid justification.

- d. Given a knowledge of the properties of macromolecules, students should be able to **devise** a method to separate a mixture of known macromolecules with known physical properties or **critique** the effectiveness of a given standard method proposed to separate the mixture.

Expectation: Students should be able to identify the physical property or properties by which the macromolecules can be resolved one from another and select the appropriate technique to exploit them or, alternatively, relate the physical property which each standard technique exploits, the correctly predict the relative behavior of each macromolecule in the mixture.

- e. Given the DNA sequence, expression pattern and regulation of a particular gene, students should be able to **compose** an experiment that would help determine the gene's function.

Expectation: Students will be able to devise either a knockout experiment or knockdown experiment and explain the outcomes to be expected for each function postulated.

- f. Given a monogenic phenotype in an asexually reproducing organism, students should be able to **design** an experiment to determine the gene responsible for this phenotype.

Expectation: Students will design a feasible and logically sound mutagenesis/gene replacement experiment and describe how the possible outcomes would lead to the identification of the gene responsible.

- g. Given a specific gene sequence, students will be able to search a genome database (e.g. Genbank) to find the most closely related species contained within the database.



Expectations: Students will be able to identify the most closely related organism.

3. Given a data set, students should be able to assess the reliability of the data and draw appropriate conclusions.

- a. Given a set of data and a possible conclusion, students should be able to **identify** any datum that is inconsistent with the conclusion presented.

Expectations: Students will identify every inconsistent datum.

- b. Given a histogram, students should be able to **select** data that differs in a statistically significant manner from the negative control.

Expectations: Students will identify all statistically significantly different data as compared to the negative control.

- c. Given two data sets that presented as normal populations with overlapping data, but no overlapping standard deviations, students should be able to **infer** that the data sets are statistically different, even though they contain overlapping data.

Expectation: Students will be able to identify those data that are statistically significantly different data as compared to the negative control.

- d. Given a standard curve of an assay that exhibits a clear breakpoint, students should be able to **estimate** the upper limit of detection of the assay.

Expectation: Students will correctly identify the upper limit of detection, within plus or minus 5%.

- e. Given an experimental protocol and an unreasonable outcome, specifically an unrealistically large or small value, students should be able to **synthesize** a plausible source of the discrepancy.

Expectation: Students should be able to synthesize a plausible possibility.

4. Given a set of data, students should be able to appropriately present and interpret the data.



- a. Given a set of data, students should be able to **design** the most effective type of graph (e.g., bar, line, scatter) to present the data and label its axes.

Expectation: Students will **state** (one of) the most effective graph type and correctly **label** the axes, including appropriate units.

- b. Given an understanding of fundamental BMB concepts and data analysis students should be able to **assess** a set of experimental data from a JBC paper and **critique** it.

Expectations: Performance: Students should be able to write a results section, describing a given set of figures.

FOOTNOTES:

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APPENDIX VI

MEMBERSHIP OF THE ASBMB CERTIFICATION COMMITTEE & CERTIFICATION ADVISORY COMMITTEE, APRIL 2012

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