Standards for Doctoral Degrees in the Molecular Biosciences: Recommendation of the International Union of Biochemistry and Molecular Biology

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Abstract

In 1989, the (then) International Union of Biochemistry published for the first time a set of Standards for the PhD Degree in Biochemistry and Molecular Biology. This was a time of unprecedented growth in the molecular biosciences, and also of fragmentation into specialisations such as developmental biology, neuroscience, molecular cell biology, structural biology and molecular pharmacology. The IUB document articulated a clear and relatively generic set of standards for the PhD across these specializations.

These standards have been revised in 2010 to accommodate the additional significant changes to the research environment in the molecular life sciences research in the 21st century, in particular the advances in genomics and associated use of computing, the increase in interdisciplinary research and systems-based approaches, the impact of industry funded research, the drive to develop applications of basic science and the associated emphasis on intellectual property.

These revised Standards emphasize (i) the desired characteristics of those awarded a doctor’s degree in Molecular Bioscience; (ii) suggestions as to how these abilities may be acquired and how their attainment may be assessed; and (iii) suggestions regarding the criteria for the overall evaluation of candidates. They are intended as an aid to university departments and boards of graduate studies, to national organizations that set standards for graduate education, to those scientists who serve as external examiners to evaluate theses, and to candidates for a degree in these sciences.

Key Words: PhD education, Standards, IUBMB

Introduction

The International Union of Biochemistry and Molecular biology seeks to advance the international molecular life sciences community by:

- Promoting interactions across the diversity of endeavours in the molecular life sciences
- Creating networks that transcend barriers of ethnicity, culture, gender and economic status
- Creating pathways for young scientists to fulfil their potential
- Providing evidence-based advice on public policy
- Promoting the values, standards and ethics of science and the free and unhindered movement of scientists of all nations.

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One of the key focus areas for the Union is education. The associated vision statement is: *Enhancing teaching and learning in the molecular life sciences through international collaboration.*

In 1989 the Committee on Education of the International Union of Biochemistry first published its Standards for the Ph.D. Degree in Biochemistry and Molecular Biology. These were well received internationally, and a second iteration was published in 2000 that was broader in scope, addressing not only Biochemistry and Molecular Biology but all the Molecular Biosciences.

A further revision has now been undertaken [1], necessitated in large part by the dramatic changes in the molecular life sciences over the past decade. The introduction to the new Standards paper expresses this environment very well:

“Biological Science has been changing at a stunning pace with unprecedented growth, a deepening of knowledge and proliferation of methods of investigation. At this time interdisciplinary has become commonplace and even essential as the barriers among the traditional biosciences disappear. Biochemistry and molecular biology, cell biology, structural biology, developmental biology, genetics, immunology, microbiology, neurobiology, nutrition, physiology, pharmacology, and molecular medicine now speak the same scientific language and use the same molecular tools. It is not unusual for elements of these molecular biosciences to be combined in a single degree. In addition, informational science has made possible the birth of genomics, proteomics and bioinformatics, while interest has been moving from molecules to mechanisms and to whole organisms, from a focus on individual components to biological systems.”

The 2010 Standards document is international in emphasis. It recognises that some institutions may have lower research capability than others, and these institutions are encouraged to develop external networks that improve opportunities and outcomes for students. One specific requirement identified for doctoral students is ready access to the scientific literature and electronic databases, now regarded as essential for modern research in the molecular life sciences. A working knowledge of English is also highlighted as a prerequisite for functioning in a modern scientific community.

The document also gives emphasis to flexibility of approach – recognising firstly that different pathways can lead to research excellence, and secondly that there is a need for flexibility in areas of the molecular life sciences that are rapidly evolving. Rather than proposing an “ideal PhD training program” the goal has been to recommend (i) a set of graduate attributes for the PhD graduate (i.e. Standards), (ii) some strategies by which these attributes might be achieved and (iii) criteria by which the work of the candidates might be appropriately evaluated.

There is also emphasis on breadth and diversity as opposed to narrow specialisation, and on support for the acquisition by doctoral students of generic and transferable skills such as communication skills, time management, independence and collaborative skills, with a corresponding de-emphasis on over-specialisation. Understanding the importance of integrity in science, and what constitutes ethical behaviour as a scientist, is also seen as integral to the training of doctoral students. (See IUBMB Code of Ethics).

**Standards**

The Standards proposed for PhD graduates in the molecular sciences are [1]:

1. The candidate should demonstrate a general knowledge of physics, organic and physical chemistry, mathematics (including calculus, probability and statistics), computer science, biology and cell biology, genetics, biochemistry and molecular biology, bioinformatics, the particular Molecular Bioscience, and good knowledge of the topic of research.
2. The candidate should be familiar with the research literature of the particular Bioscience and should have the ability to keep abreast of major developments and to acquire a working background in any area.
3. The candidate should demonstrate skill in the recognition of meaningful problems and questions for research in the particular Bioscience.
4. The candidate should possess technical skill in the laboratory, including computational and mathematical, manipulations.
5. The candidate should demonstrate the acquisition of oral, written and visual communication skills.
6. The candidate should demonstrate skill in designing experiments and in conducting productive self-directed research.

**Strategies**

Formal and informal courses, student-run seminars, contributions to undergraduate teaching, presentation at group meetings, journal clubs, seminars and conferences and are among the range of activities that can usefully contribute to a graduate program of study leading to increasing confidence and sophistication as a scientist and independent thinker. The role of the research supervisor in this development is seen as critical, requiring careful judgement regarding the amount and type of guidance needed as the thesis progresses. The valuable contribution that other academics can make to the supervisory process, especially in the form of a supervisory committee, is recognised. Processes for enriching the graduate student experience at a departmental level and for facilitating active involvement of students in their departmental community are also suggested.

**Thesis**

The thesis should demonstrate “... that the candidate has conducted successfully and meaningful research by solving an original problem with an increasing degree of independence, has made significant contributions to the work and understands how the results fit into the scheme of current knowledge” [1].

Recommendations for the preparation of the thesis include: (i) consideration of the options of a written thesis with standard literature review, methodology, results and discussion vs a collation of published papers with an introduction and discussion, as well appropriate supplementary information. For thesis defence, an oral defence before at least one external expert and the supervisory committee is recommended. Elements of the thesis recommended to be considered in assessing quality include: fluency of style, quality of critique of the literature; clarity of experimental methods such that they can be reproduced; rigorous experimental design, clear presentation of results and appropriate interpretation and conclusions, attribution of the contributions of others. Rejection of the thesis is appropriate if defects cannot be easily remedied to the satisfaction of the supervisory committee in a reasonable timeframe.

**Conclusion**

A final theme that permeates the Standards document is the importance of the development of doctoral students as independent and creative thinkers. Pertinent statements include:

- The naive beginner must evolve into a self-reliant and professional investigator during the thesis work.
- Candidates should have opportunities to practice looking at problems from different perspectives and applying integrative thinking
- Candidates should participate actively in selection of the [research] problem.
- The original description of the doctoral thesis problem should not be too restrictive.
- The supervisor must decrease detailed direction as the project proceeds and the candidate becomes more self-reliant, and may have to accept, within reasonable limits, a degree of loss in efficiency in the work of the laboratory as part of the cost of professional education.

The IUBMB offers these Standards for Doctoral Degrees in the Molecular Biosciences with the hope that they will be helpful to the international community of researchers and educators across the broad landscape of investigation that shares in common the study of living processes at a molecular level.

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**References.**


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