

A Brief History of Biochemical Education

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Introduction

To understand where you want to go, sometimes it is necessary to look back to where you have been. My students will remember, with heavy sighs, hearing this statement each time I introduced a new topic in class and insisted on giving them an historical background. But I do believe that by retracing our paths, we gain insight into the future. It is fortunate that our discipline, unlike other basic sciences, has a relatively brief history, beginning, most say, at the time of Wohler's synthesis of the physiologically important compound, urea, from "lifeless" inorganics in 1828. Even the short lifetime of 175 years is too long to give details and to name names. Rather, in this essay I will use events that, in my opinion, have shaped modern biochemical education. Emphases will be placed on three categories of events: changes in the subject content, curriculum, and research funding. For most of my comments I will use the year 1985 as a starting point, which may appear arbitrary, but looking back, it was a time when a brighter light began to shine on biochemical education at the undergraduate level.

Pre-1985 Biochemistry

Throughout much of its history, biochemistry has been a field reserved for post-baccalaureate study. Universities established biochemistry departments primarily to train students for the M.S., Ph.D., and M.D. degrees. One of the first documented formal courses in the field was taught by Russell Chittenden (probably the first "Professor of Physiological Chemistry" in the United States) at the Sheffield Scientific School at Yale in 1874. Although the exact time and place of the first undergraduate program in biochemistry are uncertain, a few colleges and universities began offering the bachelors degree in the late 1960's (Rumors abound that the first undergraduate program in biochemistry was at Beloit College, but others also claim that honor). During the 1970's and even early 1980's it was a luxury, especially for chemistry and biology departments at predominantly undergraduate institutions (PUI's), to have a faculty member with biochemistry expertise. In those earlier days, the vast majority of undergraduate students preparing for careers in biochemistry completed a chemistry degree. The curriculum for these students might include one, or with luck, two semesters of biochemistry. Perhaps, if a student were really lucky, she or he could fit one or two biology courses into a tight curriculum of chemistry, physics, and math. Biochemistry at this time was considered by many in the U.S. to be outside of the realm of "real" chemistry which included the traditional areas of organic, physical, analytical, and inorganic. Your biochemistry book was something you read in the privacy of your dorm room after the lights were out!

The turning point for undergraduate biochemical education occurred, I believe, in the mid 1980's when ASB (American Society for Biochemistry; later changed to ASBMB) formed the Educational Affairs Committee (EAC) with a charge to study aspects of biochemical education at the graduate **and** undergraduate levels. Members of the Committee included fourteen biochemists from major research universities, medical schools, the pharmaceutical industry, and government funding agencies, and one biochemist from a PUI. Committee agenda items consisted of several issues for undergraduates: curriculum, research, and career planning. Especially effective has been the Committee's activities in planning educational symposia for national ASBMB meetings.

Content of Biochemistry

Textbooks play not only a primary role in educating students at all levels, but they serve as windows to the past showing how a discipline has developed. We have all scanned the pages of the biochemistry textbooks by Harrow (1935), Fruton/Simmons (1953), White/Handler/Smith/Dewitt (1954), Mahler/Cordes (1969), Lehninger (1970), and Stryer (1975). During this time period a standard "core content" developed which included 1) the structure, function, and metabolism of the important

biomolecules (especially proteins), and 2) quantitative aspects including bioenergetics, kinetics, transport, and reaction equilibria. However, there was no formal, organized set of core concepts until Lehninger used what he called “molecular logic” to outline the fundamentals:

1. the molecular components of cells
2. catabolism and the generation of phosphate-bond energy
3. biosynthesis and the utilization of phosphate-bond energy
4. replication, transcription, and translation of genetic information.

Biochemistry has, in my opinion, undergone a major change in focus since these early years. Topics that were considered “other” – molecular biology, molecular genetics, cell biology, immunology, etc. and hidden in the backs of biochemistry textbooks—are now part of the mainstream. Experimental design in biochemical research now tends to place increased emphasis on the nucleic acids. Genetic approaches are routinely used to study all biological processes including the traditional core topics of biochemistry: structure, metabolism, and bioenergetics. Students now need to study the Krebs cycle **and** the cell cycle.

The modern blending of biochemistry and molecular biology has brought us to a very special time in the molecular life sciences. Biochemists and other life scientists have recently uncovered the molecular mechanisms of many fundamental biological processes especially in the areas of immunology; DNA structure/function; RNA structure/function; cell differentiation, development, and death; neuroscience; and signal transduction. In addition, we now know the sequence of the human genome as well as that of many other organisms. This important work will not just influence the course of biochemistry, it will lead the way by expanding biomolecular research in the chemical sciences, computer science, the pharmaceutical sciences, and other fields.

Textbooks in biochemistry since 1985, which are too numerous to mention, still follow the basic Lehninger organization, but most now have greatly expanded the concepts of information transfer and nucleic acid structure/function. Some have even rearranged topics to move the nucleic acids ahead of metabolism. This not only enhances the level of nucleic acid importance, but it also allows instructors to use regulation at the gene level to explain control of metabolic processes. I believe that an important impetus for these changes was the decision by the members of ASB to change the name of their Society to the American Society for Biochemistry **and** Molecular Biology in 1987 and thus open the door to a broader range of molecular life scientists.

Curriculum

Prior to 1987, most students who wanted to work or attend graduate school in biochemistry majored in chemistry and/or biology because few institutions offered degrees labeled ‘biochemistry’. In 1988, after several years of study, the American Chemical Society’s Committee on Professional Training (CPT) announced the establishment of an ACS-certified bachelors degree in chemistry **with biochemistry emphasis**. Approximately 100 of the nearly 600 chemistry departments certified by the Society now offer the degree.

The Educational Affairs Committee (EAC) of the American Society for Biochemistry and Molecular Biology (ASBMB), in 1989, sought to study current requirements for the undergraduate degree in biochemistry in all chemistry, biochemistry, and biology departments at U.S. colleges and universities. Approximately 300 such programs were identified. Although the EAC had been consulted regarding the ACS chemistry/biochemistry curricular program, several members of the Committee and especially colleagues in biochemistry and biology departments, believed that the ACS degree had only a minimum of molecular life science courses and was not well suited for students who wanted careers in

biochemistry and molecular biology. In 1992, the EAC designed and published a “recommended” curriculum for the bachelors degree in biochemistry. This served as a useful guide for colleges and universities that desired an undergraduate biochemistry major and the degree has become an important route to graduate school, medical school, and to jobs in biotechnology.

In the ten years since the ASBMB developed the recommended curriculum, the fields of biochemistry and molecular biology have undergone enormous changes, thus requiring an updated version. The ASBMB committee (now called the Education and Professional Development Committee) has modified its recommended curriculum by basing it on content (skills and concepts) rather than standard course requirements (Spring 2003).

As further proof that biochemistry has become a full-fledged discipline, the Educational Testing Service announced in 1990 the introduction of the GRE Subject Test in Biochemistry, Cell, and Molecular Biology. It is intended to meet the needs of the growing number of graduate programs and students in the molecular life sciences as well as related programs in microbiology, genetics, neuroscience, and immunology.

The design and dissemination of biochemistry curricula have been greatly enhanced by Project Kaleidoscope (PKAL) and by the journals, *Biochemistry and Molecular Biology Education (BAMBE)* and the *Journal of Chemical Education*. PKAL has sponsored biochemistry teaching workshops at Rice University and Macalester College, and Summer Institutes at Keystone, Snowbird, and Williamsburg. Topics ranged from the subject content of biochemistry courses to appropriate skills for the biochemistry laboratory. Biochemical education now has its own journal for publication of manuscripts that assist BMB instructors in the lab and classroom. BAMBE (formerly *Biochemical Education*, published by IUBMB and Elsevier) is now published by ASBMB and co-edited by Professors Don and Judy Voet.

Undergraduate Research Funding

During the 1970's and early 1980's, biochemists at PUI's received most of their research funding from ACS-PRF and Research Corporation. It was rare, though not impossible, for a biochemist to have funding from the very competitive programs at NSF or NIH. Perhaps the greatest boost to biochemistry research at PUI's has been the initiation in 1985 of the NIH-AREA and NSF-RUI grants which are funded on the bases of the science **and** the impact on student training.

The Camille and Henry Dreyfus Foundation has funded several programs including the Scholar/Fellow Award. This program provides funds for a mentor at a PUI to hire a postdoctoral associate who will participate in the departmental teaching programs and conduct research in close association with the faculty mentor. Several biochemists at PUI's have been recipients of this award.

In addition to government and foundations, undergraduate research funds have recently become available from the chemical and pharmaceutical industries. Dupont, Dow, Merck, Pfizer, and others all have various competitive programs to fund research and related programs at PUI's. These programs were initiated to encourage students to join the companies after graduation. The Howard Hughes Medical Institute has also been very active is providing funding for innovative programs that prepare undergraduates for biomedical careers.

Post-2003 Biochemistry

Evidence that biochemistry now plays a major role in undergraduate colleges comes from a study of faculty and research activity listed in the book, *Research in Chemistry at Undergraduate Institutions*, published by the Council on Undergraduate Research (CUR). In 1990, of 224 institutions listed in the

book, 190 out of 926 chemists on the full-time faculty were biochemists. Approximately 60-70% of the departments had a staff biochemist. In the latest edition of the CUR Directory (1999), 558 institutions are listed and about 85% of the chemistry departments list at least one staff biochemist. Many chemistry departments at PUI's are now graduating more biochemistry majors than traditional chemistry majors.

What changes may we expect and encourage in the next 15-20 years? Some predictions:

- the number of students in biochemistry/molecular biology programs will continue to increase, but there will be competition from the other life sciences including cell biology and neuroscience
- biochemistry/molecular biology will continue to be driven by genomics, proteomics, bioinformatics, and pharmacogenetics
- most textbooks will be web-based and BMB courses will be in the format of long-distance learning; laboratories may become "virtual"
- topics in biochemistry/molecular biology must be further integrated into traditional general, organic, and physical chemistry courses
- the interdisciplinary nature of biochemistry needs to be encouraged by the design of joint programs among departments (chemistry, biology, physics, computer science, psychology, etc.).

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