Integration of Chemical History into the Chemical Literature Course†

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The continuing increase in the volume and variety of the chemical literature emphasizes the need for some minimal formal instruction in information retrieval techniques. The traditional course in "Chemical Literature" still serves as an excellent vehicle for unifying this topic across the different subdisciplines of chemistry. Such a course should focus on the fundamentals that are necessary for future personal growth rather than attempting to prepare chemical information specialists. Consequently, a Chemical Literature course also offers the opportunity to describe the achievements and failures that occurred during the development of modern chemistry. The integration of the history of chemistry into a discussion of the chemical literature should provide additional meaning for the retrospective literature search. For students, the appreciation of what lies beneath their feet as they "stand on the shoulders of giants" should mean greater clarity in scientific purpose and a heightened sensitivity to the potential philosophical and sociological consequences of their work.

INTRODUCTION

"The history of science and of specific sciences is a neglected field of study in most American colleges and universities." This statement was expressed by Crane, Patterson, and Marr 25 years ago,[1] and yet the situation still exists virtually untouched by science educators. More recently, Skolnik has reiterated this problem with additional insight. Concerned with the ability of college graduates to continue a self-education program throughout their professional career, he concluded that "it is important for every chemist to have a fair appreciation of the literature, history, and philosophy of chemistry" since these aspects were fundamental to achieving that objective.[2]

It is unfortunate that many students learn their chemical facts by association with an individual's name, and yet are totally ignorant of the person involved, the background of the discovery, or any of the other salient facts that accompany the situation. Students of organic chemistry, for example, might be surprised to find that for Charles Friedel and James Mason Crafts the reaction that bears their names "played a comparatively minor role in their lives". Instead, they "rendered pioneering service to the development of the chemical science and teaching in their native countries" that was far greater than a single discovery.[3]

Or, consider the young organic chemistry professor, successfully publishing outstanding research papers, who reluctantly admits that while his postdoctoral research experience occurred in the J. B. Conant Laboratory, he has no knowledge of J. B. Conant. It is not surprising that this individual did not have any prior knowledge of J. B. Conant. Nor is it surprising that the name of J. B. Conant did not previously appear in either an informal or classroom setting. What is surprising, and disturbing, is the fact that once the name of James B. Conant had surfaced, the individual did not bother to obtain any information on his own.[4] This lack of historical curiosity on the part of chemists is not new, nor is it restricted to any particular generation. How many students and faculty on any campus can provide the background for the name of the science or chemistry building in which they work and study? How many industrial chemists have similar information about the origin and development of their employer?

Chemical history continues to be a neglected topic in the chemistry curriculum, nothing more than a "laboratory" curiosity kept alive by isolated professors who occasionally interject historical anecdotes to maintain student interest. Constrained by the increasing "mass" of information from which to select course content, professors can rarely provide historical background and development and must relegate history to a brief mention that hopefully will be read by the students at a later time. The students are also constrained by the increasing mass of information coming from their professors and, therefore, ignore any suggested history readings unless they become part of the testing procedure. The result is an increasing number of historically "illiterate" scientists.

When the Chemistry Department at Wilkes College established its first 4-year curriculum in 1948, it also established a continuing commitment to the liberal arts tradition. Included in the requirements for all baccalaureate degree chemistry majors were two one-credit courses in the History of Chemistry and the Literature of Chemistry. Both of these courses were originally designed to provide the proper context for the technical content of the rest of the curriculum, and with slight modification they are still in existence. In 1970, the department, recognizing that the student work load in the Chemical Literature course had exceeded the normal load expected for a one-credit course, introduced a formal 3-h library "laboratory" and increased the credit loading by one credit. In 1979, utilizing the premise that a retrospective literature search is, in itself, an evaluative investigation of a small segment of chemical history, the department merged the two courses into a single three-credit course titled The History and Literature of Chemistry.

INFORMATION FLOW

Chemists have had a long tradition of providing "user education" for the wealth of existing library information, for they are only too aware that the library must be virtually as equal in importance as the laboratory. Thus, any experimental[5] investigator must be aware of the total flow of information that exists outside of the laboratory (Figure 1). In order to be productive, it is necessary to extract from the total "information flow" that portion which is of interest for the problem at hand. Current research is thus directly influenced by the literature "extraction" or survey, which is still part of the total information system but also enters the experimental process as well. When the original literature portion extracted from the "mainstream" is enhanced, modified, adjusted, corrected, or otherwise altered with new information obtained at the "cutting edge", it also enters the mainstream of information flow. Each small tributary of this kind also serves to increase the total volume of information available at a given time.

However, information flow is a dynamic process, and what is "current" today is but history tomorrow. As each laboratory feeds current information into the mainstream for use by others who are downstream, the identifying tag of "current" moves

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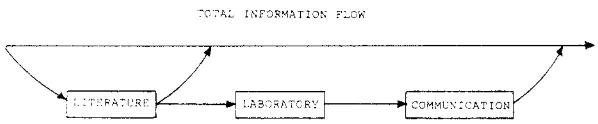

Figure 1. Schematic representation of "information flow".

downstream as well. In the expanded view of total information flow, the cyclic process of "literature extraction to laboratory work to information communication" is repeated many times but at any given instant can be separated into three sections (Figure 2).

From the viewpoint of the "current" research investigator, there must be an awareness that those involved in the "future" work may very well be extracting the current results for further scrutiny. In this sense, errors of omission or commission may not be immediately apparent but may become so in the next evaluation "downstream". In this respect, then, the communication of immediate results will be in the total information flow forever and are as good as being etched in stone.

While an author is obviously writing for the future, considerable attention must also be paid to the retrospective aspects of the work. Once research results appear in a communication and enter the mainstream of information flow, they automatically become history. Therefore, those who are "current" are, like Newton, "able to see further" only because they "are standing on the shoulders of giants".[6] Consequently, anyone who uses the chemical literature, whether it be specialist or novice, student or faculty, bench chemist or administrator, cannot escape the history of chemistry. They can, however, choose to ignore it.

HISTORY IN THE CHEMICAL LITERATURE COURSE

The problem of selecting or ignoring the history of chemistry is exemplified by the changing attitude of information specialists and the textbooks that have been written in the past 25 years (Figure 3). In 1957, the second edition of Crane, Patterson and Marr still continued to make specific mention of the historical aspects of periodicals, abstract services, books, and retrospective searches, emphasizing the importance of an understanding of science history in providing source material that would otherwise be difficult to locate.

In the years that followed, the newer texts continued to decrease their coverage of chemical history, brought about in part by a decline in courses offering formal training in the chemical literature and increasing economic pressures of the

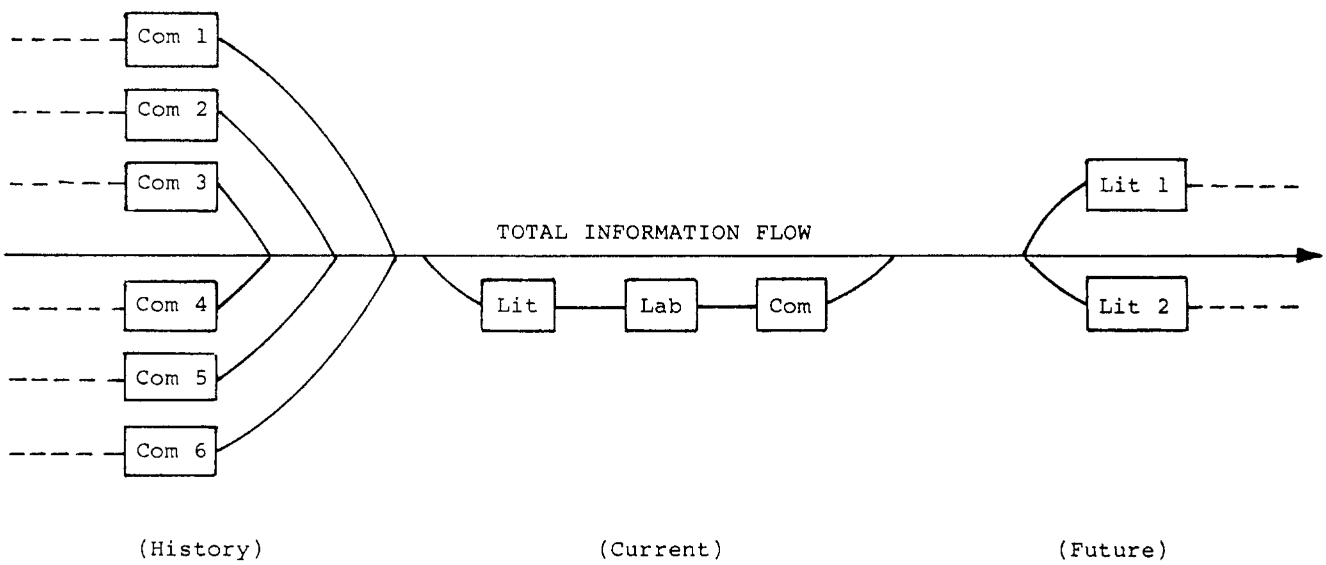

Figure 2. Expanded schematic representation of "information flow".

YEAR	AUTHOR(S)	COVERAGE OF HISTORY AND THE LITERATURE
1957	Crane, Patterson, Marr (2nd ed.) (Ref. 1)	Periodicals, Abstract Services, Books, Retrospective Searches
1965	Mellon(4th ed.) (Ref. 39)	Introduction, Periodical Lists, Patents, Search Procedures
1974	Woodburn (Ref. 40)	Line-formula Notation, Retrospective Searching (minimal)
1979	Bottle (3rd ed.) (Ref. 41)	Periodicals, Chapter on History and Biography of Chemistry
1979	Maizell (Ref. 42)	Patents (minimal)
1982	Skolnik (Ref. 14c)	Introduction, Books, Patents, Journals, Abstract Services, Evolution of the Literature, American Contributions
1982	Mellon (5th ed.) (Ref. 14d)	Introduction, Periodical Lists

Figure 3. Summary of chemical history in chemical literature texts.

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1. Obtain desired information efficiently,
   accurately

2. Historical curiosity

   a. Appreciation of the accomplishment
      of earlier workers

   b. Personalities of chemistry

   c. Correct vs. incorrect

   d. Major developmental phases

3. Retrospective searches as history

   a. Time-frame for searching

   b. Suggestions for source material

   c. Authors

   d. Sociological impact

4. Reading the original literature
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Figure 4. Course objectives for "The History and Literature of Chemistry".

publishing industry. Instead, the more scholarly works of an earlier time were replaced by manuals designed as guides for "practicing chemists, teachers, and students".

This "no-frills" approach was meant to be as practical as possible and to assist the individual to get in and out of the library quickly with just the facts needed, but frequently little else. This situation is compounded by the existence of information specialists who frequently insulate the bench chemist from the actual information tools. Consequently, the need to obtain a fact quickly and accurately, brought on by pressures of real or imagined deadlines, has continued to relegate historical aspects into obscurity.

Recently, this trend has been offset in the new book by Skolnik, who has proclaimed that "the study of history is more than just a luxury".[14c] But, why is the study of history more than just a luxury? What are the advantages to be gained by including the history of chemistry in the chemistry curriculum, and how can it possibly be included in a reasonable fashion when it is already impossible to fit everything into the available course time? Since the use of the chemical literature automatically leads to chemical history, the Chemical Literature course becomes a possible vehicle for presenting a unifying approach as opposed to dismemberment over several different courses. Some of the answers to these questions can be found in the course objectives that are listed in Figure 4.

COURSE OBJECTIVES

(1) Information Extraction. First, and foremost, of course, is the extraction of the desired information from the chemical information flow as quickly, efficiently, and accurately as possible. This objective can obviously be met by the "no-frills" approach as well, where the principal emphasis is on the nature and use of the source material in the chemical literature. This aspect will not be considered further here.[7]

(2) Historical Curiosity. The second major objective is the development in the student of an appreciation of our chemical heritage and the kindling of at least a spark of historical curiosity. Many students today continue a resistant attitude toward history that was produced at an earlier time in their education and frequently tend to believe that any information more than 10 years old is almost obsolete and therefore deserves little attention. They are encouraged in this mode of thinking when they turn to the current chemical data bases and find that the computer can only return to 1967! There are several different ways in which that attitude can be corrected.

Anyone who has read the older literature directly cannot help but be amazed at what was accomplished under what might now considered to be less than ideal conditions. Yet the apparently inferior equipment and incomplete theories of the past century will only be replaced during the next century by those we currently accept as valid and useful. After all, since double-beam spectrophotometers were being used as early as 1835, the current microprocessor-controlled instruments are simply the most recent in a long series of modifications of a concept established over 150 years ago.[8]

A second way of highlighting the chemical heritage is through an examination of personalities. Even freshman students can appreciate some information on Erlenmeyer, Bunsen, Gooch, and the elusive George Beaker. However, to know that Bunsen did not invent the Bunsen burner, or that Ludwig Boltzmann comitted suicide, or that Max Planck was found alone and destitute wandering the German countryside after World War II serves to bring lofty giants back down to normal proportions.[9] In addition, this kind of information creates an empathy between the student and that previously unknown personality whose name is attached to a mathematical equation, chemical process, theoretical interpretation, or experimental result. In many cases, it can also serve as a source of inspiration for struggling students to understand that many now famous chemical results were also the result of personal and professional struggles.

A study of personalities leads to a third aspect of the chemical heritage, for those concepts immortalized with an individual's name frequently did not occur without question and controversy. The refusal of John Dalton to accept H_2O as the formula of water, the refusal of Joseph Priestley to discard phlogiston, the refusal of the faculty at Uppsala to pay attention to the theory of ionization, and the complete disregard of Avogadro's hypothesis by the chemical community for more than 40 years provide important clues to the whole process of scientific discovery. The history of science is filled with similar examples of the reluctance of scientists to accept new scientific discoveries and concepts,[10] for it is only through the continual process of questioning which is the correct answer that the "truth" will finally emerge, only to be caught up in a new discussion, evaluation, and possible controversy at a later date.

It was just such a tortuous path that was followed by the development of chemistry, and the way is dotted by brilliant achievements and monumental failures. Thus, a review of the history of chemistry reveals several distinct stages over a period of centuries. A knowledge of these stages, coupled with the events and reasons that led from one to the other, emphasizes the dynamics of chemistry and the continual but gradual change that is imperceptible on the daily level but is quite obvious on a larger time frame.

(3) Retrospective Searches as History. Each of these aspects of the history of chemistry, utilized to ignite the historical interest in the chemical heritage, also plays an important part in a retrospective search of the chemical literature. While the individual using the "no-frills" approach may obtain the facts, there is also the nagging thought that regardless of how thorough and efficient the search was planned, there is still additional important information hiding somewhere in the literature. That concern can be minimized by utilizing a knowledge of the history of chemistry. In addition, the original search can also be enhanced with the same information.

For example, the establishment of a search profile is augmented considerably when the proper time frame is established. It would be impossible to appreciate this time frame without a sense of history—of an understanding of the people, the laboratories, and the equipment that were responsible for earlier developments. Armed with this kind of timing, and with only the briefest knowledge of major developments, it is possible to approximate the time sequence for even the most cursory search. Decreasing the amount of time required for searching is essential, and beginning with the proper core or time slot (which can later be followed by a time expansion if necessary) is much more reasonable than to blindly work backwards or forwards within a particular data base. In fact, accessing the correct data base is facilitated by a knowledge of the proper time frame.

From a knowledge of the personalities of chemistry, it is possible to use authors' names more efficiently in a search. This technique is frequently overlooked by students, but it can be very helpful in locating citations that may not be found otherwise. In addition, this kind of search can help to delineate when a major author has moved on to other topics and provides the possibility of obtaining information from letters, pamphlets, and other nonstandard publications.

The second most important aspect of establishing a search profile is the topic list. If the searcher is not aware of changes in nomenclature, major source material, or even the country of origin, then many useful citations may be missed. For example, the foreign language requirement for chemistry majors was generally predicated on the necessity to read the literature during a period when the center of chemistry resided in Europe. Many students who studied German were not appreciative of that requirement until they took a chemical literature course where they were confronted with the "foreign" literature. Not only were they then able to understand the chemistry, but they could also utilize the cultural background to establish new search topics. Such topics are also uncovered with an understanding of the changes in techniques, theories, and mannerisms that are reflected in the changing language of the indexer. The greatest challenge in the literature search is to understand exactly the language used by the indexer. Otherwise, the citations are, like misshelved library books, lost forever.

Finally, there is one more aspect of the historical approach that is often overlooked. The scientific discoveries of the past did not occur in a vacuum, but were in part the result of an environment controlled by political, philosophical, and sociological concepts, which may, in turn, have been affected by scientific changes and developments. It is important for the student who is now so willing to question past events to understand why DDT was originally hailed as an important discovery, why many scientists worked so willingly on the Manhattan project, why associates of the Curies considered it a sign of honor to display a radium burn, or why Henry Mosely did not refuse to serve his country in 1915. This kind of awareness of past events should produce a similar awareness of current work as well.[11]

(4) Reading the Original Literature. Since there are now bibliographies of bibliographies and reviews of reviews, it is rare that anyone returns to all of the original source material, relying instead on an earlier colleague to have performed that task. There are obvious practical reasons and time constraints to minimize that activity, but then there is also the real possibility that an error has been encoded into the literature along the way. For example, consider the fact that a particular technique is described in some detail in a textbook. Subsequent authors then cite the textbook as the source of this technique, without realizing that the original textbook's reference to this technique is a "private communication".[12] This problem of one author using another author's citations without verification is not uncommon. In a similar fashion, the meeting held at the Priestley House in 1874 has frequently been described as a meeting for the centennial of the discovery of oxygen. However, if the original literature of 1874 is examined, it becomes clear that the meeting was rather a centennial of the beginning of modern chemistry.[13] It is thus important that the student know how to access original literature outside of the *Chemical Abstracts* network, while also gaining experience in reading and evaluating older manuscripts in light of current theories and facts.

THE INDIRECT APPROACH

To achieve these goals, we have utilized the extra time made available with a three-credit course to introduce the history of chemistry in both a direct and an indirect manner. In the latter case, historical aspects are emphasized in most of the normal topics generally found in the standard course in chemical literature.

(1) The Library. The historical development of the written record in general and the evolvement of the vast array of chemical sources in particular is emphasized.[14] This is followed by a discussion of special libraries (such as the Chemists Club Library) and special collections (such as the Edgar Fahs Smith Collection).[15] From a historian's standpoint, many libraries are themselves repositories for original documentation, and there is a growing interest on the part of historians to move this documentation out of private hands and into the public domain. As a result, there is more information becoming available for the chemical historian and researcher.

(2) Primary Periodical Literature. There is probably no better place in which to integrate the history of chemistry than in the primary periodical literature. The development of the journal as the communication form of original research has been widely discussed by several authors.[16] While the lists of journals that generally are included in such discussions are not necessarily interesting reading, they do provide the necessary insight for an important part of retrospective searching. Skolnik's treatment is better than most, for he includes a substantial discussion of journal development, trends, and in-depth statistical analysis of rankings, languages, and influences.

Revealing the nature of the editorial process is usually a very enlightening experience for most students. Describing the methods for translating a manuscript into the finished product in the journal covers concepts most students have not even considered before. In addition, such information also provides the opportunity to show the changes in the editorial process over the years and how the function of the editor has changed.

Finally, the nature of the group responsible for publishing the journal provides ample opportunity to introduce the concept of scientific societies, their origin, history, function, and purpose.[17] At the same time, students can be urged to consider membership in a professional organization, thus enhancing their exposure to the profession at an early stage of development. In addition to academic, industrial, and governmental sponsors, the generally discontinued practice of privately printing lecture notes, speeches, and other miscellaneous communications in the 19th century is cited as a crucial source of information when historical background is required.

(3) Abstracts. The historical background in the formation of an abstract has been very carefully reviewed by Skolnik.[18] Discontinued abstracts are still of considerable interest since they provide entrance into the literature in a period when *Chemical Abstracts* was unavailable or incomplete. Further, since some abstracting services have been in existence for some time, it is imperative to understand the changes that have occurred if any search of that publication is to be useful. For example, in the 75-year history of *Chemical Abstracts*, there have been changes in indexing, coverage, format, and type of abstract.[19]

(4) Patents. A brief history of the evolution of the patent system has been given by Skolnik.[20] This history is a key to understanding the true meaning of a patent, the requirements for obtaining a patent, and the changes in patent law that are still continuing. Patent history also reflects the changes in the chemical industry and its services as the needs of the consumer changed with time.

(5) Secondary Sources. The development of the written record in book form has been traced back to 3600 B.C.[21] Within this general framework, the history of the development and production of such major compilations as the *Beilstein*[22] and *Gmelin*[23] handbooks provides considerable detail of the purpose and nature of such resource material. In addition, these compilations are themselves the source of much historical information on the discovery, identification, and characterization of innumerable elements and compounds. Modern production processes and the purpose of encyclopedic data bases in the computer age have been thoroughly discussed in a recent article on the "Kirk-Othmer Encyclopedia of Chemical Technology".[24]

(6) Nomenclature. Generations of chemists have been plagued by the difficulties encountered in the literature because of a lack of uniformity in the language used by a particular indexing system. Quite typically, the sometimes drastic transformations between the *8th* and *9th Collective Indexes* of *Chemical Abstracts* emphasize the need to understand these changes and the mechanism for locating them in a retrospective search. Otherwise, there could be little distinction between the unavailability of subject information and a change in its indexing.[25] There are many possibilities for classroom discussion, including the development of unambiguous descriptors for double-bond stereochemistry,[26] the current status of nomenclature in inorganic chemistry,[27] or a delightful description of how the term "ligand" became part of the chemical language.[28] On a higher level, we have also included an extensive analysis of the Wiswesser line notation (WLN) and the encoding and decoding of chemical structures. Even the history of the WLN is now available, and it is instructive for students to see the manner of thinking that originated the original concept, the modifications that have been made as the system expanded, and the challenges it faces in the future.[29]

THE DIRECT APPROACH

The continual emphasis on the history of chemistry in the chemical literature course is quite subtle in many respects and provides only selected glimpses into the development of the discipline. In order to provide students with the larger and more comprehensive view, it is also necessary to devote some class time to a more direct approach. This is readily accomplished by utilizing a modified version of the more detailed but now out of print Mallinckrodt Chart on the History of Chemistry[30] (Figure 5). From the ancient roots that have defined chemistry as the study of the composition and transformation of matter to the beginning of the modern era in 1774, the major periods are delineated by their characteristics, philosophies, and personalities. These changes can then be tied together by tracing how the concept of an element was also modified during the same time period.[31]

With the background in both the history and literature of chemistry now established, the last major topic is a discussion of the literature of the History of Chemistry. Only Bottle[32a] provides a chapter that directly lists source material in chemical history and provides a brief description of that history, although Skolnik does include an interesting blend of literature, text titles, and personalities in his chapter on the "Evolution of the Literature from Antiquity to the Early Twentieth Century".[32a,b] Consequently, the literature sources for extracting specific history are enumerated in the course and include biographies,[33] sources of original works,[34] and specific histories of science in general and chemistry in particular.[35] In addition, some of the more unconventional techniques and sources are also given, such as the location of manuscript collections, personal contact with descendants, students, and colleagues of a specific individual, reference librarians, and the identification of the most important journals during a specific time period.

Throughout all of these potential techniques, emphasis is placed on using one citation as the source of other citations, many of which would not otherwise be found by conventional means. A great deal of useful information is often buried in footnotes, and thus, students are warned to pay careful attention to these footnotes as useful leads to other sources, search topics, or additional help.

Finally, the student is urged to constantly be aware of the historical aspects in all of his reading. Since the period of "modern" chemistry now covers over 200 years and since many of the 20th century activities have been in existence for some time, there is more history continually being written. For example, the first footnote of most technical papers leads directly to a historical review of the topic. In addition, many anniversary celebrations, such as those of *Organic Reactions*,[36] *Chemical Abstracts*,[19] and the *Research Corporation*,[37] contain "in-house" information that will not otherwise be found in the literature.

In order to tie the literature and history combination together at the end of the semester, each student is required to present a special project, which of necessity calls on all of the course resources and techniques. While there are many possible types of projects that could be used, we have selected the investigation of a chemical personality as the format. There are many advantages to selecting this method as opposed to using periods of chemical development, name reactions, theoretical concepts, discovery of the elements, etc. First, there is an essentially endless list of topics that can be assigned, and thus, no two students will ever have the same report. Second, it is possible to assign names that have not already been thoroughly reported in the historical literature and yet are not too obscure to cause frustration in the literature search. Third, fulfilling the project assignment will generally require that the student utilize most of the various types of literature discussed in the course. Finally, it will be necessary for the students to do more than just collect facts; they will also have to be critical, evaluative, and creative.

The result becomes part of the on-going "Chemist of the Month" project, which has now been in existence for several years. The final student report includes four distinct items: (1) A minimum of a two-page biographical sketch that concentrates on the more personal details of the individual's life. (2) A biographical data sheet that includes the usual personal details such as professional affiliation, principle scientific accomplishments, awards, honors, obituary and biography references, picture and signature references, and references to a tombstone and monuments. (3) The design and preparation of a complete display which will remain on public view for one month. Within the minimum requirements of the brief biographical sketch and a picture, the student has complete freedom in the design and is encouraged to produce an attractive and informative display.[38] (4) A scientific "biographical" paper that is much more substantial than the personal biography and requires an analysis of the principle scientific accomplishments in view of the scientific "climate" during the individual's lifetime and with regard to current concepts.

We have also used a somewhat discarded educational technique—the field trip. While we are fortunate to be within an easy distance of several important historical locations, such

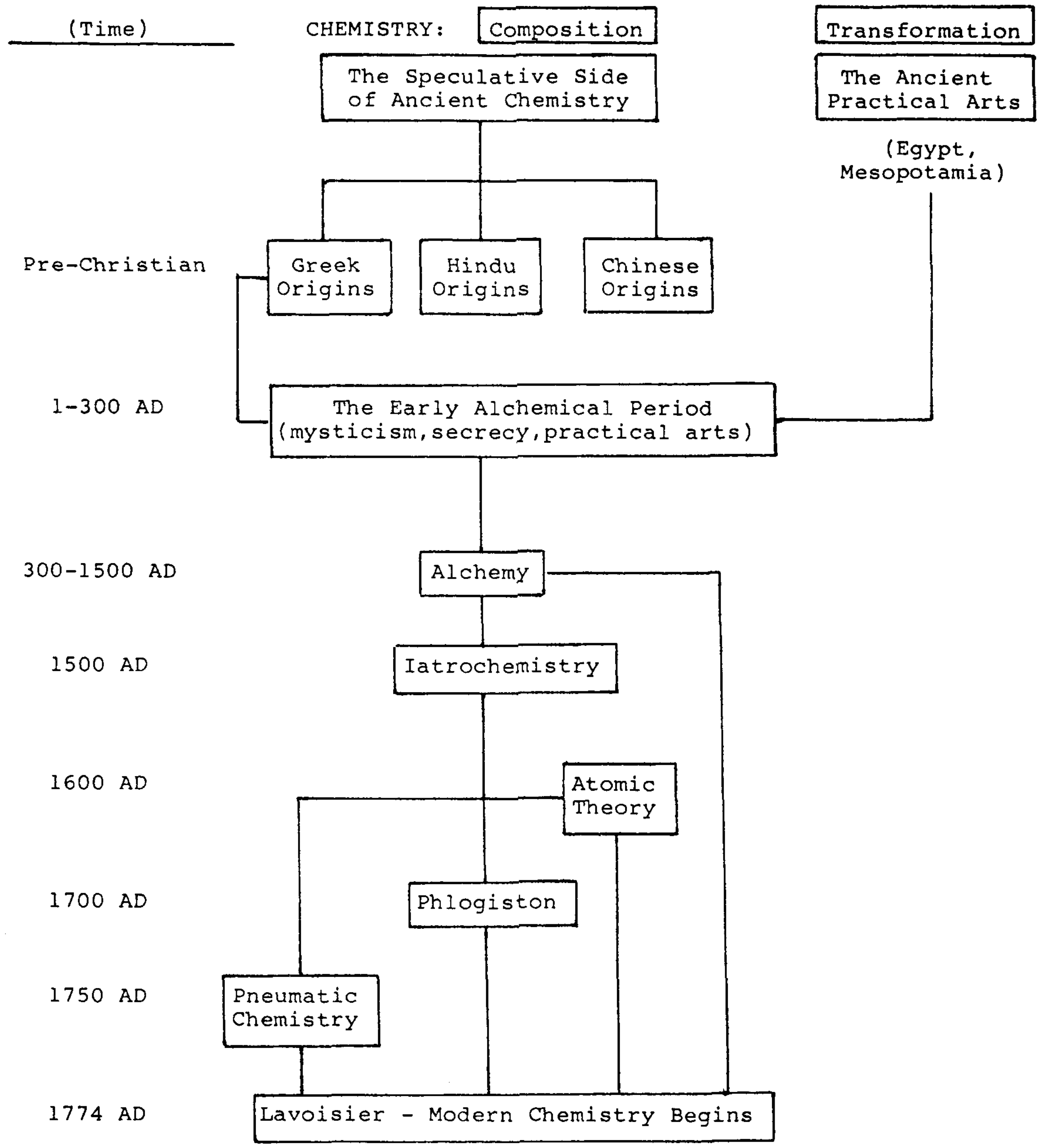

Figure 5. Brief outline of the early history of chemistry.

as the Priestley House, there are many aspects that can be combined on a successful field trip that are not specific historical sites. For example, one trip combined a visit to the Edgar Fahs Smith Collection and the library of a major industrial research laboratory. With proper advanced planning, we found both curators and reference librarians more than willing to share their facilities, their expertise, and their instructional abilities to present an extremely valuable experience. In addition to understanding more about other libraries (and perhaps gaining some appreciation about how good their own library might be), the students also had the opportunity to do some of their own library research with materials that were not available locally. The history of chemistry became exciting when they found that the alchemical book they were holding came from Issac Newton's personal library and contained his own hand-written marginal notes.

SUMMARY

When the course is completed, we have produced neither literature specialists or chemical historians, nor did we have that as our intention. As the course syllabus explains, "it is important that the serious chemistry student understand at least the rudiments of the origin of the discipline, for in doing so we avoid the reinvention of the wheel, and purposely climb on the shoulders of giants in order that we may see further". The combination of information tools and chemical history can be a potent one if the student takes advantage of it.

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(5) The term "experimental" does not necessarily imply a laboratory investigation but includes all those processes that require a knowledge of external occurrences and results.
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(13) For a recent analysis of the "Centennial of Chemistry" celebration at the Priestley House, see Bohning, J. J. "Opposition to the Formation of the American Chemical Society"; "Abstracts of Papers", 184th National Meeting of the American Chemical Society, Kansas City, MO, Sept 1982; HIST 008.

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(15) The Edgar Fahs Smith Collection at the University of Pennsylvania served as the nucleus for the creation of the Center for the History of Chemistry. See *CHOC News* **1982**, *1* (1), p 5.

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