II. UNDERGRADUATE CURRICULA

The 1970s brought three major changes in the undergraduate core curriculum, probably the greatest changes in Stanford's chemistry curriculum in the 20th century. They are considered as follows:

First--Revised core sequence of courses--the introduction of organic chemistry in the freshman year after one quarter of a chemical principles course.

Second--The introduction of qualitative organic analysis laboratory course for **all** chemistry students, not just chemistry majors.

Third--Dropping instrumental analysis course and incorporating the material in this course into the qualitative organic analysis and the physical chemistry laboratory courses.

We became aware in the early 1970s from conversations with students in the organic chemistry course that the biology students were studying structure and reactions of complex organic molecules, i.e. biochemistry, in their biology courses before the basis for these subjects had been taken up in the core chemical curriculum. This seemed to be a poor pedagogical arrangement. The biology department would not consider delaying study of biochemical material until the spring quarter of the sophomore year when the chemistry courses would have arrived at the relevant treatment of the organic chemistry pertaining to proteins, carbohydrates, heterocyclic compounds etc.

The only solution from chemistry's standpoint was the introduction of organic chemistry earlier, in the freshman year, which was a novel concept. Traditionally the freshman year course dealt with principles of chemistry, which covered the study of atomic and molecular structure, bonding, molecular spectra, thermochemistry, chemical equilibria and kinetics, acidity-basicity, pH, and molecular orbital theory. The new plan was to present in the first quarter of the freshman year an introductory basic course on the principles of chemistry, using **inorganic chemical** examples. This would then be followed by the winter and spring courses in **organic chemistry** based on the principles of structure and bonding, molecular spectra, equilibria, etc. In our discussions it was suggested that the teaching of organic chemistry could be started in the winter quarter of the freshman year and that we could introduce many of the same principles using organic rather than inorganic examples. This change, started in 1973 and phased in over a three-year period, was firmly established by 1976. The result was that one quarter of general chemistry (Chemical Principles 31) was taught in the autumn quarter of the freshman year, followed by Chemistry 33 (Structure and Reactivity which was the organic chemistry of functional groups) in the winter quarter and Chemistry 35 (Monofunctional organic compounds) in the spring quarter. It was recommended that only students with a good background in high school chemistry start this sequence in their freshman year.

In the autumn quarter of the second year, polyfunctional compounds of biochemical interest (amino acids and proteins, carbohydrates and other natural products including nucleic acids) were treated before the biochemical aspects of these compounds were taken up in the biology sequence.

The scheduling of organic chemistry into the freshman year turned out to be successful and probably enhanced the students' interest in chemistry because of the greater relevance of organic chemistry *versus* inorganic chemistry to the basic biological curricula.

Qualitative Organic Analysis Laboratory for All Chemistry Students

About the same time that the changes in the organic chemistry lecture courses were taking place, the students in the organic chemistry laboratory course, Chem 35, told us that the experiments they were doing had little or no relation to their projected careers in biology and medicine. They were bored and felt that they were spending time learning irrelevant techniques, such as the nitration of benzene to give nitrobenzene that was reduced to aniline that in turn was acetylated. Stanford is supposed to challenge students, not bore them. What organic laboratory chemistry experience should a biomedical student have? We certainly could not give them biochemical experiments that would not be in our purview or our expertise. It was suggested that what might be most valuable would be the ability to identify an unknown substance. For instance, confronted with a white powder that might be sugar, or salt or aspirin or cocaine, how could a doctor, or medical researcher, tell which it was? This is the subject of qualitative organic chemical analysis. A medical doctor might never be required to do such an identification, but should be familiar with the process used and have the basic understanding to evaluate the results.

As in biology, chemistry had undergone major changes. By the early 1970s the developments of automatic instruments for determining the infrared (IR) and nuclear magnetic resonance (NMR) spectra had brought about a revolution in the procedures, greatly simplifying the identification of organic compounds. These instruments were being used routinely in research laboratories and some of the basic theory was being taught in our organic chemistry lecture courses. Most of our organic graduate students were familiar with these techniques from their own Ph.D. research projects. If we could utilize these methods in a course for all the organic laboratory students, it might be possible to teach the course to the large number of students involved in the time allotted. It would certainly challenge our students with the chemical laboratory science as it was practiced in the real world.

To teach such a course to a <u>large</u> number of students who were not chemistry majors, was a revolutionary suggestion at that time. Almost every chemistry major will tell you that qualitative organic analysis was the course where he or she really learned what organic chemistry was all about. He or she will also, in the same breath, tell you it was one of the most difficult lab courses taken. The prospects of teaching such a course to 300-400 students were so staggering, that the suggestion seemed impractical. Since we were already teaching a similar course to the chemistry majors in a class of about 15 students, we well knew the logistical problems involved and the difficulties our chemistry majors had with this kind of course. Could we give such a course to the large number of non-chemistry majors without initiating a rebellion? Extrapolating from a class of 15 students to 20 sections with 20 students in each, indicated an undertaking of major proportions. In our Qualitative Organic Lab for chemistry majors, each student received three unknown samples to identify--two samples of one pure compound and a third sample which was a mixture of three compounds, (the components of which had to be separated before they could be identified). If we were to base the large course for all the organic chemistry students on the same number of unknowns, we would need to pass out approximately 1200 vials, properly coded and arranged in groups of appropriately diverse compound types. Since we had only about 200-300 suitable pure organic compounds in our stockroom, there would be duplication in unknowns given to students, necessitating a complicated coding system. We could certainly anticipate that students in living groups would accumulate files with code numbers and correct answers over the years. The physical arrangements required of such an enterprise were daunting. If there were a major foul-up, the resulting chaos would haunt the Department for many years. Finally we agreed that, even considering all the problems, this proposed course would be best for the students' education and we should institute the change. It was not impossible, only difficult.

There was no obvious way to phase in such a course gradually. It was first given in the autumn of 1975 in the large second-floor laboratory in the old Main Chemistry Building. Although the stock room for all the laboratory classes was on the first floor, the room for solutions and unknown samples was in the basement. Since there was no elevator, the mechanics for operating the laboratory were awkward. In recognizing these problems, we did gain experience which was valuable in planning laboratories and support facilities for the new S.G. Mudd Chemistry Building to accommodate the many requirements of this course, including 1) an office for a director or manager of the undergraduate teaching laboratories, 2) facilities for the washing of lab glassware by staff using commercial dish-washing equipment, 3) separate room(s) near the laboratory for infrared spectrograph and gas chromatograph, 4) secure separate room for storage of organic chemicals used as unknowns, 5) room to serve as office, storage and laboratory preparation room for an individual in charge of stocking undergraduate labs. It was planned that all of these, with about eight, 20-student laboratories would occupy the second floor of the new S.G. Mudd Building.

The course as given that first year certainly had some rough spots. With only two laboratory sessions a week, most students did not have enough time to identify all their unknowns, although they were supplied with the nuclear magnetic resonance spectra (after taking the IR spectra and correctly classifying each of their unknowns). We had underestimated the difficulty of the course. It was also apparent that the cadre of ten or more graduate teaching assistants needed additional special instruction in guiding the students in interpreting their data. Certainly the students were not bored! The use of the Chemistry Library rose dramatically in the quarters when this course was given; this was gratifying, as was a student’s sense of accomplishment when he or she was successful in identifying an unknown.

It should be added here that the technique involved in taking an infrared spectrum was easily mastered by the students. The Perkin-Elmer instrument in l976 cost about $6,000 and several were available in the department. By 1989 in the S.G. Mudd Building, the students were using several Varian FT-IR (Fourier Transform Infrared) instruments, which cost about $12,000 each and were much faster than the older Perkin-Elmer instruments. In the small class for the Qualitative Organic Analysis course for the chemistry majors the students could be taught to take their own NMR spectra; however, the techniques were too specialized, varied and time consuming and the cost of the instrument (about $200,000) such that this was impractical for the large number of students. Therefore it was necessary for us to supply the NMR spectrum to each student in this large class.

Lectures were given on the interpretation of IR and NMR spectra in connection with this laboratory course instead of in the regular organic chemistry lecture course; this saved time in the latter, which was appreciated. An extra unit of credit was assigned to the laboratory course. The students were motivated to learn the theory and rules for interpreting the spectra of their unknowns, which was a great improvement over memorizing rules as a sterile paper exercise.

An innovation that was initiated when we moved from the old Main Chemistry to the S.G. Mudd Building was the washing of dirty glassware for the students. In the standard old system, each student was assigned a desk equipped with the glassware and hardware required in the course. Thus most of the time of the first class was consumed in “checking in” and the last class session in “checking out”, a waste of about 10% of laboratory time on a totally non-educational exercise. After all, students didn't come to Stanford to learn how to wash dirty laboratory glassware. In the laboratories in the new building, the students were assigned desks but the required clean glassware was available in open bins along one side of the room, for them to pick up as needed. At the end of each period, dirty glassware was placed in trays and then washed in commercial dishwashers in the staff-run facility. The concern that breakage would be much higher was unfounded and two laboratory periods for productive work had been added to the quarter.

These course changes were not without problems and they did create a controversy amongst some of the students as shown by the following article that appeared in the

Stanford Daily, Jan. 25, 1977: **"Pre-meds Air Gripes about Chem. Series**...a reexamination of the Organic Chemistry series is being called for in petition (250 signatures) which was being circulated through chemistry and biology classes last week." This petition called for "constructive changes that need to be made in the Organic Chemistry series.......the laboratories were singled out as the weakest link in the organic chain....The Chem.132 lab is under a very tight time schedule; if something goes wrong you are out of luck......The Physics and Biology Departments used to be as bad as Chemistry but they have improved. The Bio labs are now Pass/Fail, very low key and very good as a result." The main petitioner took exception to the Daily article and wrote a rebuttal "To the Editors" that was published in a subsequent issue clarifying his position. A few quotes from this later communication characterized the first article as "well-intentioned but an inept attempt to delineate the position of those students seeking reforming of the chemistry series....We are not asking that the organic chemistry courses be made easier. Organic chemistry is a difficult and tedious subject.... We are simply saying that it is capable of being taught more effectively.....The major complaint is that students are completing the organic chemistry series without learning chemistry.......The primary difficulty lies in the Chemistry Department's conception of the organic chem series as little more than an early selection process for medical students.....laboratory courses are poorly taught, poorly examined and unnecessarily high pressured."

These discussions in the Stanford Daily did get the attention of the Chemistry faculty involved in the organic sequence. In the first years of the Qualitative Organic Analysis course we underestimated the time that the course would require and the ability of non-majors to tackle successfully the basic problem-solving nature of the course. When we moved from the old Main Chemistry into the new S G. Mudd Building, it had been decided that one faculty member alone could not be expected to handle this course and that we needed an additional staff member who would be the full-time Director of Undergraduate Laboratories, in charge of scheduling the many different laboratory classes, the scheduling and supervision of the teaching assistants, ordering of laboratory supplies and overseeing services such as glassware cleaning etc. One of the applicants for this new position was Dr. James LuValle, who had been Director of the Research Laboratories of Smith-Corona Merchant located in the Stanford Industrial Park. Because

SCM was moving its laboratories to Chicago, and because he had bought a home in Palo Alto, he was not interested in moving. We were pleased when he accepted the position as Director of Undergraduate Laboratories although he certainly was over-qualified. Dr. LuValle earned his B.S. (1936) and M.S. (1938) degrees from UCLA and his Ph. D. degree from Cal. Tech. in Chemistry and Mathematics (1941) with Prof. Linus Pauling as his major professor. When Dr. LuValle retired as the first Director of the Undergraduate Laboratories in 1982, he was succeeded by Dr. Kirk Roberts (1982-92) and then by Dr. Sharon Brauman (1992-).

As a result of our experiences in the first few years, some course details were changed. It was changed from a three- to a four-unit course to compensate for the large amount of library work required outside of the laboratory and lectures. The course has been greatly refined but remains with essentially the same format. The unknown compounds have been sorted by actual student tests; we know that they can be solved in reasonable times by the majority of students.

This course has been a source of satisfaction for most of the students who feel that they have developed a first-hand understanding of organic chemistry and the properties of organic compounds. Few students have complained that they weren't learning anything useful or were wasting their time. During the period 1975-80, major changes in the teaching of chemistry were made, Stanford responding in the educational forefront.

Quantitative and Instrumental Analyses

With analysis at the heart of most experimental branches of chemistry, the situation with respect to teaching analytical chemistry has also evolved drastically with time. For example, when the Main Chemistry building was constructed in 1900, a separate one-story sandstone building with a basement was built directly behind the Chemistry building. Originally it was referred to as the Assay laboratory but was known as the Chemical Engineering building by about 1950. The importance of assaying ores in the early days of California's gold rush explains the construction of a separate building for the teaching of this branch of quantitative analytical chemistry; many mineral assay methods required heating crucibles to very high temperatures, best done in a building set apart because of heightened fire danger. The U.S. government operated an official assay office in San Francisco on Gold St (between Jackson and Pacific Avenues), now marked by a brass plaque. The <u>Courses and Degrees</u> Stanford catalog carried announcements of a course in mineral assays from 1900 to 1912 ("4 afternoons a week for students who wanted to become assayers"). The old assay laboratory was demolished in 1962 when Stauffer III was built to house Chemical Engineering. Santa Clara County code would not permit the two buildings to be so close, which explains the broad lawn area that currently exists between the old Main Chemistry and the Stauffer buildings.

In a totally different way, the teaching of analytical chemistry was undergoing major changes in the mid 1970s, triggered by the emergence of new instruments and methods of analysis which were replacing the classical wet chemical methods. As an example, one of the initiation rites for a chemistry major in the 1930-40s was learning the meticulous techniques required for precisely weighing a sample on a classical double pan balance. With the new electrobalances, the sample is placed on a single pan and a digital read-out gives the weight with a precision commensurate with the qualities of the balance being used, a procedure that requires no special talents or learning. A single old, elegantly encased, double pan balance is now relegated to an antique showcase in the S.G. Mudd Lobby.

Most of these new analytical methods use an instrument based on advanced spectroscopic measurements or other physical properties and the signal is processed electronically. The data appear as a number on a dial or as a generated graph or an LCD (liquid crystal display). The theory behind the instrumental methods involves sophisticated principles and mathematical analysis of signals which call for more advanced treatment than was envisioned even a few years earlier. Where should such a course fit in the regular chemistry curricula?

At Stanford it was decided to no longer offer a separate course in instrumental analysis. Instead, the subject was to be treated throughout several courses as it came up in terms of practical applications. Some basic principles of quantitative analysis are taught in Chem 134, Theory and Practice of Quantitative Chemistry; the use of IR and NMR instruments and the interpretation of these spectra are covered in Chem 132, Qualitative Organic Analysis. In the Physical Chemistry Laboratory (Chem 174) many more instruments are routinely being used in analytical measurements. The theory and practice of these instruments are considered as they are introduced in the physical chemistry measurements laboratory.

A complicating aspect of the teaching of analytical chemistry was that Prof. Skoog, who had been the Associate Head of Chemistry, decided to retire early in 1976. He was the only designated analytical chemist on our faculty at that time. He had written, with Prof. D. West of San Jose State University, two widely used, successful texts for courses in quantitative analysis--one, a short course for premedical students and the second, a complete text for chemistry majors. He wanted to spend time writing a text on The Principles of Instrumental Analysis, which he did; it became the premier text in this field, a position it has retained with several revisions, into the twenty-first century.

The American Chemical Society has a program for certifying chemistry graduates who complete an approved program from a college or university that is on the ACS list of approved schools. This program is monitored by their Committee on Professional Training (CPT). A department that wants to be on the list first goes through an approval process and then sends in annual reports to maintain an approved status with a major review every five years. It was not long before CPT noticed that Stanford no longer had a bona fide analytical chemist on the faculty. They also interpreted our placement of the undergraduate organic chemistry sequence in the freshman year as an indication that we were over-emphasizing organic chemistry at the expense of analytical and inorganic chemistry. At a CPT meeting in Atlanta (April 1981) Prof. Mosher discussed the Stanford program and explained in more detail how the subject of instrumental analysis was being treated in the qualitative organic analysis and the physical chemistry laboratory courses and defended the emphasis on organic chemistry by the student composition of the course---more than 80% were biologically oriented students receiving instruction in biochemical subjects at the same time they were taking their organic chemistry course.

Objections were made by the committee that this still probably was not adequate. There was a feeling that the major universities, including Stanford, were arrogant in presuming to know more than CPT about how to educate the undergraduate chemistry majors. Furthermore, if a Stanford, Harvard, or MIT could deviate so drastically from the CPT approved and recommended criteria, how could CPT maintain the stated minimum standards? Further explanation and correspondence led to additional consideration by the

CPT and in the spring of 1983, Profs. Brauman and Ross again met with CPT; as a result they received a very encouraging letter indicating "approval of your program". This led Prof. Brauman to send a memo to the Dean of Humanities and Sciences (April 15, 1983)---- "As you can see by the enclosed we have done well in persuading the American Chemical Society that we should lead and not follow.......you should be aware, however, that there is a strong feeling there, as well as at Stanford, that our laboratory programs need to be enhanced........these improvements will probably require an increase in teaching assistants and laboratory".

This optimism was premature. On behalf of the ACS's Committee on Professional Training, Prof Harry Pardue, an analytical chemist from Purdue University, visited Stanford for an on-site inspection and conferences with faculty concerned with undergraduate teaching. After CPT met again to discuss Stanford's compliance with the CPT guidelines, a letter was sent to President Donald Kennedy with copies to the Chemistry Department that said in part: "If your department does not change its program, the ACS must put you on probation; if you wish to remain on the ACS approved list, the Committee would like to discuss with you possible solutions to the problems that it sees in your program." The letter was accompanied by fully detailed reports by CPT and by Prof. Harry Pardue.

As a result, the Department's curriculum committee with Prof. Wray Huestis as chairperson held many meetings; in 1985, an extensive proposed revamping of the undergraduate curriculum was developed. The proposed changes included reinstituting a course in instrumental analysis (Chem 172, 3 units of laboratory) and installing a new course in advanced inorganic chemistry (Chem 152, 3 units of laboratory). With these changes the curriculum would meet the ACS recommendation for more laboratory hours and more inorganic chemistry. When submitted to CPT, they responded ---"(We) are pleased to inform you that the Committee concluded that your program continues to meet the guidelines that have been established for ACS approved schools. The Committee would like to commend you for your efforts in upgrading your program with respect to analytical and inorganic chemistry." The story of Stanford's being on the probation list of the ACS's CPT was thus over with no further adverse reaction concerning our program.

The Courses and Degrees Catalog for 1987-88 listed Instrumental Analysis (Chem 172), however it disappeared from the catalog in 1990.

A new appointment to the faculty vacancy in analytical chemistry was never made. In recruiting new faculty it seemed that the best and brightest young chemists were not attracted to this special branch of chemistry. As a result, without a designated analytical chemist on our faculty, the assignment of teaching the quantitative analysis course for chemistry majors (Chem 134, Theory and Practice of Quantitative Analysis) fell to the lot of the newer assistant professors in physical chemistry in the period 1976-1998. Both Profs. Harden McConnell and Richard Zare are renowned physical chemists who have made major research contributions of new methods and techniques to the frontiers of analytical chemistry, but neither is considered a classical analytical chemist. Professor Zare won the ACS Award in Analytical Chemistry in 1998. He took over the teaching of Chem 134 in 1999.

Special Non-required Chemistry Courses

In 1996-97, the University inaugurated a new series of optional 2- to 3-unit freshman courses under the general title of "Introductory Seminars". The basic idea was "to give freshmen an opportunity to experience lectures by Stanford professors, on topics of special and current interests that were not part of the regular core curricula but would give an insight into the frontiers of thought and research going on in the world today." Professors were invited to submit proposals for such a course that they would be prepared to give. Following is a list of such chemistry-sponsored courses, "Stanford Introductory Seminars", for the period 1996-2000 which were accepted into this program.

Chem 21N. "Tactics and Strategies of Science", Prof. Ross

Chem 22N. "The Frontiers of Science", Prof. Collman

Chem 23N. "Chemistry and Biology", Prof. Khosla

Chem 24N. "Nutrition and History", Prof. Huestis

Chem 25N. "Science in Fiction is Not Science Fiction", Prof. Djerassi

Chem 26N. "Macromolecules--Is Bigger Better?", Prof. Waymouth

It has so evolved that freshmen, mostly Biology or Human Biology majors (pre-medical students), entering Stanford who want to take chemistry courses, have the choice of two beginning courses, in addition to the "Introductory Seminars" described above.

1. In 1992, Profs. Collman and Zare perceived that there were many talented first year students taking Chem 31who were not challenged by the course because their high school honors chemistry training had covered the same subjects. Accordingly they introduced a new course, Chem 32 “Frontiers of Chemical Science”, to accommodate these students which would also fulfill the requirement for Chem 31. In spite of its advanced and challenging nature, in 1999-2000 there were about 90 freshman students enrolled in Chem 32.

2. Prof. Djerassi taught a course, generally in alternate years in the Human Biology sequence, Bio 130 “Biological Aspects of Birth Control”. It was an advanced course, also listed under chemistry courses, which involved student participation in an international study with students' first hand reports from summer assignments in various countries. This course was first given in 1972, but was discontinued in 1999.