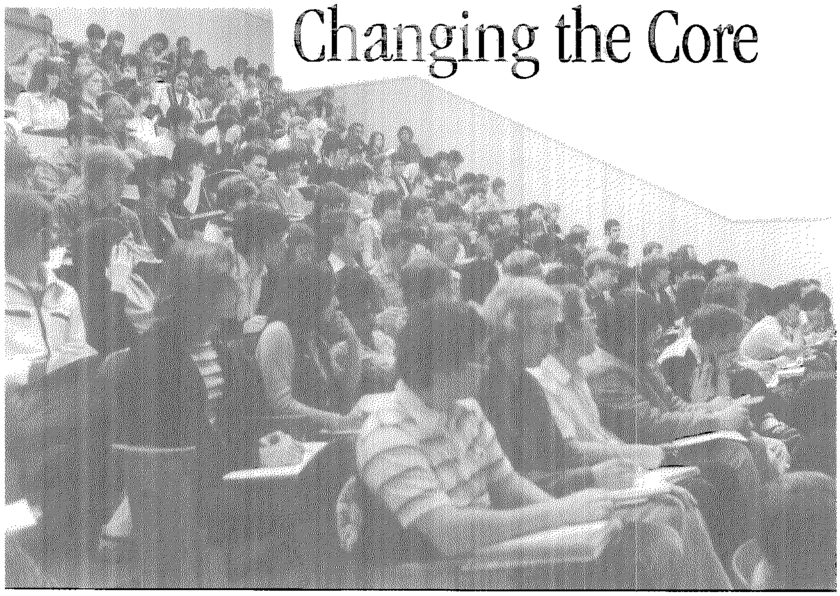
Changing the Core



by David J. Stevenson

Freshman physics in 201 East Bridge in 1980.

"If a man does not learn his physics, chemistry, and mathematics in college, he never learns it."

Among the distinctive features of Caltech is one that its alumni and students know all too well: the demanding set of math and science courses that all Caltech undergraduates since the 1920s have taken in their first two years. This set of courses, known as the core curriculum, or simply the core, is going to change beginning with the next freshman class—fittingly the class of 2000.

The modern Caltech, which began in the 1920s with the arrival of Robert A. Millikan, emphasized from the outset a rigorous training in basic science and math. Millikan himself told a Caltech audience in 1920: "If a man does not learn his physics, chemistry, and mathematics in college, he never learns it." Consequently, the 1920–21 course catalog articulated that "a thorough training in mathematics, physics, and chemistry must precede the application" of other sciences (which were thought of then as engineering and applied science), and, therefore that, "the first two years are given over to a common training." Also in 1921, the Board of Trustees stated our educational mission as being "to train the creative type of scientist or engineer urgently needed in our educational, governmental and industrial development." For the most part, this mission seems as appropriate now as then, although some might hesitate to embrace the sentiment behind the phrase "governmental and industrial development," given the current concern about limits to growth in those areas.

Certainly, the need for creative scientists and engineers is as great now as ever. The world, however, has changed immensely in the past 70 years, many of the changes occurring in just the recent decades. The scientific enterprise has grown enormously, driven in substantial part by the technological needs of the Second World War and later conflicts, including the Cold War—the need for nuclear weapons, radar, and jet aircraft, for example. During this period, physics was in the ascendancy, but more recently we have seen the explosive development and increasing importance of biological science, and the growing recognition of environmental issues, which dominate so many of the world's science policy decisions. Although Caltech has not grown very much, alumni and faculty have participated considerably in these changes. But has the core curriculum kept pace?

The current core consists of two years each of math and physics and one year of chemistry, pretty much what it was in Millikan's day. There is no required biology, earth science, or astronomy. Actually, Caltech did require courses in geology in the forties, and some options continued to require geology and biology for some time, but the trend in the last few decades has been toward fewer requirements and a more flexible curriculum. It is possible for a student to graduate from Caltech knowing little or nothing about biology, the area that now occupies more of the global scientific community than all other areas combined. The biology that students encounter in high school is highly variable but often conveys little of the intellectual groundings of modern biology, including molecular biology. Many students also encounter little or no earth science and environmental science in

ALL COURSES

FIRST YEAR

For Classes Entering September, 1922, and Thereafter

SUBJECTS	Subject Number	Hours per Week			Units
		Class	Lab.	Prep.	
I. FRESHMAN YEAR					
REQUIRED (Throughout the Year)					
Physics	401-403	2	4	3	9
Chemistry	301,302 311	3	6	3	12
Mathematics	453-456	3	0	6	9
English and History	601-603	3	0	6	9
Orientation	771-773	1	0	1	2
Drawing	701-703	0	6	0	6
Physical Education	....	0	3	0	3
Military Science	781-783	1	2	1	4
Shop Work[1]	741-744	0	4	0	4

Although "thereafter" sounds ominous, clearly the core has been tinkered with since Millikan first decreed it in this course catalog (*Bulletin*) of December 1920. Modern students are at least spared orientation, drawing, military science, and shop work.

high school and have little notion about the quantitative and intellectual basis of these areas of science.

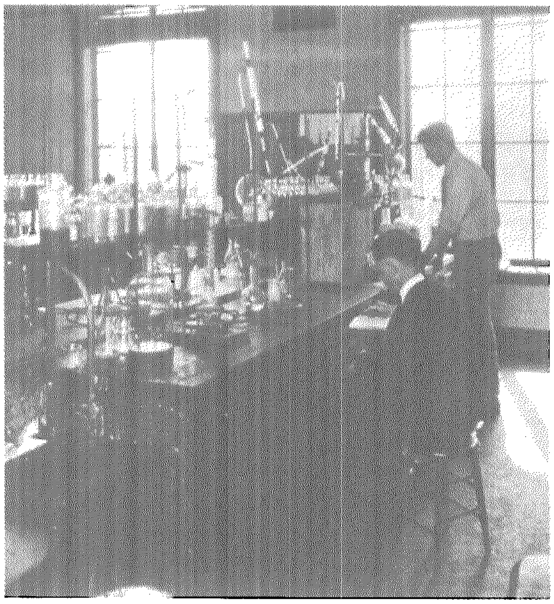
Important features are shared by many of the sciences outside the current core: they make a practical application of the basic sciences; they deal with complex systems; they require skills and ways of thinking that may not be evident or strongly encouraged in the current core; and they are frequently information-rich, or at least deal with large amounts of data from which one must extract information. Physics, for example, seeks to identify a small number of laws whose operation can often be exemplified in just small amounts of well-chosen data. Biology and astronomy, on the other hand, are examples of sciences that often seem to make sense of very large amounts of data, which the computer revolution has now made it possible to process. It is important in today's world for a well-educated scientist to be aware of the issues and approaches of these other areas of science, even though they may continue to choose to be an electrical engineer or a physicist. This is necessary simply to be scientifically and technologically literate.

Caltech faculty, like Caltech students, do not have a monolithic view of what the core should contain and accomplish. Certainly the current core is strongly oriented toward the acquisition of tools, and the large enrollments in de facto core courses in computer science and applied mathematics shows that there is widespread acceptance of the importance of basic tools, no matter which option is chosen. It is also widely accepted that the existing basic physics, math, and chemistry courses have served our students well. The challenge, then, is to find a balance between an existing core that still seems to work, and the desire to introduce elements of other sciences, without imposing too many requirements on the students. Core curriculum reform is also needed to address shortcomings in the coordination or coherence of current core courses, and to consider new ways of teaching science and of improving the ability of students to communicate their science to others.

The daunting process of changing a 70-year-old tradition has not been undertaken lightly. It began in 1992, with the Academic Policies Committee, chaired by Professor of Aeronautics Tony Leonard. The committee, which included students and which sought input from students and alumni, had by the end of 1993 distilled the diversity of opinion into three basic views. About the only thing those views had in common was to leave the humanities and social science requirement untouched (which would have pleased Millikan, who had insisted on it in the first place). One of the viewpoints held that the status quo worked just fine, and minor tinkering would bring it up to date. The second, dubbed the "minimalist" view, wanted the smallest possible core, arguing that the individual options had the best understanding of what their students needed, and that there was little need for a common core for all students, irrespective of option. The third, labeled the "fundamentals" approach, thought that the core curriculum should provide a broad education that would allow students to address the complex, interdisciplinary issues that today's scientists and engineers must learn to deal with.

Faculty Board meetings in early 1994 were devoted to what the minutes describe as "lively and fruitful discussions," during which proponents of the two more revolutionary proposals argued passionately in favor of their views. Ultimately, a proposal based on the fundamentals approach won out, but in deference to the strong sentiment against increasing the size of the core, it was agreed that the total units of the core would stay the same.

The Academic Policies Committee also submitted a number of related proposals to the Faculty Board; the one that received strongest support proposed placing the core curriculum firmly in the hands of the Institute faculty at large rather than in the hands of the individual options. This is consistent with the "fundamentals" approach. It means that the content of the core mathematics courses will not be solely determined by the traditional instructors of those



Chemistry lab in 1923.

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courses (primarily pure mathematicians), or the physics courses by the physicists or the chemistry courses by the chemists. This decision required setting up a group—now called the Core Curriculum Council—to oversee the core, decide on its content, and select the best instructors for the courses.

In 1994–95, a task force cochaired by Harry Gray (the Beckman Professor of Chemistry and director of the Beckman Institute) and David Goodstein (professor of physics and applied physics, the Gilloon Distinguished Teaching and Service Professor, and vice provost) proposed changing from pass/fail to letter grades in the third term of the freshman year. The pass/fail system for freshmen did not begin in the ancient past with Millikan, but had been instituted in 1966–67 on an experimental basis, which lengthened into a 30-year tradition. The philosophy behind pass/fail was to instill in students the importance of their first-year work, while still providing them with the opportunity to settle into an environment that is vastly different from that of their high school. The change to letter grades for the third term of the freshman year has already been implemented for the current class, but it is too soon to know the full consequences. The Gray-Goodstein task force also suggested some specific ideas about how the core curriculum should change—reducing core physics by 9 units (from 54 to 45), math by 9 units (from 54 to 45), and chemistry by 3 units (from 24 to 21, 6 of which are required freshman lab), thus freeing up 21 units and providing the opportunity to insert some new courses. These new courses, in areas such as biology and earth science, are often referred to as menu courses, since it is likely that there will be some limited choice available to the students as to which ones they will take.

The basic structure of this proposal was accepted by the faculty, and the implementation was left to the Core Curriculum Council, which I currently chair. This council has about 30 members, including the current instructors of core courses and four students. Since a committee of 30 would be too unwieldy to get much done, we also have a steering committee, which will be doing the bulk of the work of defining the new curriculum and will use the larger council as a sounding board and source of advice. The current steering committee membership is Jacqueline Barton (professor of chemistry), Roger Blandford (Tolman Professor of Theoretical Astrophysics), Charles Brokaw (professor of biology), David Goodwin (associate professor of mechanical engineering and applied physics); Richard McKelvey (professor of political science), Barry Simon (IBM Professor of Mathematics and Theoretical Physics), two student members, Stephanie Haussmann and Alison Slemp (both of whom are seniors in biology), and Tony Leonard and myself.

Before defining the new menu courses, the steering committee had to figure out when to schedule them. Should they show up in the third term of the freshman year or first term of the sophomore year or even later? To the extent that they may serve to guide students in their choice of options, an early scheduling is preferable. On the other hand, the basic tools in math, physics, and chemistry also need to be properly covered. So, first the committee had to decide on how to structure and modify the existing math, physics, and chemistry requirements to fit into their new reduced number of units.

The proposed implementation is still under discussion, but the following less controversial aspects appear to have wide support: first-year math and physics will probably continue to occupy all three terms; the contraction in math and physics will likely occur in the third term of the sophomore year, and will be accomplished by the judicious removal of particular topics scattered throughout the current syllabi, rather than by wholesale amputation, or by speeding up the delivery of material; all students will be required to take two new courses in areas of science that are not currently part of the core, and these new courses will be offered in the third term of the sophomore year. Because there will no longer be a required chemistry class third term, it will be possible for students to take both new courses in

Although nothing is yet set in stone, here is an example of what a schedule under the new core might look like, compared to the current one. The net increase in the freshman year is three units in both the second and third term. Since most students do actually take 45 units or more, this is not out of line, although it does reduce flexibility.
*Refers to all noncore science courses, whether electives or option requirements.
**The introductory computer science course is not required in the current core, but almost everyone takes it anyway.
•If the menu course (e.g. astronomy or Earth and environment) was not taken freshman year.

FRESHMAN YEAR

Current		Proposed	
First Term		**First Term**	
Ma1a	9	Ma1a	9
Ph1a	9	Ph1a	9
Ch1a	6	Ch1a	6
CS1**	6	CS1**	6
HSS	9	HSS	9
PE	3	PE	3
	42		42
Second Term		**Second Term**	
Ma1b	9	Ma1b	9
Ph1b	9	Ph1b	9
Ch1b	6	Ch1b	9
HSS	9	HSS	9
Chem3a	6	Chem3a	6
PE	3	PE	3
	42		45
Third Term		**Third Term**	
Ma1c	9	Ma1c	9
Ph1c	9	Ph1c	9
Ch1c	6	Bi1	9
HSS	9	HSS	9
Elective	6 or 9	Elective or menu	6 or 9
PE	3	PE	3
	42 or 45		45 or 48

SOPHOMORE YEAR

Current		Proposed	
First Term		**First Term**	
Ma2a	9	Ma2a	9
Ph2	9	Ph2a	9
Science*	18	Science*	18
HSS	9	HSS	9
	45		45
Second Term		**Second Term**	
Ma2b	9	Ma2b	9
Ph2b	9	Ph2b	9
Science*	18	Science*	18
HSS	9	HSS	9
	45		45
Third Term		**Third Term**	
Ma2c	9	Science*	27 to 36
Ph2c	9	Menu Course•	9 or 0
Science*	18	HSS	9
HSS	9		45
	45		

their freshman year or one in each of their first two years. The structure of the menu is, of course, a very important issue and is still being debated. Should biology be required? Some have argued that the best way to succeed with the menu is to provide choices but put much effort into assuring that the choices are so enticing that the goals are accomplished without coercion. Others say that biology is so important and ties in so well with the (now shrunken) chemistry core that it ought to be required. The current proposal under consideration includes biology as a required course in the third quarter of the freshman year.

There are still other aspects of core curriculum reform that have not yet been discussed by the committee at length. We hope to introduce a short course on science communication for all students. We also hope to be able to to introduce innovative approaches to teaching, both in the classroom and through utilizing material available on the World Wide Web. Perhaps the new structure will also encourage greater interplay between the sciences than is currently evident—for example, the use of biological and chemical examples in the teaching of basic physics. Last but not least, we hope to draw on a wider pool of instructors, so that, for example, core math classes might be taught by people who are not part of the pure math faculty.

Of course, it's desirable and appropriate that there be some experiments in this evolutionary process of curriculum revision; an "experiment" is something that can be abandoned later if it doesn't work. The reform under way obviously presents great challenges, not the least being the students' views. When I talk to students, I find many to be very conservative in their views on the core. The views many of them express about biology or other currently noncore areas seem to have been determined by high school experiences or by existing course offerings (although the new menu courses may not even remotely resemble existing courses.) For example, some students have only vague ideas about the revolutionary nature of molecular biology and the extent to which the behavior and development of biological systems can now be quantified.

Alumni, although they may have intensely disliked some courses at the time, are also generally supportive of the traditional Caltech core and not always enthusiastic about proposed changes. But final decisions have yet to be made; this is a community effort and we welcome alumni views. The Core Curriculum Committee will be presenting its final recommendations to the Faculty Board in February, so alumni still have an opportunity to influence the outcome. You may e-mail me at djs@arms.caltech.edu or call me at 818-395-6534. □

Dave Stevenson is professor of planetary science and was recently appointed the first holder of the newly established George Van Osdol Professorship. Stevenson received his bachelor's and master's degrees from Victoria University in his native New Zealand and his PhD from Cornell. A member of the Caltech faculty since 1980, his research concerns the origin, evolution, and structure of the planets, including Earth.