Politics of Academic Natural Scientists and Engineers

A survey of faculty in the United States systematically explores political opinions and commitments.

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It is probably true, as Don K. Price has observed, that as recently as the period between World War I and World War II most American scientists "were simply not interested in . . . politics" (*1*, p. 21). The other side, of course, is that there was not much reason for anyone else to be interested in the politics of scientists. All this has changed. Perhaps few would want to go as far as Price did a decade ago in describing science as "the major Establishment in the American political system" (*1*, p. 20), but fewer still would question that science has moved from the periphery to the center of public life in the last three decades.

In this article, we explore the political commitments and concerns of academic natural scientists and engineers in the context of their position as an important segment of a strategically placed "skill commonwealth" (*2*). Interestingly enough, although there is general recognition of the centrality of science in the contemporary United States, as well as a substantial literature on its structural position in the polity and extensive commentary on a variety of specific controversies in which scientists have been engaged (*3*), there has previously been no comprehensive survey of the social and political orientations of the academic segments of the scientific community. It is another case in point of the phenomenon that, while the political opinions of the general public, and of principal social and economic strata therein —such as Protestants and Catholics, whites and blacks—have been studied at length, smaller occupational groups with key positions in the policy process often have not received much systematic attention (*4*).

Our data come from a large-scale national survey of American college and university professors, conducted in the spring of 1969 under the sponsorship of the Carnegie Commission on Higher Education (*5*). The questionnaire in this survey solicited more than 300 items of information from each respondent, including details of his social background, professional activities, and achievements, as well as his opinions on a broad range of political issues and controversies—from those largely restricted to the campus, to those on a national and international level. The sample was exceptionally large, just over 60,000 full-time faculty members, and this allows us to deal with disciplinary subgroups that have too few faculty members in national surveys of a conventional size. Included are 1707 physicists, 1884 chemists, 2916 mathematicians, 812 geologists, 4567 biological scientists, 2395 faculty in colleges of medicine, and 4382 engineers (*6*). Sampling and weighting procedures allow us to generalize from these respondents to the entire professoriat in the respective natural science and engineering disciplines (*7*).

The areas that invite discussion in this general subject of the political responses and orientations of scientists are obviously too diverse for adequate treatment in a single article. In the analysis that follows, we focus on three dimensions that seem to be of special importance. First, we determine what the political commitments of scientists and engineers are on a variety of major national issues, paying particular attention to differences among disciplines. No other variable, we have found, differentiates politically among American academics as effectively as their professional fields. We need to locate natural scientists and engineers in the context of faculty opinion generally and to explore the sources of the immense differences among the scientific and engineering disciplines.

A second dimension that seems especially important involves comparing the most eminent and successful scientists to their less academically distinguished colleagues. A great deal of the current discussion and debate surrounding the politics of academics deals with the allegedly more conservative views of those who comprise the "establishment." While the argument that those who consult for business and government, who receive large research grants, who hold tenured and high-salaried positions at major universities, and who dominate the professional activities of their disciplines have been co-opted into "the system" (thereby having the most to lose from any significant social or academic change, and hence being the most conservative) has been carried furthest by social scientists (*8*), it is frequently made by critics in the natural sciences as well (*9*). Are the "notables" in fact more conservative than the "backbenchers"? Are those natural scientists and engineers who act as consultants to agencies of the federal government to the right of their nonconsulting colleagues? What, in sum, can be said of the politics of the most highly achieving and influential scientists and engineers in relation to the orientations and concerns of the rank and file of the academic scientific-engineering community?

The final area we will examine comprises evaluations of the scientific enterprise itself. How strong are the currents of self-criticism of various phases of scientific activity? Are such criticisms more frequently encountered among younger scientists, signaling perhaps a secular reorientation? To what extent have controversies concerning the role of science, along with those surrounding the organization and responsibilities of higher education generally, produced a crisis of confidence among scientists?

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How influential is political ideology, in terms of commitments on national issues, in defining position on controversies internal to science? What, in general, seem to be the consequences of politization on professional questioning and disillusionment?

Politics: Comparisons among Disciplines

The faculties of the various academic fields are very sharply differentiated in their politics, in a pattern that persists across the entire range of measures of political orientation. Natural scientists and engineers are consistently more conservative than social scientists and humanists, the most liberal groups in academe. Within the "hard" sciences (including engineering), the most liberal faculty members are in physics; the range from liberal to conservative then continues from biochemistry, molecular biology, medicine, and mathematics, on to physiology and chemistry, then to general biology (zoology and botany) and geology, and finally to the engineering fields, in which electrical engineering is the least and civil and mechanical engineering are the most conservative. The remarkable uniformity of distributions by discipline across a varied set of political questions attests to the highly ideological character of the thinking of academics. In contrast to much of the general public, they apply what Converse described as "an overarching conceptual dimension" to order a disparate array of policy choices (*10*, p. 215).

Table 1 compares the responses of faculty in various academic fields on a five-item liberalism-conservatism scale for national issues (*11*). In working with this scale, we computed the raw scores for all respondents to the Carnegie survey, from + 12 (the most liberal) to −12 (the most conservative), and then collapsed the raw scores into five approximately equal categories: from that fifth of the faculty with the most liberal responses, to that fifth with the most conservative responses. If more than 20 percent of the faculty in any given field is classified as "very liberal," then the proportion of very liberal faculty in that field is larger than it is in the entire faculty.

Physics, with the most liberal faculty in the natural sciences, is only very slightly to the left of the professoriat as a whole. All of the other hard sciences, except biochemistry, are more conservative than the faculty average. Social scientists, humanists, and professors of law are significantly more liberal in national politics than any group of natural scientists. Engineers run a close third to the faculties of business schools and colleges of agriculture in being the most conservative group. Indeed, civil engineers are second only to the agriculturalists in conservatism.

The range in political liberalism-conservatism within the natural sciences is fairly large. Physicists and chemists are separated by a full 20 points—computed in terms of the percentage in the two most liberal minus the percentage in the two most conservative quintiles. Within the life sciences, biochemists and general biologists are separated by 23 points, a margin comparable to that between electrical and civil engineers. All of the scientific disciplines in the liberal arts and sciences are considerably less conservative than is any division of the applied science engineering; but the faculty of medical schools are among the most liberal scientists and show a distribution similar to that among biologists.

In the 1968 presidential election, Richard Nixon received the votes of about 38 percent of the faculty who went to the polls. Only physics and biochemistry, among the natural science and engineering fields, gave him less support, while mathematics and physiology followed the faculty average exactly (Table 2). All of the other hard sciences were more Republican than the professoriat as a whole. Civil engineers, 68 percent of whom backed Nixon, were the most heavily Republican group in academe. It is interesting

Table 1. Faculty positions on the liberalism-conservatism scale, by discipline.

Discipline	Number	Very liberal (%)	Liberal (%)	Middle-of-the-road (%)	Conservative (%)	Very conservative (%)	Liberal (%) minus conservative (%)
Physics	1,707	23	22	18	20	17	+ 8
Medicine	2,395	13	25	20	24	19	− 5
Mathematics	2,916	16	20	18	24	22	−10
All biological sciences	4,567	14	21	18	26	21	−12
Biochemistry	658	18	25	18	23	16	+ 4
Molecular biology*	816	19	21	18	23	19	− 2
Physiology	953	14	21	18	29	18	−12
General biology†	2,140	12	20	19	26	23	−17
Chemistry	1,884	13	22	18	26	21	−12
Geology	812	12	20	17	22	30	−20
All engineering	4,382	9	15	15	27	33	−36
Electrical	1,024	11	19	15	26	29	−25
Chemical	360	9	19	12	27	33	−32
Mechanical	896	10	12	17	28	33	−39
Civil	684	6	15	13	27	40	−46
All fields	60,028	19	22	18	23	19	− 1
Social sciences	7,160	34	30	17	13	7	+44
Humanities	10,333	29	26	17	18	11	+26
Law	611	23	28	18	18	14	+19
Fine arts	3,475	20	25	19	21	16	+ 8
Education	3,401	13	19	20	29	19	−16
Business	2,338	8	13	17	30	32	−41
Agriculture	1,398	3	10	16	30	42	−59

* Includes molecular biology, bacteriology, virology, and microbiology. † Includes general botany, general zoology, general biology, and "other biological sciences."

to note that Nixon received a higher proportion of the vote among the faculty in chemistry, geology, general biology, medicine, and all the engineering divisions than he did in the public at large. This comparison, however, in one sense overstates the conservatism of natural scientists; George Wallace, who picked up more than 13 percent of the total popular vote, received only negligible support among professors. Overall, Nixon's 41 percent of the vote among physical and biological scientists and 58 percent among engineers were markedly greater than his share of the vote in the heavily Democratic social sciences and humanities, where he received only 19 and 22 percent, respectively. In the 1964 presidential election, the natural sciences, like academe and, indeed, the rest of the country generally, were overwhelmingly Democratic. In the hard sciences, biochemistry and physics produced the strongest support for Johnson (83 and 81 percent), although they were somewhat less Democratic than the social sciences (89 percent) or social work (95 percent), the field that gave Johnson his biggest margin. Only civil and mechanical engineering were more Republican than the national electorate.

Physicists were the strongest McCarthy backers in the natural sciences, 61 percent preferring him to Humphrey as the Democratic nominee in 1968. This is 10 percent higher than McCarthy's support in chemistry and 20 percent higher than his support in chemical engineering, exceeding even the 54 percent for McCarthy in the entire professoriat and the 58 percent in the social sciences. All of the disciplines in the hard sciences, except civil engineering, preferred Rockefeller to Nixon as the Republican nominee; and here again, physicists and biochemists gave the strongest backing to the candidate perceived as the more liberal.

For the last half decade, the war in Vietnam has been the overriding national concern, and on this issue academics in the various fields have shown the same sharp differences evident in their general ideological commitments. In the spring of 1969, when the Carnegie survey was conducted, opposition to the war was greatest, among natural scientists, in the ranks of the physicists, medical scientists, and biochemists, where about two-thirds (67, 66, and 65 percent, respectively) took issue with the policy of the American government and called either for an immediate, unilateral withdrawal or for the reduction of U.S. involvement and support for a coalition government that would include the Vietcong. These positions were taken by 59 percent of the entire faculty and 77 percent of all social scientists. Engineers were among the most pro-war professors, with 55 percent at least as "hawkish" as the Administration, favoring either a phased withdrawal conducted to prevent a Communist takeover or the commitment of even more forces to achieve a military victory.

Among the generally left-of-center social scientists, sociologists and anthropologists were most heavily of the opinion (84 percent of each) that the police did not "act reasonably in curbing the demonstrations at the [1968] Democratic Convention." In comparison, 70 percent of the faculty in physics, 59 percent in mathematics, and 41 percent in civil engineering took positions critical of the Chicago police. The legalization of marijuana was endorsed by 54 percent of the social scientists and 44 percent of the law faculty, compared to 33 percent of professors in medical schools, 31 percent of those in the biological sciences, and 30 percent of those in chemistry. The proportion of sociologists indicating approval of "the rise of radical student activism in recent years" (71 percent) was more than twice that of chemists (34 percent) and three times as great as that of chemical engineers (24 percent). Only physicists (48 percent) and biochemists (45 percent) among the natural scientists topped the faculty average (44 percent) in expressing at least qualified support of the student protests.

Table 2. Electoral preferences (percent) of natural scientists in the 1968 and 1964 presidential politics, by discipline.

Disciplines	1968 Vote				1968 Democratic convention choice		1968 Republican convention choice		1964 Vote*		
	Humphrey	Nixon	Wallace	Third party, left†	McCarthy	Humphrey	Rockefeller	Nixon	Johnson	Goldwater	Third party, left‡
Physics	65	31	1	3	61	39	76	24	81	18	1
Medicine	54	45		1	51	49	71	29	74	25	1
Mathematics	56	39	2	3	58	42	69	31	76	23	1
All biological sciences	55	42	2	1	54	46	69	31	77	22	1
Biochemistry	64	34		2	54	46	79	21	83	17	
Molecular biology	57	41		2	58	42	68	32	76	23	1
Physiology	59	39	1	1	53	47	68	32	77	23	
General biology	52	44	3	1	52	48	67	33	76	23	1
Chemistry	52	44	2	1	51	49	65	35	73	26	1
Geology	46	52	1	1	53	47	64	36	66	34	1
All engineering	38	58	2	1	47	53	54	46	60	40	
Electrical	45	49	4	3	50	50	59	41	67	33	
Chemical	41	57	2	1	41	59	60	40	65	35	
Mechanical	37	59	3	1	48	52	51	49	58	42	
Civil	30	68	1		50	50	48	52	56	44	
All fields	58	38	1	2	54	46	69	31	77	22	1
Social sciences§	77	19		4	58	42	85	15	89	10	1
Agriculture§	36	62	2		35	65	51	49	59	40	1
Popular vote	42.7	43.4	13.5	0.2					61.1	38.4	0.1

* Nonvoters excluded from the computation. † Includes those voting for Eldridge Cleaver, Dick Gregory, and the minor parties of the left, including Socialist Labor, Socialist Workers, and Communist. ‡ Includes such minor parties of the left as Socialist Labor and Socialist Workers. § Included here as, respectively, the most Democratic and most Republican disciplinary groups.

Academic Subcultures:

Basic versus Applied Sciences

In all of the above measures of political orientation, the faculty in engineering are decidedly the most conservative of faculties in the hard sciences. What makes engineers different? To get the answer, we must address a broader question: What makes the liberal arts and sciences different from such vocationally oriented fields as engineering, business, and agriculture? The "liberal versus applied" distinction is probably the most commonly encountered means of differentiating academic subcultures. The distinction is useful in a general way if the notion of a dichotomy is replaced with that of a continuum, with the liberal arts and sciences in a loose cluster at one end and the applied disciplines at the other, but with some "deviant" fields. What characteristics define this continuum and determine the place of a discipline on it?

One characteristic is intellectuality. Observers in a great variety of settings since the end of the Middle Ages have found intellectuals in a common posture—standing outside their own societies, acting as critics of them. As a group, intellectuals are people engaged in work that emphasizes the importance of creativity, originality, and innovation. Many writers have pointed out that inherent in the obligation to create is the tendency to reject the status quo, to oppose the existing or old as philistine. Intellectuals are more likely than others to be partisans of the ideal and thus to criticize reality from this standpoint. This pressure to reject the status quo is compatible with a conservative or right-wing position, as well as with a liberal or left-wing stance. But in the United States since the 1920's (and increasingly in other Western countries as well), intellectual politics have become left-wing politics, in large part, it seems, because the American value system, with its stress on egalitarianism and populism, fosters criticism that challenges the system for not fulfilling the ideals inherent in the American creed (*12*).

If intellectual pursuits predispose one to a critical position, then such an orientation should be found most heavily among the faculty of the more "intellectual" fields. This was implied over 50 years ago by Thorstein Veblen, who observed that "the first requisite for constructive work in modern science . . . is a skeptical frame of mind." He went on to argue that, for the gifted scientist, "the skepticism that goes to make him an effectual factor in the increase and diffusion of knowledge among men involves the loss of that peace of mind that is the birthright of the safe and sane quietist. He becomes a disturber of the intellectual peace . . ." (*13*). Individuals in the liberal arts and sciences, on the whole, appear to be somewhat more engaged in academic activity corresponding to the historic function of the intellectual, involving a creative, innovative, and critical orientation, while work in the vocationally oriented fields is closer to that of the professional—the use of knowledge to solve immediate problems. C. P. Snow has stressed the importance of the dimension of intellectuality in differentiating the natural sciences and engineering (*14*).

> The engineers . . . the people who made the hardware, *who used existing knowledge to make something go*, were in nine cases out of ten, conservatives in politics . . . interested in making their machine work, indifferent to long term social guesses. . . . Whereas physicists, *whose whole intellectual life was spent in seeking new truths, found it uncongenial to stop seeking when they had a look at society.* They were rebellious, protestant, curious for the future and unable to resist shaping it. The engineers buckled to their jobs and gave no trouble, in America, in Russia, in Germany; it was not from them but from the scientists, that came heretics, forerunners, martyrs, traitors [italics added].

The second, related factor defining the continuum involves the *uses* to which knowledge in a given discipline is put and the resultant contacts with groups and interests outside academe. A large segment of the faculty in the applied subjects subsumed by "technology and business" is in close association with the private business corporation. This is the case with engineers, whom Shepard described as marginal men between science and business (*15*). The faculty in the arts and sciences, on the other hand, as seekers "for truth aside from any consideration of practicality or usefulness," have lacked outside associates organized around economic interests. The more closely a discipline is linked to the business world, the more conservative—in the context of academe—it is likely to be.

If the argument that the engineering fields are more conservative than the basic sciences partly because they are less intellectual is valid, we should expect the most intellectual engineering field to be the least conservative. This, in fact, appears to be the case. Electrical engineers are significantly more liberal than their mechanical and civil colleagues; and electrical engineering, through the innovations in computer science and artificial intelligence, seems now to be the most intellectually creative of the engineering disciplines.

Something of this same distinction between the basic and applied fields can be seen within the liberal arts and sciences, partially accounting, to take one example, for the greater liberalism of physicists in comparison to chemists (*16*). J. P. Nettl argued that the differentiation of scholarship within a field into a variety of highly particularistic specialties reduces the potential for the type of behavior associated with intellectuality—which he saw as including a concern for broad structural rearrangements according to universal principles (*17*). If this view is accepted, physicists, whom Wright has described as "the generalists among physical scientists (if not among all scientists)" (*18*, p. 294), should approximate the archetypal intellectual more closely than do chemists or geologists. Meier has maintained that physicists are relatively more left-of-center politically because (*19*):

> [They have been] schooled in the proposition that progress is made by discarding various assumptions and premises and thereby making it possible to create a more powerful theory upon a simpler underpinning. The physicist, more than any scientist, deals with abstractions which make nonsense out of observations based upon the commonplace; he is educated in doubt and can disregard evidence which to the ordinary observer is both convincing and conclusive.

Chemistry, as a more "practical" field, is in closer contact with private industry. Relatively more chemists than physicists are employed in industrial positions. And 10 percent of the academic chemists, compared to just 2 percent of the physicists, reported that they had received research support from private industry during the year prior to the Carnegie survey. As a result, the faculty in chemistry are closer in their outlook to the conservative engineers, while physicists are more disposed to view social problems in idealistic terms and not to identify with the problems of "establishment" institutions.

Academic Subcultures: Natural versus Social Sciences

All of the natural sciences, we have seen, are significantly more conservative politically than the social sciences. It is apparent that the professional subculture of the latter fields is more politicized because social and political problems are vastly more central to their subject matter. But this does not in itself explain why their faculties are more oriented toward critical, left-of-center politics than are faculties in the natural sciences. Three factors seem to be the most important here—one relating to recruitment, the others to professional socialization.

First, the several features of a given subject matter—the areas of activity it encompasses, the problems and concerns it involves one with, its distinctive styles and modes of thought—together influence the kind of person who will be attracted to that field. That is to say, a given discipline selectively recruits people with consistent interests and values (*20*). The social sciences, given their subject matter, appeal far more than do the natural sciences to those who would combine an academic career with a concern for social problems. Donald Emmerson, for instance, has reported that "evidence from 19 countries shows, on the whole, students in the social sciences, law, and the humanities are more likely to be politicized and leftist than their colleagues in the natural and applied sciences" (*21*, p. 403).

A second element in the political differentiation of social and natural scientists arises from the fact that the former, as intellectuals, are uniquely drawn by their expertise to cast a critical eye on the social norms and political practices of societies, often the one in which they live. Lazarsfeld and Thielens were making this point when they observed that "the intellectual task involved in these and many similar endeavors of the social scientist are contingent on his ability to visualize a state of human affairs radically different from that of today . . . [F]or him ultimate scholarly accomplishment must depend upon a kind of imagination which has initially to be akin to criticism . . ." (*22*).

Finally, there is the matter of the "dissensuality" of the social sciences, in contrast to the relatively "consensuality" of most of the natural sciences. Pinner developed this distinction between consensual and dissensual fields, assigning to the former category disciplines "with respect to which the public at large tends to have no reservations, either as to the competence of the scholars and the truth of their findings or as to the values which inform their work," and to the latter those fields "whose values or procedures are widely questioned among the public, either explicitly or implicitly" (*23*, p. 943). This distinction splits the liberal arts and sciences. Mathematics and the natural sciences today are consensual, while the humanities and the social sciences are for the most part dissensual. Pinner maintains, and we concur, that the dissensual disciplines give rise among their faculty members to a view of the "world outside" that is quite different from the view of faculty members within the consensual disciplines. In the case of the dissensual disciplines, the public questions the worth of the undertaking; the faculty, in turn, feels frustrated over the lack of an appreciative public (*23*, p. 949). A somewhat greater sense of estrangement from society seems to be present in the dissensual disciplines than in those fields basking in general public approval; and since the social sciences, for the most part, are dissensual, the resulting estrangement contributes to their critical political orientation.

Our findings, that natural scientists and engineers are more conservative than their academic colleagues in the social sciences, speak to the position of the natural sciences in an open and democratic society today. At other times in history, and in other societies today, the natural sciences have occupied very different political positions, and in some instances have been the principal centers for social criticism and dissent. A field of study becomes highly ideological when, under a given set of circumstances, it offers a fulcrum for the rejection of established social arrangements; and throughout much of the West in the 18th and 19th centuries, natural science occupied this position. Feuer notes, for example, that in late 19th-century Russia "the students of natural science and medicine were the most active in the student disorders" and that "Russian students long regarded chemistry as the most ideological science and expected from it the solution of the social question" (*24*). In 19th-century Germany, the humanities and subjects now in the jurisdiction of the social sciences were strongly linked to the national ethos, were perceived as being at the heart of the *Volkswesen*, the national essence. As such, they were the particularistic fields. Jews and radicals were barred from them, since such people were *wesenfremd*, alien to the national essence. The natural sciences, in contrast, were freer and more open, more universalistic.

The first Minister of Education in Meiji, Japan, Arinori Mori, argued that a modern technological society must have scientists in the forefront of research and, consequently, that the natural sciences must be allowed much more freedom than other fields (*25*). This freedom of inquiry would inevitably produce some persons who were disloyal, yet it was a price that the country would have to pay if it were to become "modern." The social sciences, in contrast, were to be given only "limited freedom." They were not expected to train "free seekers after truth." And in authoritarian societies such as the Soviet Union, the social sciences have been committed to a conservative, regime-sustaining function; academics in these fields could not hope to report findings that clashed with party dogma, a factor which presumably discouraged critical and imaginative students from going into them. Parry, for example, cites reports that students in the natural sciences in Russia are the most active and dissenting politically. According to one, "the physical-science majors . . . were by far more alert and critical of the regime than social-science students. . . . Physical-science students were aware of the difference and proud of their own critical attitude" (*26*). Students inclined to question and criticize have gone into the natural sciences at that point in the history of nations when those fields offered them greater freedom. In short, the natural and social sciences have changed positions over time and now occupy contrasting positions in democratic and authoritarian societies.

Academic Subcultures: Social Origins

Much of the commentary on variations in the subcultures of the natural sciences and engineering has dealt with selective recruitment from social groups, maintaining that the collective back-

grounds of faculty in the several disciplines differ significantly (*27*).

The sciences do contain differing mixes, in terms of the social backgrounds of their members, and at the extremes these differences are really quite substantial. The percentage of Jewish faculty ranges from highs of 22 percent in medicine and 21 percent in biochemistry, to lows of 6 percent in chemistry and civil engineering, 5 percent in general biology, and 4 percent in geology. Of the disciplines outside the natural sciences, only law (25 percent) has a higher proportion of Jewish faculty than medicine. This heavy representation of Jews in the two major, free professional fields of medicine and law is interesting and indicates that the early penchant of Jews for these areas, which have been both prestigious and least subject to the prejudices of employers, has carried over into teaching and research. It is noteworthy that within the biological sciences Jews are most heavily represented in the two fields having the strongest links to medical problems—biochemistry and the complex including molecular biology, virology, and bacteriology. This finding is paralleled by the very heavy involvement of Jews in clinical psychology, the closest field to medicine among the social sciences.

The faculty in medical schools come from families of much higher socioeconomic status than the entire professoriat or any other group of scientists: the fathers of nearly 60 percent of the medical school professors, for example, attended college, and only 10 percent were blue-collar workers—compared to 23 percent of the entire professoriat and 60 percent of the country's male labor force in 1950. Physicists, on the whole, do come from families of somewhat higher status than chemists, but the differences are not large. About 25 percent of the natural scientists are from working-class families, with the percentage significantly lower only in medicine, as we have already noted, and in geology.

Interesting as the data on class origins are, they do not account, to any significant degree, for the differences in the political orientations within disciplines because neither parental occupation nor parental education is significantly correlated with any political opinion variable in the Carnegie survey. Religious background, however, is another matter. The Protestant-Catholic differences are not large, but, as we demonstrated elsewhere (*28*), Jewish faculty are much more liberal-left than their gentile colleagues. Disciplines that for nonpolitical reasons have attracted a high proportion of Jews show, as a result, a somewhat more left-of-center distribution. In Table 1, medicine appears slightly more liberal than mathematics, but Protestants and Catholics in mathematics are somewhat to the left of their coreligionists in medicine.

Academic Subcultures: Institution and Function

Just as disciplines have their distinctive subcultures, so do institutions. Specifically, we find that faculty at the elite, cosmopolitan, research-oriented schools are significantly more liberal-left than are their colleagues at lesser institutions. The relatively liberal subcultures prevailing at the major institutions, related to their status as centers for creative, innovative activity, move their faculties in a liberal-left direction. This fact is important to our discussion of variations in the political views of natural scientists when their disciplines are differentially located, in terms of major research centers and less prestigious teaching colleges. And there are indeed sharp differences in the distribution of science faculty by type of institution. Two-thirds of the medical school professors, for example, are at schools we have classified as elite, and all are at universities rather than at 4- or 2-year colleges. Colleges of medicine, of course, are exclusively university enterprises, and the lesser (and therefore more conservative) institutions do not, for the most part, have medical schools. Fifty percent of the faculty in general zoology and general botany are at institutions without graduate programs, compared to just 13 percent of biochemists—indicating that general zoology and general botany are more strictly teaching fields. Among the general biologists, only 26 percent professed to be primarily interested in research, as contrasted to 76 percent in biochemistry.

The relative liberalism of medical science results from a kind of homogeneity in the field: most of its full-time faculty are scientists engaged in creative research; as a result, they are disproportionately located at and exposed to the liberal subcultures of elite universities. Actually, as the data in Table 3 make clear, medical school professors at elite institutions are more conservative than most of their fellow natural scientists and are about as conservative as the engineers. Similarly, when the type of school is held constant, biochemists and faculty in general zoology and botany show comparable distributions of political opinion, although overall the former appear significantly more liberal than the latter. Mathematicians at elite universities are more liberal than their counterparts in any other natural science discipline, indicating that the relatively less liberal position of the entire mathematics faculty results from the field's heavy mix of teachers rather than research-oriented scholars. Fifty-eight percent of mathematicians, compared to 40 percent of physicists and 35 percent of molecular biologists, are at 4- and 2-year colleges rather than at universities.

The differences in political orientation among faculty in the natural science and engineering disciplines appear, in summary, to have a variety of sources, of which selective recruitment, postprofessional socialization, and exposure to varying institutional subcultures are the most important. Overall, our analysis indicates, the postprofessional experiences, concerns, and associations dictated by subject matter are the most influential. But these variables can and do intrude to produce patterns quite different from those that discipline socialization alone would account for.

Politics: "Dominants" and Rank and File

In comparing the orientations of the most successful and influential faculty ("dominants") in engineering and the natural science disciplines to the orientations of the general membership of their professions, we worked with a number of different definitions of the successful and influential. One that we will refer to here is the "achievers"—faculty who had published ten or more professional works in the 2 years preceding the survey and who held positions at elite universities. In the Carnegie data set, of course, respondents are anonymous and only limited pieces of information on their scholarly activities are available. In addition to the achievers, we will discuss the "consultants"—faculty members who indicated that they had served in the 12 months preceding the 1969 survey as paid consult-

ants to some agency of the national government.

The most striking finding is that in all disciplines achievers are much more liberal than the rank and file, and consultants somewhat more liberal. In the 1968 presidential election, 61 percent of the achievers and 47 percent of the consultants in engineering voted for Hubert Humphrey, compared to 38 percent of all academic engineers. For the biological sciences, the comparable percentages are 72, 66, and 55. Eighty-one percent of achievers in physics and 74 percent in mathematics opposed Administration policies in Vietnam, in contrast to 67 and 59 percent, respectively, of the rank and file. Forty-six percent of engineering achievers score in the two most liberal quintiles of the liberalism-conservatism scale, compared to only 24 percent of academic engineers at large (Table 4). Just 35 percent of all faculty in the biological sciences, but 45 percent of consultants and 58 percent of achievers in those disciplines are recorded in the two most liberal quintiles. The proportion of achievers in engineering who are in the liberal categories is higher than the percentage of all physicists in those categories. Overall, the differences among achievers in engineering and the several natural science disciplines are much smaller than the differences among the rank and file.

In campus politics, the same pattern persists, with the dominants being generally to the left of the total membership of each field. Thus, only 16 percent of achievers in chemistry described classified weapons research as a legitimate academic activity, compared to 42 percent of all chemists. The proportion of achievers in engineering who endorsed classified weapons research on campus (28 percent) was only one-half that of the rank and file (56 percent). More than two-thirds of achievers in physics (68 percent) said they approved of the emergence of "radical student activism," in contrast to slightly less than one-half (48 percent) of the total faculty in that discipline.

These differences between the achievers and the general membership are made all the more striking by the fact that the former are, on the whole, older than the latter. Fifteen percent of all physics faculty, for example, are under 30 years old, compared to just 2 percent of the achievers in that field. The correlation between age and political orientation in the faculty is a strong one, with the youngest being the most liberal-left; however, the dominants, who are disproportionately older, are substantially to the left of the younger rank and file.

Before leaving the achiever and consulant distinctions, we should comment on the consistently greater liberalism of those in the former category. Our point has been that the most successful academics in the natural sciences and engineering are more liberal than the rank and file; the conclusion should not be drawn that high achievers, as such, are inherently to the left of consultants. The fact is simply that "achiever," as we defined it, is the much more exclusive category. The highest achievers (in terms of scholarly productivity) among those who have consulted for the federal government are consistently more liberal-left politically than consultants with less substantial scholarly attainments. Insofar, then, as the category "consultant" identifies scholarly success, it designates a more liberal group; but those consultants who are also publishing scholars are generally to the left of all consultants.

By any measure we choose—position at an elite university, a large number of scholarly publications, governmental consulting, the ability to secure research grants—the most successful, highly achieving, or influential faculty are more critical and left-of-center politically than is the general professoriat. This relative liberalism of dominants is a manifestation of the general tendency on the part of achieving intellectuals to support a politics of social change—to foster what Lionel Trilling has perceptively called the "adversary culture" (*29*). Many of the more eminent scientists are now linked closely to government, but this scarcely means

Table 3. Percentage of natural scientists ranked liberal and very liberal on the liberalism-conservatism scale, by discipline and school quality. [Colleges and universities were classified on the basis of an index that was set up by combining data on institutional selectivity (measured by the Scholastic Aptitude Test scores required for admission), affluence (revenue adjusted for the number of students), and research commitment (research dollars per student).]

Discipline	Elite 1	2	3	Lowest 4
Physics	66	47	28	33
Medicine	42	30	26	
Mathematics	67	45	29	18
All biological sciences	54	36	26	24
Biochemistry	57	41	17	n.s.
Molecular biology	58	37	33	27
Physiology	47	30	26	31
General biology	49	35	28	19
Chemistry	52	42	26	28
Geology	46	32	25	17
All engineering	39	20	17	16
Electrical	47	23	27	18
Chemical	32	23	12	
Mechanical	43	17	15	15
Civil	27	21	11	n.s.
All fields	55	41	33	30

Table 4. Positions (percent) of natural scientists on the liberalism-conservatism scale, achievers and consultants, by discipline.

Discipline and achievement	Very liberal	Liberal	Middle-of-the-road	Conservative	Very conservative	Liberal minus conservative
All physicists	23	22	18	20	17	+ 8
Achievers (N = 37)	33	27	13	15	12	+33
Consultants (N = 222)	20	27	25	17	11	+19
All mathematicians	16	20	18	24	22	−10
Achievers (N = 23)	9	44	20	25	2	+26
Consultants (N = 207)	19	26	20	19	17	+ 9
All biological scientists	14	21	18	26	21	−12
Achievers (N = 197)	20	38	13	15	13	+30
Consultants (N = 613)	17	28	18	24	13	+ 8
All chemists	13	22	18	26	21	−12
Achievers (N = 100)	15	43	12	24	5	+29
Consultants (N = 167)	13	28	20	27	11	+ 3
All engineers	9	15	15	27	33	−36
Achievers (N = 98)	20	26	22	13	18	+15
Consultants (N = 622)	11	16	19	29	26	−28

Table 5. Positions on activities and practices in academic science; natural scientists and engineers, by age and scholarly achievements.

Age (years) and scholarly achievement	Number	Agree, successful professors are "operators"* (%)	Disagree, weapons research on campus is legitimate† (%)	Agree, large grants corrupt recipients‡ (%)	Agree, scholarship threatened by research centers§ (%)
		Age			
60 and older	1,104	43	48	36	40
50–59	2,616	42	51	39	38
40–49	5,217	46	53	36	34
30–39	7,321	50	56	32	29
Under 30	2,550	47	57	27	26
		Quality of university¶			
1 (Highest)	7,423	46	64	30	29
2	8,068	48	52	35	31
3	2,993	47	48	37	35
4 (Lowest)	509	48	51	33	34
		Federal grants received, last 12 months			
Have received	9,130	47	63	28	28
Have not received	9,431	48	45	38	34
Total scientists and engineers	18,997	47	54	34	32

* "Many of the highest paid university professors get where they are by being 'operators' rather than by their scholarly or scientific contributions." † "Classified weapons research is a legitimate activity on college and university campuses." ‡ "The concentration of federal and foundation research grants in the big institutions is corrupting to the institutions and the men that get them." § "Genuine scholarship is threatened in universities by the proliferation of big research centers." ¶ Colleges and universities were classified on the basis of an index that was set up by combining data on institutional selectivity (measured by the Scholastic Aptitude Test scores required by admission), affluence (revenue adjusted for the number of students), and research commitment (research dollars per student).

they are political tools. The governmental "establishment" supports through grants, and draws its consultants from the ranks of, the achievers—which means that segment of the academic community most disposed to left-wing views. Backbenchers are more conservative and less critical of governmental policy than the scientific "establishment"—a fact that radical critics of science and the university should evaluate (*30*).

The State of the Scientific Enterprise

A series of questions bearing on the activities of scientists and the soundness of the position of their professions in the university provide striking documentation of the questioning and, for a significant number, of the disillusionment referred to at the outset of this article. Since our analysis shows that, for this series of questions, differences among disciplines are not large, we will present only data for the entire community of academic natural scientists and engineers.

About one-third of the scientists agreed with the propositions that the proliferation of research centers poses a threat to "genuine scholarship" and that the concentration of research grants in major universities corrupts both the men and the institutions receiving them. Half of the respondents accepted both the charge that the most successful men in their fields gained their positions more as "operators" than as scientific achievers and that large-scale research is more a source of money and prestige for the researcher than an effective means of advancing knowledge. Over half of the scientists felt that classified weapons research was not a legitimate activity on the campus, and nearly two-thirds agreed with the statement that "most professors in graduate departments exploit their students to advance their own research." These are harsh judgments for scientists to make of colleagues in their own field.

Interestingly, acceptance or rejection of such criticism is significantly correlated with general political ideology only when the link to national politics is direct, as in the case of weapons research. Outside of this area, the very liberal are no more or less likely than their very conservative colleagues to engage in criticism of scientific activities or procedures.

In their judgments on what is appropriate in scientific practice on campus, natural scientists and engineers vary by age, but the differences are not as large, or as consistent in the picture they provide, as we had expected (Table 5). Brown's claim, commonly advanced by critics within science, that "it is the young scientist who is most aware of the failure of science and most willing to do something about it" (*31*, p. 271) is in no sense clearly supported. In every discipline of hard science, those who entered academe in the 1960's are the most opposed to classified weapons research, but the overall variations are modest. If agreement with the proposition that the most successful scientists achieve their place primarily because they are "operators" is reflective of at least a partially jaundiced view of academic science, then the youngest are only slightly more disillusioned than their seniors. On the other hand, when presented with the statement that the concentration of research grants in big universities "is corrupting to the institutions and men that get them," it is the younger scientists who express the greatest disagreement. Along this same line, the older scientists are the ones most concerned that "genuine scholarship" in universities is threatened "by the proliferation of big research centers." Clearly, those who first entered their professions in the age of Big Science are the most reluctant to part with the largesse it provides. There is certainly no basis for suggesting that younger academics are, on the whole, more questioning and critical of existing practices than are their colleagues who entered upon scholarly endeavors in an earlier, simpler, smaller age of university science.

Questioning and dissatisfaction are by no means confined to the backbenchers, to those denied entry into the bright world of Big Science. Faculty at elite universities, who have published a great deal and who have received research grants and served as consultants to federal agencies, are more opposed to classified weapons research than their less highly achieving colleagues. The less successful faculty are more critical in such matters as the use to which large-scale research expenditures are put and the exploitation of students by research-oriented professors, but for the most part the differences here are modest. More than 40 percent of those who received federal grants in the 12 months preceding the Carnegie survey agreed that "big contract research has become more a source of money and prestige for researchers than an effective way of advancing knowledge." Almost one-third of all scientists at the major grant-getting universities concurred that "the concentration of federal and foundation research grants in big institutions is corrupting to the institu-

tions and men that get them." Thirty percent of the scientists with ten or more professional publications in the previous 2 years maintained that "teaching effectiveness, not publications, should be the primary criterion for promotion of faculty."

Taken together, these data indicate that an intellectual atmosphere of general uneasiness is widespread in academic science. The contemporary criticism, while having components that are clearly ideological, is reflective of a broader erosion of confidence in the enterprise of science.

Conclusions

Four general sets of conclusions emerge from this analysis of the politics of academic natural scientists and engineers. First, there is a firm and consistent rank ordering of the professions, in terms of the general ideological orientations of their members. Scientists in colleges of liberal arts and science are to the left of their colleagues in the business-related applied fields of engineering, but at the same time are significantly more conservative than social scientists and humanists. The array within the "pure" sciences, from physics and biochemistry (the most liberal) to chemistry and geology (the most conservative), parallels, and in significant measure appears as a function of, the arrangement of these disciplines by their "intellectuality" (or conversely their "practicality"), with all that that connotes in orientations and extra-academic associations. Somewhat deviating cases, such as medicine, can be explained by unusual mixes in social background and the sharply skewed patterns of institutional distribution.

Second, the "establishment," understood as the most successful and influential practitioners, is more liberal and change-oriented than the rank and file of academic scientists and engineers. This finding is fully consistent with the long-established pattern in which achieving intellectuals are inherently the most critical of existing social institutions and practices. The scientific "establishment" is by no means radical, and is doubtless much less socially critical than radical scientists would like it to be, but it is to the left of the general membership of the scientific professions.

Third, if significant changes are occurring in the orientation of scientists to their professional roles and activities as these affect the polity, this is not the result of the large influx of young academics. Younger scientists are somewhat more liberal in national politics and in campus controversies relating to the former, but they do not display any greatly different conception of the scientific enterprise. The youngest practitioners appear, understandably, somewhat more wedded to the procedures of Big Science and, thereby, to the basic underlying link to Big Government.

Finally, within academic science, now so profoundly politicized, there is considerable dissent on all manner of political and professional issues. Some of these divisions unquestionably are highly functional, in the sense of contributing to stimulating, even creative, exchanges. But others suggest that scientists, like their colleagues in other divisions of the multiversity, have entered an era of often trying disputation that extends far beyond the boundaries of their scholarly concerns.

References and Notes

1. D. K. Price, in *Scientists and National Policy-Making*, R. Gilpin and C. Wright, Eds. (Columbia Univ. Press, New York, 1964), pp. 19–40.
2. The concept of "skill commonwealths" and "skill politics" was introduced by H. D. Lasswell [*The Analysis of Political Behaviour: An Empirical Approach* (Oxford Univ. Press, New York, 1948), pp. 133–145]. It was applied to the study of the political position of scientists by R. C. Wood [in *Scientists and National Policy-Making*, R. C. Gilpin and C. Wright, Eds. (Columbia Univ. Press, New York, 1964), pp. 44–49].
3. Among the most useful general studies are D. K. Price, *The Scientific Estate* (Harvard Univ. Press, Cambridge, Mass., 1967); D. S. Greenberg, *The Politics of Pure Science* (New American Library, New York, 1968); and H. Brooks, *The Government of Science* (M.I.T. Press, Cambridge, Mass., 1968).
4. At the 1960 meeting of the American Political Science Association, Paul Lazarsfeld stressed the need for studies in depth of specific social groupings. Peter Rossi is another who has emphasized the need for "a number of small, pointedly designed studies of crucial populations, rather than shotgun designs" [in *American Voting Behavior*, E. Burdick and A. J. Brodbeck, Eds. (Free Press, Glencoe, Ill., 1959), p. 44]. Unfortunately, there has been only a modest response to such calls. For a detailed summary of the extant studies of academics, see S. M. Lipset, in *Imagination and Precision in the Social Sciences*, T. J. Nossiter, Ed. (Faber, London, 1972), pp. 211–289.
5. This survey was conducted with the financial support of the Carnegie Commission and the U.S. Office of Education, Department of Health, Education, and Welfare. It was administered by the Survey Research Center of the University of California, Berkeley, with advice and technical assistance from the Office of Research of the American Council on Education.
6. Biological scientists were asked their special area, with the following choices: (i) bacteriology, molecular biology, virology, microbiology; (ii) biochemistry; (iii) physiology, anatomy; (iv) general botany; (v) general zoology; (vi) general biology; (vii) other biological sciences. Faculty in engineering were requested to indicate their field among the following: (i) chemical engineering; (ii) civil engineering; (iii) electrical engineering; (iv) mechanical engineering; (v) other engineering fields.
7. A disproportionate random sampling procedure was used to select colleges and universities in order to obtain adequate numbers of institutions of various types and characteristics. The 303 schools thus chosen include 57 junior colleges, 168 4-year colleges and 78 universities. Next, a random sample of six out of seven faculty members was drawn from the rosters of the institutions included, yielding a sample of 100,315. A very high return of 60,028 completed questionnaires (60 percent) was achieved as a result of the standing of the sponsors, the careful administration of the survey, and the systematic follow-up with faculty who did not respond initially. Finally, the returned questionnaires were differentially weighted, adjusting the data for the disproportionate sampling of institutions and for the unequal rates of response. Tabulations from the weighted data of this survey, then, may be taken as reasonably representative of the entire population of teaching faculty at colleges and universities in the United States.
8. See, as a forceful statement of this position, A. Gouldner, *The Coming Crisis of Western Sociology* (Basic Books, New York, 1970).
9. For example, C. Schwartz, *The Nation* **210**, 747 (1970) and M. Lappé, in *The Social Responsibility of the Scientist*, M. Brown, Ed. (Free Press, New York, 1971), pp. 96–118.
10. P. Converse, in *Ideology and Discontent*, D. Apter, Ed. (Free Press, New York, 1964), pp. 206–261.
11. It was difficult to reduce the complex interrelations among faculty opinions on political matters (that is, their correlations) to a small number of neat and distinct categories. The mass of opinions did coalesce around four primary dimensions, three involving campus politics and one containing issues from the national arena. (A factor analysis and orthogonal rotation was performed.) Opinions on five questions were combined to construct a general liberalism-conservatism scale for national issues. Four of these were equally weighted: position on Vietnam war, the legalization of marijuana, the causes of Negro riots, and busing as a means for school integration. One question was double weighted—the faculty members' self-characterization of his political views. The text of the questionnaire items was as follows: (i) "The main cause of Negro riots in the cities is white racism" (strongly agree, agree with reservations, disagree with reservations, strongly disagree); (ii) "Marijuana should be legalized"; (iii) "Racial integration of the public elementary schools should be achieved even if it requires busing"; (iv) "Which of these positions on Vietnam is closest to your own?" (The United States should withdraw from Vietnam immediately; the United States should reduce its involvement and encourage the emergence of a coalition government in South Vietnam; the United States should try to reduce its involvement, while being sure to prevent a Communist takeover in the South; the United States should commit whatever forces are necessary to defeat the Communists); (v) "How would you characterize yourself politically at the present time?" (left, liberal, middle-of-the-road, moderately conservative, strongly conservative).
12. Lipset has discussed the political orientations of American intellectuals [S. M. Lipset, *Political Man* (Doubleday Anchor Books, Garden City, N.Y., 1963), pp. 332–371], of Soviet and American intellectuals as "critics and rebels" [S. M. Lipset and R. B. Dobson, *Daedalus* (summer 1972), p. 101], and of students responding to this tradition [*Rebellion in the University* (Little, Brown, Boston, 1972)].
13. T. Veblen, *Essays on Our Changing Order* (Viking, New York, 1934), pp. 226–227.
14. C. P. Snow, *The New Men* (Macmillan, London, 1954), p. 176.
15. H. A. Shepard, *Explor. Entrepreneurial Hist.* **4**, 211 (1952).
16. The relative liberalism of physicists, evident from our survey data, manifests itself in the higher level of political activism in the American Physical Society. For a discussion of recent activity in APS from the perspective of a critical physicist, see C. Schwartz, in *Social Responsibility of the Scientist*, M. Bowen, Ed. (Free Press, New York, 1971), pp. 19–34.

17. J. P. Nettl, in *On Intellectuals*, P. Rieff, Ed. (Doubleday, Garden City, N.Y., 1969), pp. 67–70, 80–82.
18. C. Wright, in *Scientists and National Policy-Making*, R. Gilpin and C. Wright, Eds., (Columbia Univ. Press, New York, 1964), pp. 257–302.
19. R. L. Meier, *Bull. At. Sci.* **7**, 170 (1951).
20. M. Rosenberg, *Occupations and Values* (Free Press, Glencoe, Ill., 1957); ——— and J. A. Davis, *Undergraduate Career Decisions* (Aldine, Chicago, 1965).
21. D. K. Emmerson, in *Students and Politics in Developing Nations*, D. K. Emmerson, Ed. (Praeger, New York, 1968), pp. 390–426.
22. P. F. Lazarsfeld and W. Thielens, Jr., *The Academic Mind* (Free Press, Glencoe, Ill., 1958), p. 149.
23. F. Pinner, in *The American College*, N. Sanford, Ed. (Wiley, New York, 1962), pp. 940–971.
24. L. Feuer, *The Conflict of Generations* (Basic Books, New York, 1969), p. 146.
25. M. Nagai, *J. Soc. Polit. Ideas Jap.* **2**, 29 (April 1964).
26. A. Parry, *The New Class Divided* (Macmillan, New York, 1966), p. 280.
27. See, for example, R. L. Meier (*19*); *Fortune* **48**, 106 (1948); ———, R. Helson, R. Crutchfield, *J. Consult. Clin. Psychol.* **34**, 255 (1970).
28. S. M. Lipset and E. C. Ladd, *The American Jewish Yearbook, 1971* (American Jewish Committee, New York, and Jewish Publication Society of America, Philadelphia, 1971), pp. 89–128; *Change* **3**, 54 (May/June 1971); *Psychol. Today* **4**, 45 (November 1970); *Amer. J. Sociol.* (July 1972), p. 78; E. C. Ladd and S. M. Lipset, *PS* **4**, 135 (1971).
29. L. Trilling, *Beyond Culture* (Viking, New York, 1965).
30. While considerations of space prevent us from discussing them, it should be noted that a number of other studies support our finding that the more eminent and highly achieving academics are politically to the left of the general memberships of their professions. See, for example, (*22*) and C. E. Noll and P. H. Rossi, *General Social and Economic Attitudes of College and University Faculty Members*, mimeographed (National Opinion Research Center, Chicago, 1968).
31. M. Brown, in *The Social Responsibility of the Scientist*, M. Brown, Ed. (Free Press, New York, 1971), pp. 267–272.
32. We wish to acknowledge our debt to Clark Kerr, chairman of the Carnegie Commission, and Martin Trow of the University of California, Berkeley, who directed the administration of the surveys, and to their colleagues. We also wish to express our appreciation to the staff of the Social Science Data Center of the University of Connecticut for assistance in the preparation of this paper. Especially valuable was the work of Dennis Meltzer, Anne-Marie Mercure, Eleanore Wilcox, Margaret Russ, Ferdinand Engel, and Bartley Horwitz. Cynthia Ladd provided editorial assistance at a time when it was much needed. Preliminary presentations of these data were made by S.M.L. while he was in residence at The Salk Institute (San Diego) in the summer of 1970, and at the Weizmann Institute in October 1971. Comments from members of these institutes were quite helpful.

Scientists and Surgeons

The need for the surgical scientist and the Ph.D. in departments of surgery is discussed.

Francis D. Moore

Most of the great referral centers for surgical and medical care in the United States are university clinical units in the teaching hospitals. It is in these hospitals and their supporting academic departments that patients find final authoritative consultation and to which physicians throughout the country turn not only for complex surgery for their patients, but also for teaching, research, and updating by postgraduate education for themselves. Referral centers that were formerly outside of academia, in the private clinics, have developed increasingly strong university associations or teaching institutes in the past decade.

Such centers of excellence fill a national need that is both clinical and academic. Enactment of a national health insurance plan or any legislative expansion of health maintenance organizations will urgently require the expansion of our academic establishment in medicine—not only to provide manpower, but also to provide backup for patient referral and developmental research in all fields, especially in surgery.

In any assessment of manpower needs in surgery, one must look to the clinical responsibilities of surgeons in the university centers, as well as to their role in education. Manpower projections must also take into account the continuing need for a small, although key, group of highly trained scientists in university surgical departments. The development of the latter group has been the particular function of the research training grant programs in surgery.

What percentage of surgeons should be sophisticated about modern quantitative biology in relation to human illness? How many of them should understand the biosciences background of human illness and the pathophysiological responses to treatment? Obviously the answer to these elementary questions is "100 percent—all of them." All physicians who are privileged to carry out this most effective but dangerous modality of therapy should have a clear understanding of the biological processes with which they are concerned in the operative care of human illness. No shift in social focus will ever alter the need of the patient for perfection in surgery, nor alter this basic requirement for a strong biosciences orientation for all surgeons. The addition of less highly trained allied health personnel to the surgical team will only increase, rather than decrease, this quest for perfection in the surgeon, who is ultimately responsible for care.

It is quite another matter to define precisely that fraction of surgeons who should be productive scientists, devoting a decade or two to the development of new data by research—that is, the fraction who should be research training grant trainees. Although but a small fraction of surgeons needs this additional research capability, this small group will determine the quality of the total enterprise and the level of recruitment for the national surgical establishment, just as it will for pediatrics, internal medicine, psychiatry, and the other clinical fields.

Each of the 105 medical schools in this country needs several surgical laboratories, including some in general surgery and in the various special divisions of surgery. On this basis, I estimate that approximately 500 to 750 surgeons between the ages of 30 and 50 should be at a level of attainment that would enable them to make significant contributions to scientific journals

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