# ORIGINAL CONTRIBUTIONS

## ARTICLES

# Characteristics of a Productive Research Environment: Literature Review

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**Abstract**—What environmental factors stimulate and maintain research productivity? To answer this question, the authors conducted an extensive review of articles and books on research productivity published from the mid-1960s through 1990. This review revealed that a consistent set of 12 characteristics was found in research-conducive environments: (1) clear goals that serve a coordinating function, (2) research emphasis, (3) distinctive culture, (4) positive group climate, (5) assertive participative governance, (6) decentralized organization, (7) frequent communication, (8) accessible resources, particularly human, (9) sufficient size, age, and diversity of the research group, (10) appropriate rewards, (11) concentration on recruitment and selection, and (12) leadership with research expertise and skill in both initiating appropriate organizational structure and using participatory management practices. Some of these characteristics are not surprising, although some findings were unexpected, such as that participative governance correlated consistently with research productivity. The differential impact of each of these 12 characteristics is unclear. It is clear, however, that the leader has a disproportionate impact through his or her influence on all of the other characteristics. Yet, an overarching feature of these characteristics is their interdependency. These factors do not operate in research groups as isolated characteristics. Rather, they are like fine threads of a whole fabric: individual, yet when interwoven, providing a strong, supportive, and stimulating backdrop for the researcher. The authors conclude that while at a distance the productive research enterprise looks like a highly robust entity, upon closer inspection it is revealed to be a delicate structure highly dependent on the existence and effective working of numerous individual, organizational, and leadership characteristics. *Acad. Med.* 67(1992):385–397.

What factors promote faculty vitality, research productivity, and teaching quality? Many university-wide conditions — increasing financial constraints, renewed emphasis on undergraduate education, removal of mandatory retirement, tenured-in departments, expected faculty shortages — raise concern about this question and prompt interest in learning what factors help maintain research quality and productivity.[1–5] By contrast, at the departmental level, emerging disciplines such as family medicine and general internal medicine and evolving ones such as dentistry and nursing want to know how to develop researchers in order to establish the academic bases of these disciplines.[6–15] Thus, two questions stimulated this study: How to maintain productive research environments in the face of constraints and mission redefinition? How to develop productive research environments to help build emerging and evolving health science disciplines?

Most work in the area of research productivity has investigated the personal characteristics of a productive researcher.[16–20] These characteristics include personal motivation, research training, mentors, early scholarly habits, socialization to academic values, network of productive colleagues, resources, and substantial uninterrupted time. Our paper focuses on the environmental factors that affect productivity. It is now clear that research productivity is affected by both personal characteristics and environmental ones. In fact, several studies[21–25] suggest that environmental characteristics are the most powerful predictors of research productivity. For example, Long and McGinnis[22] studied scientists who had moved from one organization to another. They found that when changes in an organization take place, changes in research productivity occur also. These changes are not a result of training, mentors, values, or a national network of colleagues, since these remain the same. Rather, the organization emerges as the significant factor. Even the most productive scientists suffered decreases in productivity when the organizations to which they moved had less research-conducive environments. This finding is not surprising. As Fox[26] articulately points out, research is a highly social and political process of communication, interaction, and exchange. Scientific creativity extends or revises existing knowledge. Scientists do this through publications and conference presentations,

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and even more informally in conversations in the lab, lunchroom, corridor, bathroom, and after-hour gatherings. This is not to say that personal characteristics are unimportant, rather that personal characteristics are essential but insufficient by themselves. To be productive, researchers, it seems, must have certain personal characteristics and in addition must work in environments conducive to research. Just what are the characteristics of such an environment? To answer this question, we searched the relevant literature.

## Method

A literature search on Bibliographical Retrieval Service (BRS) Colleague was performed using the following keywords: productivity, research, group, organization, and characteristics. The databases within BRS Colleague that were searched were MEDLINE (1966–1990), Educational Resources Information Center (ERIC) (1966–1990), Psychological Abstracts (1967–1990), Sociological Abstracts (1963–1990), and Management Contents (1984–1990). Databases for books were searched in a similar manner within BRS Colleague and the computer reference system for books of the University of Minnesota regional library. Once a group of references was established, a reverse-citation search was performed using the database of Social Science Citation Index (1972–1990) as well as manual reverse tracking of references. Reverse tracking revealed references that either were not on the computerized databases or had been published outside the years searched in the databases. We (the authors) and a library consultant performed these steps independently. The search process excluded studies of individual productivity, industrial or nonacademic employee productivity, and organizational development. Keyword searching yielded about 75% of the references; the reverse-citation work produced the remainder, all from time periods not covered on the computer databases. The literature search was determined to be exhaustive when extensive redundancy of information or viewpoints had been achieved.

The sources identified via the process described above were screened through a series of steps. First, all journal article abstracts were read and all books were scanned for two initial exclusionary features: (1) opinion pieces not based in data or theory, or (2) outcome measures that did not directly or indirectly relate to research group productivity. Sources with these features were eliminated from further review. All remaining articles and books were read and abstracted by one or both of us. Abstracts followed a standard format: citation; research question; methods; results; environmental issues addressed; positive, neutral, or negative impact of environmental issues on group's research productivity; relation of group studied to medical research group; and quality of article on a scale of excellent, good, fair, and poor. The environmental issues were pulled out of results and listed separately because these were the factors of interest to us and because many studies looked at variables in addition to environmental ones that might affect a group's research productivity. Examples of other variables are characteristics of the individual researchers in the group, such as where they had trained or their genders.

The ratings on quality were our judgments of how well each study met the standards of the research paradigm employed. For example, for a survey study, validity and reliability of the survey form, sampling strategy and size, response rate, and effect size were considered. On the other hand, for a qualitative study, areas considered were appropriateness of data collection method, purposive sampling, inductive analysis of the data, grounded theory, emergent design, and trustworthiness. Both of us rated each source. When differences in ratings occurred, they were discussed and a consensus reached.

The literature review revealed several substantial bodies of literature that address the elements of a productive research environment. Across these bodies of literature, however, there is variability in the dominant underlying theories and constructs used, and in the study designs (from single-site interviews to multinational surveys) and analysis methods used (from mathematical modeling to content analysis). Thus, although a great deal has been written in the area, the various contributions are not easily weighted or ordered according to the "power" of their analyses, nor are they amenable to the attractive quantitative procedures for processing accumulated evidence, such as meta-analysis.[27] Rather, a summary of these studies calls for an intellectual synthesis. To insure, however, that our synthesis was based on the strongest available literature, only sources with ratings of good or excellent were synthesized in the findings that follow.

This synthesis of information on productive research environments was initiated without a prior list of possible characteristics associated with productivity. The list of possible characteristics was developed through the review of eligible studies identified, as just described. As the studies were reviewed, we developed and agreed upon a list of characteristics. The list was constantly revised as new items were uncovered and the previous studies were reviewed again to see if a newly identified item had been addressed. This process was repeated many times to refine the list. The list was determined to be complete and to represent the available data when no new characteristics or evidence to consistently refute any of the identified characteristics could be found.

## 12 Characteristics

Before looking closely at the characteristics, it will help the reader to know more about important features of the literature from which they were drawn.

*Definition of "Research Group."* The seminal work in the area, edited by Andrews,[28] defined a research group as at least three people working together for at least six months, with an expected time span of at least one year, and at least one recognized leader significantly involved in the

group's work. Andrews' groups ranged from four to 40 and were located in universities, institutes, cooperative organizations, and industry. Andrews studied 10,000 scientists in 1,200 units in six countries. Baird's[29] research groups were 24 departments of chemistry, 25 of history, and 25 of psychology in major research universities. Harrington[9] used entire dental schools as the research groups. Andrews' definition of a research group was used in several other studies; however, no one definition was used frequently. The three examples just described illustrate the range of types of research groups represented in the literature.

*Fields Studied.* Although these also varied broadly, most were in the natural sciences. Andrews,[28] for example, covered mathematics, physics, chemistry, astronomy, life sciences, earth and space, agriculture, medicine, technical sciences, and social sciences.

*Outcome Measures.* Research productivity was recognized by one or more of the following variables: books, articles, citations to works, grant dollars, patents, blueprints, internal reports on original work, prototypes, audiovisual creations, and prototype computer programs. Number of articles published and number of citations of published works were the most frequently used outcome measures. Other common outcome variables were reputation of the group, success at staying in budget, application of research results, and morale. The latter measures, while less direct outcomes of productivity, are useful indicators of it.

Some authors measured outcomes in a very sophisticated fashion; others simply counted. Andrews[28] illustrates a sophisticated example. The international research team on this study gathered both quantitative (e.g., number of articles or patents) and qualitative (e.g., international reputation or social value of work) performance indicators from five sources (e.g., unit head or external evaluator). Then, differential weights were given to the indicators. Finally, the individual weighted measures were aggregated to yield a small number of comparable effectiveness measures for each of the 1,200 research and development units studied.

*Study Design, Data Collection Methods, and Analysis.* Design was usually cross-sectional, although occasionally a longitudinal approach was used. Data were most frequently gathered via a review of public documents, vitas, journals, or science citation indexes; interviews; and questionnaires. The most commonly used data-analysis technique was some form of regression.

In spite of this diversity in investigating what organizational factors affect research productivity, our analysis identified 12 characteristics consistently found in productive research environments: (1) clear goals that serve a coordinating function, (2) research emphasis, (3) culture, (4) group climate, (5) assertive participative governance, (6) decentralized organization, (7) communication, (8) resources, (9) size, age, and diversity, (10) rewards, (11) recruitment and selection, and (12) leadership.

For purposes of explanation, each of these is discussed separately. These factors, however, do not operate in research groups as isolated characteristics. Rather, they are like delicate threads of a whole fabric: individual, yet when interwoven, providing a strong, supportive, and stimulating backdrop for the researcher. The following descriptions occasionally point out connections among characteristics. In the concluding section we return to the overarching feature of the connectedness of these characteristics.

## Clear Goals that Serve a Coordinating Function

Productive research groups have clear organizational goals; and the people within them have articulated personal goals compatible with the organizational ones. This characteristic resounds strongly from several bodies of literature. Bland and Schmitz[30,31] reviewed the last 20 years of research on faculty and institutional vitality across all of higher education and found that a vital organization is characterized by clear, coordinating goals.

This focus on organizational goals may appear inconsistent with the commonly held belief that a scientist needs autonomy. Yet, in *Scientists and Organizations: Productive Climates for Research and Development,* Pelz and Andrews[20] found coordination of the research group toward common goals clearly compatible with individual freedom. As one of the research leaders at Bell Labs told them, "Everyone must know what the overall goal is, so that within each person's area he or she can look for those solutions that are most relevant to the major goals." Another scientist put it like this, "The organization points out what mountain they want us to climb, but how we climb it is up to us."

Pelz and Andrews'[20] look at freedom versus coordination revealed another interesting finding. Their more productive scientists said many people had influenced their choices of research areas. In fact, productivity was greatest when a scientist reported that he or she had at least 30% of the weight in the decision, and no one else had more than 30% of the weight. Performance was low when few people had some influence on the decision, and lowest when the chief alone decided on what a researcher would work. Thus, when a scientist had both high influence in a research direction and high involvement from several others, maximum performance resulted. It seems a combination of coordination and freedom is not only feasible but essential for high productivity of scientists.

This finding is reminiscent of *In Search of Excellence,*[32] which describes excellent, innovative companies as having a "tight–loose organization." But just how tight and how loose should a *research* group be? Again, Pelz and Andrews'[20] work provides guidance. They looked at levels of organizational coordination and found that in the more loosely coordinated groups, only the most personally motivated researchers continued to achieve. Complete autonomy usually resulted in low performance. This finding bears particularly on supervision of new scientists. In fact,

Katz[33] reported that the "most significant negative correlate" on productivity in the first year is autonomy. Similarly, when Pineau and Levy-Leboyer[34] compared successful biomedical laboratories with less successful ones, they found that the best laboratories were managed by heads "whose approach was moderately *free* but who did *formally* control" the team.

On the other hand, Pelz and Andrews[20] found that researchers in very tightly coordinated organizations were so constrained that it decreased their ability to be productive. Thus, only in the middle-range situations were scientists most productive. The middle range they describe is an environment where high individual autonomy is accompanied by clear goals, the strong influence of others, and a setting flexible enough to allow these influences to improve performance. Balancing this mix is a leader who keeps the goals of the organization in the minds of all the scientists. Also, as described in the communication and governance sections that follow, the leader assures open and frequent communication so that people talk to each other about their work and celebrate each others' achievements.

## Research Emphasis

A research-conducive environment places priority on research productivity, or at least puts priority on research equal to that on other missions.[2,21,29,35,36] Bean's[37] causal model of faculty members' research productivity in institutions defines "research emphasis" as the weight given research criteria in promotion and tenure decisions. Within research-oriented universities, Blackburn and colleagues[21] found productivity highest among faculty in universities where the educational emphasis was on graduate students, followed by progressively less productivity as the institution increased its focus on undergraduate students. Research productivity also diminished when a unit focused on applied graduate training versus academic graduate training. Baird's[29] study of 74 chemistry, history, and psychology departments found that those with clear, dominant goals of research were more productive. Effects of not having a research emphasis were illustrated by psychology departments that emphasized training practitioners and were less productive in research. Similarly, other departments or disciplines that place a high priority on practitioner training and service, such as family medicine or nursing, generally have had low research productivity.[15,24]

Other studies state the importance of an emphasis on research by showing the negative impact of not having it. Drew[36] and Clark and Lewis[2] report a significant barrier to research productivity was lack of institutional commitment to it as evidenced by lack of time, resources, finances, and facilities for research. Commitment to research is very important, as Kapel and Wexler[35] confirmed in their study of a university's transition from a primarily educational mission to a joint mission of education and research. This institution found it insufficient that faculty and administration recognize the need for and value research. Rather, productive research environments have administrators and faculty who are highly committed to research and allocate resources accordingly. Occasionally, a discipline or department has high research productivity even though it is part of a larger institution that does not emphasize research. Most often these are disciplines Biglan[38] and others[39,40] describe as pure life science with a highly developed paradigm. These disciplines have high levels of connectiveness, multiple collaboration in teaching and research, and high commitment by individual faculty within the local group and across the nation that provide an "across-institutions environment" with a research emphasis.

## Culture

Rice and Austin's[41,42] study of faculty morale at U.S. colleges found one feature foremost in the nation's colleges with the highest morale: "distinctive organizational cultures that are carefully nurtured and built upon."[41] Organizational culture is the distinctiveness that sets an organization apart from other similar organizations, and it is a distinctiveness that everyone within the organization understands, shares, and values. A clear organizational culture, writes William Tierney,[43]

> ensures that everyone is on the same boat, and they know where the boat is headed. . . . Identity provides the framework for participants to deal with the existential issues of their own worth and meaning in the organization. Because new people join the institution every year, and the institution changes constantly, a strong sense of identity must be cultivated, tended, and frequently revisited.

The corporate literature frequently talks about the importance of an organizational culture to productivity. IBM (International Business Machines), for example, is known for its organizational culture: the IBM look, the IBM ideals, the IBM business ethic. In addition, IBM has been consistently cited as the company that has built uncommon commitment from staff by emphasizing the management of human resources.[44,45] In the IBM culture, support for the individual and achievement of excellence are common basic beliefs.

Other authors[45,46] have further noted that the culture of a group is not self-preserving. Culture requires symbolic management and social organizations to keep it sustained and growing.

Organizational culture, though seldom formally articulated, plays an important role in building and bonding a group by giving the group an identity and a safe home base in which to experiment, and thereby be productive. In highly productive research groups, the culture is usually characterized by shared values about academic freedom and the ways to establish truth through that discipline's scientific method.[47] These research groups often have "war stories," sagas, tales, or rituals that make up their distinct culture.[48] Common ex-

amples of distinctive histories being retold by the members of productive research groups are the stories of the founders of Johns Hopkins and Stanford universities, known to all members of these communities. Recently, former President Kennedy of Stanford University related his repositioning plan to the original vision of Jordan and the Stanfords as a means of evoking acceptance of the plan from Stanford faculty.[49]

Organizational culture is often communicated and maintained through rituals. Rituals are patterned social activity that expresses and articulates specific meaning to the groups' members. Rituals need not involve formal recognition but can consist of paper cups of champagne at the end of a long project, cutting the ivy at Greenville College, or the yearly recognition of excelling junior members of the group.[41,50]

### Group Climate

Most studies[28,51-53] investigating the possible link between group climate and research productivity found a positive correlation. Andrews[28] measured group climate via scientists' ratings of seven items: spirit of innovation, dedication to work, degree to which new ideas are given consideration, degree to which ideas from junior members are given consideration, degree of cooperation, and frequency of staff meetings. Aggregate ratings of these items correlated positively and directly with group productivity.

Another example of the relationship between group climate and productivity is found in Birnbaum's[53] study of 84 academic research projects randomly drawn from 14 U.S. universities and one Canadian university. The U.S. institutions were among the top 22 U.S. universities in terms of federal grant dollars. This study found article and book publication rates were higher from projects with low faculty turnover, good leader–member relationships, and a habit of open discussion of disagreements.

The importance of good group climate to productivity is also suggested by our previous discussion of goals. Recall that productive group members are influenced by their coworkers. Such influence would more likely take place in an organization characterized by mutual respect and esprit de corps. Schweitzer's[51] study of 49 "top researchers" in mass communication found that 97% of this group rated "personal relations" as a important-to-very-important factor in their productivity. Sixty-seven percent also rated "stimulation and encouragement from colleagues" as very important. Responses to open-ended questions on factors influencing their productivity most frequently referred to research-oriented colleagues and a supportive environment.

### Assertive Participative Governance

One of the most persistent findings in the literature is the correlation between participative governance and research productivity.[20,28,34,41,47,50,54-57] Rice and Austin[41] began their study of high-morale colleges with the hypothesis that effective leadership contributes to high morale. They assumed that "a variety of leadership approaches would work, but that what was important was managerial competence." Faculty morale was surveyed in more than 100 colleges. The top ten high-morale colleges were then site-visited and studied in depth. The conclusion: none of the ten case studies supported the hypothesis about effective leadership. Rather, "Every one of the ten colleges with high morale and satisfaction had leadership that was aggressively participatory in both individual style and organizational structure."

Another example comes from Pineau and Levy-Leboyer's[34] study, "Managerial and Organizational Determinants of Efficiency in Biomedical Research Teams." After studying all 155 biomedical laboratories in the Paris area, they concluded, "The best laboratories were characterized by *participatory* working relations: more meetings, the technicians were personally involved in the results, and more interpersonal relations between the researchers and the heads." Kerr[58] puts it bluntly: "Literally hundreds of studies have incontestably demonstrated the superiority of participative leadership and group decision making." Although he points out that there are certainly times when participative leadership is not the best governance approach, in research organizations it is usually preferred. He suggests that participative leadership is most effective for the following reasons: (1) the requisite knowledge may be too extensive, the conglomeration of needed skills too complex, or the simultaneity of the decisions too considerable for anything but participative leadership; (2) such leadership heightens members' morale and self-esteem; (3) it allows for diversity of perspective and variety of competencies that no one leader can possess; (4) it accords opportunity to focus on and develop commitment for the task at hand; and (5) it allows subordinates to have information that increases their abilities to contribute, and it reduces the opposition to decisions.

### Decentralized Organization

Another expression of the positive impact of participative leadership is the finding that flat and decentralized organizational structures correlate with highly productive units.[37,41,54,59] For example, Birnbaum[53] looked at predictors of long-term research performance in his sample of 84 academic research projects drawn from 15 universities, of which the 14 U.S. institutions were among the top 22 universities in federal research support. The study, conducted in 1975 and again in 1977, examined research productivity in 50 widely varied areas (e.g., electrical properties of bone, epilepsy, off-shore drilling, arms control, urban transportation). Birnbaum found that horizontal differentiation, his term for a decentralized, flat organizational group structure, was a significant predictor of research productivity. Okrasa[54] also found that research units with a decentralized structure had both greater

greater overall research productivity and more consistent research productivity across members.

Decentralization, it should be noted, does not mean anarchy. Recall that effectiveness of decentralization was found in the context of leadership that uses aggressive participative governance and where there are clear, commonly understood goals. And, as Steiner[57] described in his book, *The Creative Organization*, a decentralized organization needs feedback systems that allow leaders to track the performance of the quasi-autonomous parts.

## Communication

The characteristic of communication consists of giving or exchanging information, supportive and sympathetic relationships, physical connections and contacts, and access to the larger network of colleagues. These communication processes need to occur between the leader and the team, among team members, and between team members and their external network of colleagues.

The previous section on governance and a later one on leadership describe communication between the leader and team members. Communication among internal and external colleagues, our focus here, has been found to predict individual research performance and to be important to all staff levels to maintain productivity.[20,26,52,60,61] In fact, Visart[62] found communication between—and within—units explained as much as 31% of the variance in the number of published written products among research groups in six countries. In addition, Saxberg and Newell[63] reported it was the unanimous opinion among members of interdisciplinary research teams they polled that communication with consideration for all parties and all dissenting viewpoints was critical to group success.

Several researchers have looked at the features of the communication activities among colleagues. Pelz and Andrews[20] found that researchers with the highest productivity levels had frequent contacts with colleagues, spending up to eight to 15 hours per week in a communicative activity. The frequency of communication, however, is not the single important feature. Clark and Corcoran[17] found that the highly productive faculty member maintains professionally meaningful relationships with colleagues (e.g., discussing manuscripts, planning research studies), while the less productive faculty member maintains primarily social relationships. Similarly, Sindermann[50] found extensive references to communication and networking in his interviews with successful scientists. These scientists communicated and maintained their communication network predominantly through the following: regular and frequent discussions with peers; inclusion of the same peers in planning for workshops, symposiums and conferences; frequent late-evening, small-group conferences in offices or hotel rooms or at poolside; and requests to peers for preliminary reviews and comments about research projects. In addition, these scientists identified communication channels or networks as a mutual activity that can be professionally managed and requires periodic purging.

Finkelstein[64] developed four prototypical profiles of collegial communication patterns among faculty members. The highest publication rates were associated with the "departmental-anchored cosmopolitan" communication pattern, one that is relatively insulated from campus colleagues outside the department while strongly tied to departmental and off-campus colleagues. This communication pattern was the most common among university faculty and the most prevalent among faculty with a research orientation regardless of the setting. The importance of this pattern of communication is confirmed by Schweitzer's[51] finding that the second most important reported extrinsic factor contributing to a researcher's productivity was the stimulation and encouragement received from colleagues at other schools.

## Resources

Resources to accomplish a task or achieve a goal are essential for any endeavor, including research. Essential research resources are defined as those the individual perceives as necessary to carry out a research program.[37] "Perceives" is an important word in this definition, which we will return to at the end of this section. The following describes the commonly identified essential resources: human resources (colleagues, assistants, technical consultants, graduate students, research-knowledgeable leader), time, funding, research facilities, and libraries.[21,36,65,66]

The previous section on communication notes the importance of colleagues as a resource, wherever those colleagues are located. Several studies address more specifically the importance of having able colleagues and other human resources easily accessible within the unit. Andrews,[28] looking at the impact of major resources (workspace, equipment, colleagues, leader, library sources) on research productivity, found that satisfaction with human resources (including colleagues) in a research unit was the resource type explaining the largest amount of the variance in the unit's performance. Others note that frequent face-to-face contacts help provide ideas, catch errors, stimulate development, and provide support.[20,32,51] It further helps to have colleagues physically and conceptually close together. An MIT (Massachusetts Institute of Technology) study[32] found that the probability of communicating at least once a week was only 8 to 9% if people's offices were 10 meters apart versus 25% when 5 meters apart. As for conceptual distance, Blau's[60] study of theoretical high-energy physicists found the best departmental environment to be one in which the physicist has a few colleagues working in the same specialized area and many in other areas who share the same theoretical orientation.

Productive colleagues provide an additional, less specific resource role via the ambiance they set in a department. Braxton[67] found that the productivity of departmental colleagues indirectly influenced an individual's performance. That is, the same researcher published more when work-

ing among productive researchers than when moved to a department where colleagues published less. Similarly, Long and McGinnis[22] found that for scientists who changed institutions, changes in productivity levels correlated with the productivity of colleagues in the new department. Reskin[68] attributes high performance to the immediate reinforcement that researchers receive from colleagues in productive environments and not to the recognition gained from citation alone. Thus, faculty colleagues serve not only as a source of knowledge, skill, expertise, emotional support, and stimulation, but they also nurture the individual's "spark" or commitment to research, thereby building a culture in which the individual can survive and prosper. The lack of research-oriented colleagues has been shown to drain energy and extinguish the spark from even the most skilled and talented researcher.[24,25]

Graduate students, or, occasionally, undergraduate research assistants, are another important resource. Blackburn and colleagues[21] found that faculty teaching graduate students were six times more likely to have produced five or more articles over a two-year period than were those teaching only undergraduates. Additional support for this observation comes from the common finding that doctoral-granting institutions consistently have higher levels of research output than other types of institutions.[22,66,69-73]

Sindermann's[50] case histories highlight the importance of support staff, as in these quotes from researchers describing ingredients of a good research group: "'A secretary who knows how to wash test tubes and a technician who can type'" and "'obvious research progress during prolonged and frequent absence of the principal investigator.'" Pineau and Levy-Leboyer[34] also found that among the 155 biomedical teams investigated in their research, the least productive teams had either no or few full-time technicians, and the most productive teams had ten or more full-time technicians.

With regard to funding, Harrington's[9] evaluation of dental school research productivity found the combination of external funding, student–faculty ratio, and number of library books accounted for one-third of the variance in research productivity. The relationship among these variables was that as funding and library books increased, the student–faculty ratio decreased and research productivity increased. Similarly, Clark and Lewis[2] found that the second most frequently cited institutional condition supporting research success was research-funding availability. In addition, the institutional conditions hindering research success were heavy teaching and/or administrative responsibilities and lack of funding. Culpepper and Franks[10] found the common major impediments to research reported by family medicine university units were, in rank order, lack of time, lack of funding, lack of research skills, and lack of role models. In short, the inadequate availability of money is commonly found as a barrier to research.[65,66,74]

Finally, although the resources described above are essential for research productivity, it is not enough that they exist in a unit: they must also be obviously accessible. Pelz and Andrews[20] found that *actual* resources correlated less highly with productivity than did the resources researchers *perceived* they could access. This distinction may explain some of the correlation between unit productivity and having a research-knowledgeable leader and a decentralized organizational structure. A knowledgeable leader is likely to understand the need for appropriate resources and not only provide them but also make them easily accessible. Further, a department or unit that has an organizational structure with vertical differentiation or a high number of hierarchical decision-making levels may have reduced productivity if faculty perceive access to resources as difficult.[53]

## Size, Age, and Diversity

In general, performance increases as group size increases. Size positively correlating with productivity has been found in studies of groups, departments, schools (e.g., dentistry) and institutions (e.g., university).[9,21,29,34,75-78] This finding follows points noted previously in that one would expect more opportunities for contact, stimulation, and resources in a larger group. As for age of the group and its relation to productivity, Pelz and Andrews[20] found it helps to have a group that has been together for quite a while. They found some evidence, however, of group productivity's dropping after the group has been together for more than seven years, although this drop was not consistently found. Rather, they found creativity dropped when older groups lost their atmosphere of high standards, group cohesion, and enthusiasm. Pelz and Andrews[20] describe the demanding yet cohesive and enthusiastic atmosphere found in productive groups as "creative, supportive tension."

More recent research on age of group has been less consistent; the inconsistency may be explained by ageism. That is, if one uses supervisors' ratings of a group's usefulness, performance in older groups appears to decline. When group performance is assessed with respect to actual scientific products (e.g., patents or papers), however, the trend in productivity is more likely to be steady-state or steady increase with age of group.[79]

Studies of diversity have looked at the effects on productivity of differences among group members in disciplines and levels of terminal degrees. Generally, the trend is toward more productivity when diverse approaches to problems are represented in the group.[20,47,57,60,80] Pelz and Andrews[20] do point out that diverse approaches need to be balanced with common values and goals.

## Rewards

Latham and Wexley[81] conducted an experimental study assessing the effects of various rewards on the performances of research and development scientists. Managerial praise (from specifically trained managers), public recognition, and monetary bonuses were given to research and de-

velopment professionals judged to have performed effectively. Performances were assessed by specially trained supervisors who observed and rated each professional using a behavioral observation scale. All three rewards had impact; money and praise ranked one and two, respectively. Latham and Wexley reported, however, that "increase in performance due to the money over praise was so small as to be practically insignificant. Thus, from a cost–benefit viewpoint, it is most effective to give praise."

What is it about praise that increases productivity? McKeachie,[82] a longtime scholar of faculty vitality, suggests that praise, prestige, salary, and promotions are important not so much for the material gains they provide but for their ability to recognize the researcher's special expertise, intellectual ability, and value to one's colleagues. Support for this view is amplified in another study by McKeachie[83] that looked at events that lowered faculty productivity. The top events were critical department heads or administrators who seemed not to appreciate good work, incompatible colleagues, and lack of respect from others for one's research.

Money, it seems, increases productivity or is a motivating factor only under limited circumstances and only for a small subset of members.[84,85] The circumstances in which money rates as a preferred reward are very low salaries in comparison with other members in the unit or for a whole unit compared with other units. For example, Gustad[86] surveyed faculty members about their job satisfactions. He reported faculty valued opportunities for responsibility, achievement, independent thinking, and intellectually stimulating activities. The top three answers to his question about what is most rewarding were research, stimulating colleagues, and salary. Faculty with low salaries rated salary highest. Eckert and Stecklein[87] looked at job satisfaction of faculty members at colleges in Minnesota. They found that social significance of work and intellectual interest were most important.

Researchers in corporate settings, like their university counterparts, report preferred rewards are challenging projects, stimulating colleagues, and recognition, as well as money. For example, when Latham and Mitchell[88] had research and development scientists rank-order 30 rewards, the rank-order result was as follows: seeing one's work applied, salary increase, work put to commercial use, recognition by supervisors, monetary bonus, promotion, profit sharing, working in a group that is recognized as a topflight group, recognition by management at the top of the company, and recognition by work group. Similarly, the 63 "highly active" faculty in a major research-oriented university interviewed by Clark and Corcoran[17] reported the following situations or factors supportive of success: stimulating colleagues, strong academically oriented administration, recognition by administration and colleagues, and resources.

To sum up: although salary, awards, promotions, and the like are important rewards, what most motivates researchers are the intrinsic pleasures of challenging work, intellectual accomplishment, stimulating colleagues, and being valued by one's colleagues (local and national). It is important to note that the most effective combination of these rewards varies for each individual and for an individual over a lifetime.[84,85] McKeachie,[82] for example, uses Levinson and colleagues'[89] theory of stages of adult development to suggest how preferred rewards are likely to change over a life span. He also notes, as have others,[2] that research productivity does not predictably decrease with an individual's age. It appears then that research-conducive environments not only offer the preferred rewards described above but also enable researchers to access the rewards they prefer when their needs change.

## Recruitment and Selection

Dill[90–92] found highly productive research and development units were distinguished by their concentration on hiring talent. These units spent extraordinary amounts of time recruiting people with the specific talents—skills and socialization—wanted. Particularly important was socialization—the values and commitment that fit in their organization. These characteristics are largely determined by a person's training and mentors.[22,61,93] For example, Zuckerman[94] identified the training program as critical to achieving high performance since this is the setting where knowledge, skills, and competencies relevant to research are developed and where norms and values are cultivated. The most prestigious research universities systematically recruit new faculty with proven commitment to research from the same select group of elite institutions.[93,95,96] This recruitment and selection process concentrates talented faculty in a department with a culture and collegial climate strongly supportive of research.

An emphasis on recruitment echoes some of the characteristics previously mentioned. When one knows the organization's goals, knows to that it has a positive climate and an organizational culture one is trying to build and maintain, then one is able to recruit very carefully.

## Leadership

Without question, leadership is the most influential organizational variable our literature review uncovered. It is the one variable that affects all of the other organizational characteristics, which in turn influence research productivity.

To quote Blackburn,[74] "nearly every positively correlated [with research productivity] factor resides in administrative hands." Studies examining the characteristics of the leaders of productive units consistently conclude that the leader must be perceived as a highly skilled scientist.[28,36,45,50] Dill,[90,92] for example, studying the staffing of research and development units in Europe, found that a crucial factor in success over time in these units was the leader. Further, he suggests that the leader's professional expertise as a scientist before assuming the managerial position significantly affects the unit's productivity. Dill maintains that it is this experience that enables a unit di-

rector to influence members' knowledge and values, to facilitate contacts and networks, to attract other competent researchers, to help colleagues who are blocked or stopped in their research efforts, and so on. In addition, this experience establishes a basis of power or influence built on competence, experience, and admiration of the group members. Pineau and Levy-Leboyer[34] found biomedical research teams were more successful when the "relations between the head and the researchers were based on mutual confidence." Power based on competence has also been found to be the most effective base in studies conducted in business. These studies often use French and Raven's[97] categories of power bases to look at kinds of power between individuals. For example, Bachman, Smith, and Slesinger[98] looked at the relationship of workers' job satisfaction to the power bases their office managers use. They found worker satisfaction positively associated with managers whose power was based on competence and experience or based upon personal admiration. Dissatisfaction coincided with influence, or power based on "legitimate rights" of supervision, or based upon positive and negative sanctions. This outcome is echoed in Andrews'[28] finding that the quality of the leader correlated highly with group climate. The quality of the leader was measured by scientists' ratings of the leader's technical competence, knowledge of the field, personality and character, amount of work he or she does, and level of support he or she gives others' research. Leaders who had more of these characteristics ran groups that had more positive group climates, and, in turn, had higher productivity.

Given the previously described characteristics of a research-conducive environment, it is easy to understand how other investigators found that leaders of productive groups were highly research-oriented,[36] internalized mission and kept research emphasis clear to the group,[6] and exhibited the behaviors one would expect of a leader with a participative governance style. These behaviors included frequent meetings with clear objectives, good leader–member relationships, facilitating open communication, allowing expressions of all points of view, complete sharing of information, and vesting ownership of projects with all group members.[20,34,53,59,90,91,99,100]

This profile of the effective research leader—one who facilitates group productivity through the pairing of common goals and some structure with highly participative governance—is echoed in the research on effective university department chairs and deans.[100] The latter body of research differs from the others described in this study. But since many research leaders also serve these roles, it is important to note that the same behaviors effective in the role of research leader also best serve the roles of chair and dean.

Bensimon and colleagues[102] synthesized the work on higher education leadership into six categories: trait theories, power and influence theories, behavioral theories, contingency theories, and cultural and symbolic theories. The third category of studies, behavioral theories, applies here. These investigate leadership by "examining patterns of activity, managerial roles, and behavior categories of leaders—that is, by considering what it is that leaders actually do." Typically, in these studies, chairs' or deans' behaviors and performances on all major job tasks, not just facilitating research, are rated usually by faculty. Often these ratings are then correlated with a global indicator of a leader's department's or college's success. The overall conclusion from these studies is that two major constructs relate to effective leadership: initiating structure, and using considerate behaviors.[102–105]

Initiating structure includes the features described previously under the characteristic of establishing clear goals that serve a coordinating function. Considerate behavior includes the characteristics of leadership and assertive participative governance, as described in this article. For example, Knight and Holen[106] investigated whether there was a significant relationship between a department chair's behaviors (defined as faculty's perceptions of the chair's initiating-structure activities and use of considerate behaviors) and faculty's perceptions of the chair's accomplishment of typical responsibilities, which included facilitating research. This study analyzed the ratings of 458 chairs by 5,830 faculty members in 65 colleges and universities across the United States. The results across these sites were consistent, strikingly so. Chairs rated high on both initiating structure and using considerate behaviors were also rated highest in effectively accomplishing and performing all 15 common responsibilities of a chair. Conversely, chairs rated low on both constructs received the lowest ratings with regard to how well they accomplished their responsibilities. In summary, it appears that department chairs who are good at both initiating structure and using considerate behaviors impress their faculties as being most effective at fulfilling their responsibilities.

Skipper[107] also conducted several studies investigating higher education administrators' use of initiating structure and considerate behaviors. He consistently found that at the dean's level and above, most effective administrators were characterized by high scores on both constructs. (Interestingly, Hoyt and Spangler[103] report that Fleishman and Harris's[108] review of the literature on department leadership found inconsistencies in the desirableness of leaders' initiating structure or exhibiting considerate behaviors. But they found these inconsistencies were explained by noting that in low-consideration climates, high structure is seen as threatening and restrictive. In high-consideration climates, however, these same structures are seen as supportive and helpful.)

## Conclusions and Implications

The productive research group, then, is one that has clear organizational goals, as well as individual goals that relate to the organizational ones; emphasizes research; has a distinctive culture; has a climate of respect paired with intellectual jostling; and consciously socializes new members. The productive group has a critical mass of scientists who are well seasoned, but not so seasoned that they

do not express excitement through a great deal of communication among each other and to other groups. The productive group has sufficient resources (particularly human), but, more important, resources that group members perceive as accessible. Finally, it has a flat organizational structure with a leader who facilitates group productivity through participative governance, who is experienced in research and plays an important though not predominant role in an individual researcher's planning, who keeps the organizational goals visible, and who carefully attends to recruitment.

Many of these characteristics of a research-conducive environment are not surprising. They are similar to the factors found in the management and organizational-development literature to relate to employee productivity in business settings, particularly when the employees are professionals or "gold collar" workers.[52] Also, one would expect, for example, an organization that emphasizes research or that has a leader with research skills to be more research-productive than one without these factors.

Less intuitively obvious are other findings: that participative governance is a consistent form of leadership that correlates with productivity, and that perceived resource availability correlates more with productivity than actual resource availability.

It may also not be obvious, particularly to emerging disciplines, how to build these characteristics into a group. Fortunately, just identifying the characteristics implies some strategies: housing group members in close proximity; providing mechanisms for frequent professional communication among group members and across groups; and selecting leaders who are (or were) accomplished researchers. Naming a strategy, however, is easier done than effectively using one. Take assertive participative governance, for example. Chris Argyris,[109] one of the most prolific researchers and writers on organizations, found that leaders of research organizations tend to be blind to the extent they truly encourage participation. In a study of technical-problem-solving meetings led by more than 250 research and development supervisors, 85% of the supervisors described their leadership styles as facilitating autonomy, openness, risk taking, innovation, and self-responsibility. Yet review of the tapes of these meetings found the opposite to be the case.

Thus, a few recommended strategies for acquiring the characteristics may be helpful. Here are three:

1. Practicing effective participative governance as either a leader or a member is a learned skill; therefore, provide formal training for it. Particularly in disciplines where the "natural" governance structure is hierarchical (medicine, for example), formal training would speed up and ease members' learning how to use a second governance approach.
2. Many of the characteristics are subjective, such as culture, positive climate, perception of resource accessibility, and feelings of worth of one's work. Thus, the effective leader should systematically monitor and attend to these "soft" aspects of group environment.
3. It is difficult for a group to know how to find and recruit new members who have the research skills and socialization the group wants but does not now have. In this case, Dill[91] points out that the active, successful researcher in an affiliated field is more capable of assessing the capacity of a candidate for research and commitment to scholarly activity than is an inactive researcher in the target field. Thus, fields or departments just initiating research programs could call on faculty outside their department or field to help identify and assess new members.

Five immediate benefits are gained by having laid out the characteristics of research-conducive environments. First, we identified these characteristics by culling and synthesizing a very broad range of literature. No one study looked at or revealed all the characteristics listed above. (The two exceptions to this are the work done by Pelz and Andrews[20] and by Andrews[28] that, although now quite old, provides a comprehensive look at what constitutes a research-conducive work environment.) Pulling these characteristics together sets the stage for future work on factors that affect productivity. For example, does the impact of these factors vary by discipline? And are there characteristics unique to specific disciplines that were not revealed in this first wide, sweeping look at research-conducive factors? Most likely so. As Burton Clark eloquently pointed out in *The Academic Life: Small Worlds, Different Worlds*,[110] "the discipline has become everywhere an imposing, if not dominating, force in the working lives of the vast majority of academics. Organized around individual subjects, the disciplines have their own histories and trajectories, and their own habits and practices."

Or, for example, does the impact of these factors vary by gender? The studies reviewed here looked at research groups composed mostly of men. Recent work on women in the scientific community suggests women scientists do not thrive as well as do their male counterparts in the same environment.[111]

Second, carefully identifying these characteristics should be helpful to disciplines just developing to the point of starting to emphasize research. Some of these disciplines, such as family medicine and nursing, were begun with a training emphasis. Accordingly, leaders were chosen for their expertise in training and practice, and departments were organized in hierarchical fashions that are conducive for service and training. The message we derive from our review is that for organizations such as these now to emphasize research will require more than research training for individual faculty members. It will require major refocussing of commitments and resources, restructuring of organizations, targeted recruiting, and changes in leadership.

Third, articulating these characteristics, however, should help highly research-oriented universities that are now seeking more balance among their teaching, research, and service roles.[5,49] Knowing the conditions that facilitate research will allow these in-

stitutions to avoid unknowingly undermining research while they improve the quality of undergraduate education or in other ways redefine the mission and structure of the research university.

The fourth benefit in laying out these characteristics is the revealing of the multifaceted impact of the leader. While the differential weights of the 12 individual characteristics are unclear, it is clear that the leader has a disproportionate impact through his or her influence on all of the other organizational characteristics.

Finally, identifying these characteristics illuminates why among the many colleges and universities in the United States, only a few are highly productive research organizations. A successful research unit requires a particular set of personal characteristics within each of its researchers, a supportive set of organizational features, and leaders who are research-oriented and skilled in participatory governance. While at a distance the research enterprise looks like a highly robust entity, upon closer inspection, it is revealed to be a delicate structure highly dependent on the existence and effective working of numerous individual, organizational, and leadership characteristics.

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