no. 190-66  CANCELLED
SCIENTISTS IN A TECHNOLOGY-ORIENTED ORGANIZATION--
THEIR EXPECTATIONS, INCENTIVES, AND CAREER PATTERNS

Donald G. Marquis

May, 1966

III SCIENTISTS IN A TECHNOLOGY-ORIENTED ORGANIZATION--
THEIR EXPECTATIONS, INCENTIVES, AND CAREER PATTERNS

Donald G. Marquis

Dr. Vollmer (introduction):

Dr. Goldman mentioned that the kind of research we are talking about here is people-oriented research. It is research that lays great emphasis upon trying to set up an environment that is conducive to the utilization, the growth, the development of scientists, and the kinds of things that they are interested in in relation to the interests of their employer. Who are these people? What are they like? How are they like other men and how are they different from other men? This is the topic that we are going to discuss next.

Our next speaker received his doctor's degree in psychology at Yale University. Since then he has been a member of the faculty at Yale and also at the University of Michigan--becoming head of the Psychology Department in both institutions. He has also been active in governmental and scientific affairs as a consultant to several scientific advisory boards. He is past President of the American Psychological Association. He has done work in many different fields of psychology, and presently he is Professor in the Sloan School of Management at the Massachusetts Institute of Technology and is heading a continuing program of research studies on the management of science and technology. I'm pleased to present Professor Donald Marquis, whose topic is "Scientists in a Technology-oriented Organization--Their Expectations, Incentives, and Career Patterns."
Dr. Marquis:

One characteristic of scientists is that they are modest. The other two speakers have started with an apology, so let me say that when we got together a month ago to divide up the subject, I got stuck with one in which I am not an expert--namely, the characteristics of scientists. There are two people who are: Donald Pelz at the University of Michigan has been working for twelve years in this area. He was one of the very first to even think of it as a subject of research, and a summarizing book by Pelz and Andrews will appear probably about the end of this year. He is not available because he is in New Delhi this year. The other one is Howard Vollmer, who is not available because he is chairman of this session, but he is the one who should be giving this talk. I shall probably be misquoting some of his unpublished results and hope that he will correct me. We'll be talking, then, about people, which we've learned is an important component of research.

I will be making statements which sound like sweeping generalizations. Please take these as statements of average trends or statistical tendencies, recognizing that you can think of exceptions, and I can think of just as many as you, but it's important for planning research and for thinking about this subject that we recognize some of the general tendencies. I will not make any statements about differences or characteristics which are not statistically significant at the probability level of .05.

When we speak of scientists, who are we talking about? In order to keep it clean, let's admit that there are some scientists who are self-made. But the easiest way to define this subspecies of humanity is to speak of those who have taken a doctoral degree at a university in a field of science. There are about 80 thousand of them in this country. Of these, about 25 percent are primarily engaged in basic research, 15 percent in applied research, and a small number in development. About 25 percent are primarily engaged in teaching and 20 percent in management.
or administration. Over half of the doctoral scientists are employed in universities, and about half of these say that they are engaged primarily in research. Thirty percent are employed in industry, and 4 percent in government. Since no set of these numbers adds to 100 percent we shall have to assume that the remainder are earning their living by some legitimate means.

This gives us some idea of the number of people, where they are working, and what they say they are doing.

Incidentally, I'll use the word "science" to refer to what Jack Goldman called "fundamental" or "basic" research and what Howard Reiss talked about as the "study of phenomena," and distinguish "science" from the rather ambiguous term, "research."

"Science" is what Ph.D. scientists do in a knowledge-oriented laboratory, as distinguished from a product-, process-, or commercial-oriented laboratory. There is a homily about managing a science laboratory to the effect that all you have to do is pick the best men and leaving them alone. Fortunately, not many people believe this, and there are two things wrong with it. First, there is no good method for picking the best men until they have repeatedly demonstrated their performance, and by that time they are settled, difficult to move, and expensive. The second reason is that if you leave them alone you will get much less productivity from them than if you pay proper attention to them, so let's get rid of the homily.

I first want to talk about what kind of people they are and what we can possibly do about selecting them. How do we recognize them? And second, because of what kind of people they are, I hope that other speakers will make clear what kind of an environment they need in order to be productive.

Now let me start out with a "black and white" difference between scientists and engineers--let's consider Ph.D.'s in science and bachelor's
and master's in engineering, because this sets up the polarity very clearly. Scientists and engineers differ recognizably by the time they enter college. They come from different kinds of homes, they have had a different kind of upbringing, and they behave differently in high school.

At MIT Benson Snyder and John Rule have been giving a two-hour battery of tests to entering students which includes measures of personality, values, attitudes, and interests. One very clear result is that freshmen, including those who do not know what major they're going to choose two years later, are different at the time they enter college. Those who major in a science field, as compared with those who major in an engineering subject, score higher, for example, in theoretical orientation, tolerance of ambiguity, esthetic interests, and desire for autonomy. Engineers, by contrast, score higher on desire for economic achievement and power, and on need for order and certainty. They are more socially extroverted and they engage in more organizational activities.

When they finish their education these differences between scientists and engineers have been maintained or intensified, so that at the time they are recruited for a job, they also differ in their desired job characteristics. Here the difference is very clear. It has been rediscovered in dozens of different research studies—many of them not substantial by themselves, but together they make a clear picture.

There are certain things in which scientists and engineers don't differ—they both want a job with high salary, with good facilities and resources for work, with security, they want to be treated as individuals, and they want to work in a good organization.

The scientist, however, emphasizes that he wants a job in which he will have freedom of choice in what he works on and freedom to follow up his own ideas wherever they lead him. He wants to make a contribution to knowledge. He wants an opportunity to keep up-to-date on new scientific developments in his field. He wants to publish. He wants to gain
respect in his scientific field, and he wants to be with expert, high
caliber colleagues.

Compare that with the engineer's view. Typically, he says he wants
a chance to move up in the organization, he wants a challenging job where
he can solve practical problems, he wants an opportunity to see his ideas
put to use. He wants to work on projects which will contribute to com-
cmercial enterprise, to welfare, economic growth, or defense of the country--
a lot of very important values. But they differ from those of scientists.

Of course, there are mixed types; there are scientists who have engi-
neering values and there are engineers who have science values. But let
me call the two types "science-oriented" and, because I can't get a better
word, "commercial-oriented". The latter correspond with the values of
managers, and engineers and managers are more similar than engineers and
scientists in these respects.

Among scientists you will find variation--they are not all alike.
Some of them will have commercial values, just as some of the engineers
will have science values. In a recent study by John Hinrichs* at IBM, a
questionnaire of 79 items, which had been carefully pretested was sub-
mitted to a national sample of chemists at the time they were finishing
their doctoral work. The sample of 385 new chemistry Ph.D. graduates of
1961 included 41 universities.

Hinrichs found that there were three distinct patterns of attitudes.
(The method was that of factor analysis for those of you who are statis-
ticians; it's an objective method for finding which items cluster to-
gether.) The first pattern is what we have called science-oriented. He
describes it as "reflecting attitudes valuing freedom and support in

* Hinrichs, John R. The Attitudes of Research Chemists. J. Appl.
Psychol., 1964, 48, 287-293
research and a belief that industry raises barriers to worthwhile scientific activity."

The second cluster is what we have called commercial values. Let me tell you a few items that will help define these people. They tended to disagree with the statement, "most scientists are more interested in their profession than in an opportunity to move up in the organization for which they work." They agreed with the statements, "a chemist can put up with monotonous work if the pay is O.K.," and "in any organization, the people in power get there by manipulating other people." They disagreed with the statement, "a chemist must have freedom in applying his own ideas to solve technical problems if he is to produce significant research results."

Then there is a third category--a cluster of items such as "there is no conflict"; for example, "I can see the usefulness of science in a commercial organization and I don't see any conflict between them."

You would think that these chemists would get sorted into appropriate jobs. It turned out that of those who had taken jobs there were 152 who accepted academic jobs and 222 who accepted industrial jobs. But there was no difference in their scores on the three values. Thus the recruiting and self-selection process had not worked. I think that any of you who have had experience with recruiting know why--it's a pretty false process in which the promises of freedom and advancement are not always fulfilled. We'll get more evidence of that in a minute--that new recruits are very unhappy in the first few years on the job--whether it's academic or industrial.

Hinrichs carried out another study with an entirely different sample of employed chemists--286 Ph.D. chemists in three industrial labs. He plotted their scores on the three value components--scientific, commercial, and compatible--against the number of years they had been on the job--5, 10, 15, 20, 25.
Consider first the science value. It drops a little in the first few years and then shows no particular trend up or down. In general, those who have it hold to it.

The second component reflecting commercial values, which for these employed chemists is much higher, gets a little shock when they find that they aren't promoted in the first year; but later it goes up steadily. Those who have the compatible values of the third component show a gentle rise over time. This is the process of acculturation, socialization, or fitting into the organization.

Many of the results that have been published on some of these topics have presented a rather confusing picture when they describe the attitudes, values, and motives of employed research people. In the first place, they don't distinguish clearly between scientists, semi-scientists, and engineers. In the second place, they take a cross-section survey at some point when scientists have already become socialized, and so it's not surprising to hear statements as we heard yesterday--that scientists "love to work in industrial labs and contribute to new products and processes that will have commercial value." All right, that's true in that kind of a lab. The lab that was described yesterday is a mixed lab. It has some Ph.D.'s in it, but they don't behave like Ph.D.'s, we were told. By the end of the third year they didn't want freedom to choose their work and they didn't publish, even though the company encouraged it. So the company had already squeezed the science-oriented attitudes out of them.

Next we want to consider job satisfaction. A lot of work has been done on what makes research people satisfied--incentives, motives, job characteristics, and so on, and this is a very confused literature out of which I would like to draw a few verifiable statements. In general, the satisfaction of the individual in his job is important not for recruiting, because you can fool him on that, but for retention. The satisfaction of the individual is, in general, a result of how well the job and all of its
characteristics meet his expectations. We've seen that different kinds of people have different kinds of expectations and that they can even change their expectations and their attitudes over time.

For Ph.D. chemists, there is a positive and significant correlation between the third set of attitudes, which maintains that science and business are compatible, and satisfaction. People who have that kind of attitude (and the more of that attitude they have) are more satisfied on the job.

For the commercial attitudes, there is a negative correlation between the degree of the attitude and satisfaction. These people don't do very well economically. As you know, there is a pretty low ceiling on salary and promotion for researchers. They just got in the wrong business; they shouldn't have gone into research.

Similarly, those who are science-oriented and employed in one of these mixed labs, where the dominant atmosphere is set by those who accept the company goals and work toward new product and process improvements, also show a negative correlation—the more science attitude they have, the more unhappy they are on the job.

There is plenty of evidence that scientists and engineers are unhappy. Surveys have shown that they express more job dissatisfaction than other kinds of employed people. And we are beginning to get some clues as to why—they aren't fitted in right. It's not that they couldn't be satisfied, but it would take a different kind of organization or a different kind of job to do it.

Now let me turn to another topic—the factor of age. We have seen that there are changes in attitudes with age. There are also changes in productivity with age. You know the classic work of Lehman, published in 1953, in which he examined biographical information to determine the age at which scientists have made their major contributions. On the average, the likelihood of outstanding achievement increases to a peak in
the late 30's and early 40's, and thereafter it declines. The peak occurs earlier in the more abstract disciplines, like mathematics and theoretical physics, and later in the more empirically based disciplines--geology, chemistry, and biology. The other interesting finding is that for the most outstanding achievements, the peaking is sharper.

These are historical data. Surveys of current laboratories show that the highest productivity of Ph.D. scientists working in knowledge-oriented labs, measured by the number of publications or by the evaluation of their colleagues and superiors, is in the early 40's. Those working in applied and development laboratories, by contrast, reach their period of greatest productivity in the late 40's.*

Pelz found in addition that those who were high in their scientific values showed higher performance throughout their life and their peaks were not as exaggerated. This is confirmed in nation-wide studies of physiologists by Meltzer and others in which the highest productivity occurred in the late 30's, with another little spurt in the early 50's. For really good physiologists the peaks were sharp, for the average physiologists they were smoother, and for those in the lowest rank there was a small early peak before they disappeared from the published literature.

One last point: what's the difference between an outstanding and an average scientist? Disregarding the engineers, we will talk just about the top and the average scientists. There are three classes of factors to consider. First, there are characteristics of the people; you know that some are better than others. Second, there are some labs that are better than others; and these labs have certain characteristics which others will discuss on this program. Third, there is luck, or noise, or whatever you wish to label the large area of our scientific ignorance.

Among the factors that determine the level of individual scientific performance is the amount of education. As a matter of fact, the Ph.D.'s and those with master's degrees are two quite distinct subspecies in science. The master's are not significantly different from the bachelor's, but the Ph.D.'s are something else. They are not only finely screened, but motivation and educational experience result in a particular set of values and work habits. Among Ph.D.'s, intelligence test scores and course grades are not very discriminating, accounting for perhaps five percent of the variance in later performance on the job.

Another characteristic which has been extensively investigated is creativity, which is independent of brains or brightness. I won't take the time to go into the very confusing literature on this topic, but I can assure you that the evidence indicates that there is no test of creativity which, adequately validated on more than one sample, has shown a higher correlation with rated performance than .30, and these are results of my research. Such a test, therefore, could predict about ten percent of the variance in performance, independent of intellectual ability.

Differences in the degree of science orientation that we talked about earlier may account for about five percent of scientific productivity. Another factor studied by Pelz concerns dedication, or strength of motivation, or involvement, and showed a correlation of about .20 with productivity, and would account for about five percent of the differences in performance. These low correlations do not mean that the factors are not important—it's just that most everybody has them in sufficient degree. The differences in these factors may be small and therefore don't account for much of the variance in performance. I hope that point is clear. The age factor—which involves experience, senility, hormones, etc.—accounts for about ten percent of the variance.

All together these factors might add up to 30 or 35 percent of the variance in productivity. They do not offer, therefore, any great hopes for improving scientific performance by better methods of selection of
personnel. The policies and procedures and the atmosphere of the lab—the details of which I leave for others to discuss—are probably much more important than the differences in the people. I would recommend therefore that major attention in the management of science laboratories be given to providing challenging work, adequate resources, and discriminating recognition of excellence.
<table>
<thead>
<tr>
<th>Date</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>APR 22 77</td>
<td>NOV 20 83</td>
</tr>
<tr>
<td>JUL 3 78</td>
<td>NOV 22 82</td>
</tr>
<tr>
<td>SEP 1 78</td>
<td></td>
</tr>
<tr>
<td>MAR 14 80</td>
<td></td>
</tr>
<tr>
<td>APR 06 81</td>
<td></td>
</tr>
<tr>
<td>JUN 09 81</td>
<td></td>
</tr>
<tr>
<td>MAY 21 82</td>
<td></td>
</tr>
<tr>
<td>SEP 23 82</td>
<td></td>
</tr>
<tr>
<td>OCT 16 82</td>
<td></td>
</tr>
</tbody>
</table>

Lib-26-67